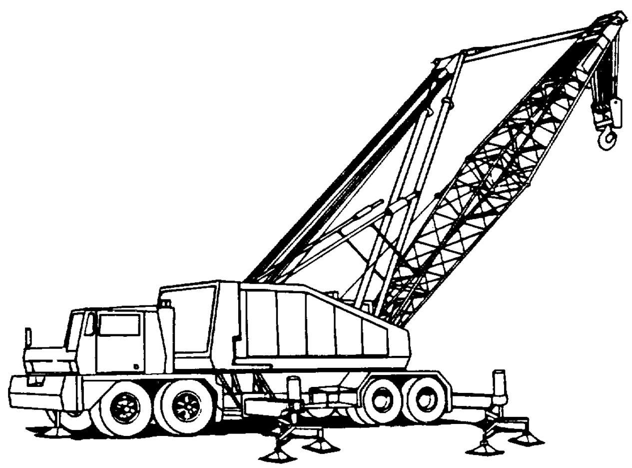
# TECHNICAL MANUAL

FOR

# CRANE, MOBILE, CONTAINER HANDLING, TRUCK-MOUNTED, 140-TON CAPACITY DED, FMC LINK BELT MODEL HC-238A, ARMY MODEL MHE 248, NSN 3950-01-110-9224



FMC CORPORATION
CABLE, CRANE AND EXCAVATION DIVISION

HEADQUARTERS DEPARTMENT OF THE ARMY

15 JULY 1985

TECHNICAL MANUAL
No. 10-3950-263-14&P-2

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC., 15 July 1985

**OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT AND GENERAL SUPPORT MAINTENANCE MANUAL (INCLUDING REPAIR PARTS) FOR**

**CRANE, MOBILE, CONTAINER HANDLING, TRUCK MOUNTED, 140-TON CAPACITY, DED, FMC MODEL HC 283A, ARMY MODEL MHE 248, NSN 3950-01-110-9224**

REPORTING OF ERRORS

You can help improve this manual. If you find any mistakes or if you know of a way to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in the back of this manual direct to: Commander, U. S. Army Tank-Automotive Command, ATTN: AMSTA-MB, Warren, MI 48397-5000. A reply will be furnished direct to you.

| | |
|---|---|
| TM 10-3950-263-14 & P-1 | Operator's Manual |
| TM 10-3950-263-14 & P-2 | Service Manual (Maintenance Instructions) |
| TM 10-3950-263-14 & P-3 | Parts Manual |

**NOTE**

This manual is published to provide an authorized commercial manual for the use of the personnel to whom this Crane is issued.

Crane Manufacturer: FMC Corporation

This technical manual is an authentication of the manufacturers commercial literature and does not conform with the format and content specified in AR 310-3, Military Publications. This technical manual does, however, contain available information that is essential to the operation and maintenance of the equipment.

**WARNING**

Always Stand In Clear View Of The Jack Or Beam Being Operated. Make Sure Nothing Is In The Way When Operating A Jack Or Beam To Avoid Injury Or Damage.

**WARNING**

Handle With Care. The Starting Fluid Is Toxic, And Flammable.

**WARNING**

Always Disengage The Master Clutch When Leaving The Operator's Seat For Any Reason, Or When Working On The Machine. Failure To Disengage Master Clutch May Result In Accident.

**WARNING**

Trying To Lift The Machine With Damaged Components In The Lifting Sling Can Cause An Accident. A Very Heavy Load Is Being Lifted. If It Falls, The Machine Will Be Damaged. Personnel Nearby May Be Injured Or Killed.

**WARNING**

Before Lifting Crane, Inspect Lifting Sling Again. 4ake Sure Everything Is Assembled Right. Make Sure All Pins Have Keepers. Don't Let Anyone Near The Machine While It Is Being Lifted.

**WARNING**

Be Careful Not To Get Burned On Hot Oil When Draining Gear Cases.

**WARNING**

Be Careful Not To Get Battery Electrolyte On Your Skin, Or Clothing, Or Especially In Your Eyes. It Is Acid And Can Cause Injury. Don't Smoke Or Use Open Flame Near A Battery. Batttery Gas Is Explosive.

**WARNING**

Moving Machinery. Do Not Service, Maintain, Or Lubricate Unless Master Clutch Is Disengaged And Rotation Machinery Has Stopped Or Severe Personal Injury May Result.

**WARNING**

Use Fuel Oil Or Cleaning Solvent In A Well Ventilated Area, Away From Flames.

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

**WARNING**

Do Not Hold The Compressor Wheel, For Any Reason, While The Engine Is Running. This Could Result In Personal Injury.

**WARNING**

Hot Oil Can Cause Severe Burns. Be Careful When Draining The Oil.

**WARNING**

Use Extreme Care When Removing A Radiator Pressure Control Cap From An Engine. The Sudden Release Of Pressure From A Heated Cooling System Can Result In A Loss Of Coolant And Possible Personal Injury (Scalding) From The Hot Liquid.

**WARNING**

Anchor The Upper Machinery Against Rotation By Lowering The Attachment To The Ground Before Working On The Swing Lock.

**WARNING**

Don't Get Under Any Part Of The Boom, Especially When Boom Sections Are Being Raised, Lowered, Or Positioned.

**WARNING**

Do Not Get Under Any Part Of Boom, Especially While Boom Sections Are Being Raised, Lowered, Or Positioned.

**WARNING**

Incorrect Disassembly Of A Pin Connected Boom May Result In Machine Damage, Personal Injury, Or Even Death. Before Disassembling Boom, Read And Be Sure You Understand Fig. 5-19, And The Disassembly Procedure On The Following Pages. As An Alternate Disassembly Procedure, Block Tightly Under The Pin Connection Before Removing Pins. Never Stand Under A Boom When Removing Pins.

**WARNING**

The Hammer And Block Method Requires Being Near Moving Machinery. Perform This Operation Slowly And Cautiously. The Operator And Workers Must Be Fully Informed Of The Procedures To Avoid Pinching Tools Or Body Parts In The Machine. Do Not Use Your Hands To Guide The Wire Rope At The Drum, Or Sheaves, Or Entanglement May Result.

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air Fpr Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

**WARNING**

Engine Exhaust Gas (Carbon Monoxide) Is Deadly! Carbon Monoxide Is An Odorless, Colorless Gas Formed By Incomplete Combustion Of Hydrocarbon Fuels. Carbon Monoxide Is A Dangerous Gas That Can Cause Unconsciousness And Is Potentially Lethal. Some Of The Symptoms Or Signs Of Carbon Monoxide Inhalation Are:

| | |
|---|---|
| Dizziness | Vomiting |
| Intense Headache | Muscular Twitching |
| Weakness and Sleepiness | Throbbing In Temples |

The Best Protection Against Carbon Monoxide Inhalation Is A Regular Inspection Of The Complete Exhaust System. If You Notice A Change In The Sound Or Appearance Of Exhaust System, Shut The Unit own Immediately And Have It Inspected And Repaired At Once By A Competent Mechanic.

**WARNING**

Do Not Smoke While Servicing Batteries. Explosive Gases Are Emitted From Batteries In Operation. Ignition Of These Gases Can Cause Severe Personal Injury.

Service Manual

**WARNING**

Before Commencing Any Maintenance Work On The Engine, Generator, Control Panel, Automatic Transfer Switch Or Associated Wiring, Disconnect Batteries Failure To Do So Could Result In Damage To The Unit or Serious Personal Injury In The Event Of Inadvertent Starting

**WARNING**

Do Not Remove Dipstick With Engine Running. Oil Will Blow Out Causing Possible Injury

**WARNING**

Do Not Use Ether Starting Aids Ether Is Extremely Explosive And May Cause Personal Injury Engine Damage Is Also Possible

**WARNING**

Use Fuel Oil Or Cleaning Solvent In A Well Ventilated Area, Away From Flames

**WARNING**

Reduce S-o-M System Pressure To Zero As Explained In Steps A And B Before Unscrewing The Relief Valve Cap, Or Before Removing The Pipe Plug From The Unloading Valve Pieces Of The Valve May Explode Under Pressure Otherwise And Could Cause Injury

**WARNING**

Tire And Rim Assemblies Are Heavy. A Hoist Should Be Used To Lift Them On Or Off Machines. If a Hoist Is Not Available, Two Men Should Lift The Assembly From The Axles Hub With Pry Bars

**WARNING**

Loss Of Shut Down Control Could Result In A Runaway Engine Which Could Cause Personal Injury

**WARNING**

Compressed Air Used For Cleaning Purposes Will Not Exceed 30 PSI Use Only With Effective Chip Guarding And Personal Protective Equipment (Goggles/Shield, Gloves, Etc)

**WARNING**

Do Not Use A Dry Brush Or Compressed Air To Clean Brakeshoes There May Be Asbestos Dust On Brakeshoes Which Can Be Dangerous To Your Health If You Breath It (Brakeshoes Must Be Wet, And A Soft Bristle Brush Must Be Used)

**WARNING**

Adhesives, Solvents, And Sealing Compounds Can Burn Easily, Can Give Off Harmful Vapors, And Are Harmful To Skin And Clothing To Avoid Injury Or Death, Keep Away From Open Fire And Use In A Well-Ventilated Area If Adhesive, Solvent, Or Sealing Compound Gets On Skin Or Clothing, Wash Immediately With Soap And Water

**WARNING**

To Avoid Injury, Do Not Work On Inflatable Seal System When Seal Is Pressurized Make Sure Petcock Is Turned Fully Counterclockwise To Open Position And See That Pressure Gage Reads Zero Before Doing Any Work On System

**WARNING**

Compress Spring With Tie Bolt Before Removing Rollpin If Tie Bolt Is Not Used, The Springs Can Propel Bands With Enough Force To Cause Injury When Rollpin Is Removed

**WARNING**

The Fuel Spray From An Injector Can Penetrate The Skin Fuel Oil Which Enters The Blood Stream Can Cause A Serious Infection Therefore, Follow Instructions And Use The Proper Equipment To Test An Injector

**WARNING**

Lower Machine Off Outriggers, Or If This Is Not Possible, Block Securely Under Outrigger Beams Before Working On Outrigger System

**WARNING**

Before Removing Any Part Or Component Of The Outrigger System, Shut The Engine Off And Bleed All Pressure From The System

**WARNING**

Fully Retract All Jacks And Beams Before Attempting To Set Pressures Never Work On The Carrier Outrigger System When The Carrier s Elevated And Supported Only By The Outriggers. If The Carrier Must Be Elevated On Outriggers, Securely Block The Carrier Before Working On The Outriggers Failure To Securely Block The Carrier, May Allow It To Fall And Cause Damage Or Injury

**WARNING**

Do Not Attempt To Disassemble Or Perform knuckle Pin Repair With Vehicle By Jacks Only

**WARNING**

When Disassembling, Take Care When Disconnecting Torque Rods Or Equalizer Beams Because Axles Assemblies May Roll Or Pivot If Not Securely Blocked

**WARNING**

Drain All Pressure From The Accumulator Before Removing The Valve Core

**WARNING**

Do Not, Under Any Circumstances, Charge With Oxygen, Acetylene, Or Any Other Combustible Gas

**WARNING**

Always Decrease Operating Pressure To Zero Before Removing The Accumulator From The System

**WARNING**

When Maintaining Or Troubleshooting These Systems, Always Make Sure That You Are In A Well-Ventilated Area Away From Heat, Open Flames, Or Sparks. Wear Goggles When Testing To Avoid Eye Injury Make Sure That Openings Of The Valve, Tube, Or Atomizer Are Pointed Away From Yourself While Testing

The Ethyl Ether Used In This Starting Fuel For These Systems Is Extremely Flammable, Toxic, Harmful, Or Fatal If Swallowed Avoid Contact With Skin Or Eyes And Breathing The Fumes If
Swallowed, DO NOT INDUCE VOMITING Call Physician Immediately

If Fuel Enters Eyes Or Fumes Irritate Eyes, They Should Be Washed With Large Quantities of Clean Water For 15 Minutes A Physician, Preferably An Eye Specialist, Should Be Contacted

Do Not Store Cylinders In Temperatures Above 160 F Contents Are Under Pressure Do Not Incinerate, Puncture, Or Attempt To Remove Center Core Valve Or Side Safety Valve From Cylinder

**WARNING**

There Are Several Important Safety Precautions To Be Followed For Preparing And Using The Solutions Protective Clothing Such As Rubber Gloves, Rubber Arm Covers, Rubber Apron And Protective Face Shield Contribute To The Safety Of Personnel Carrying Out The Procedures When Preparing The Solutions, The Compounds Should Be Added To The Water And Not Water Added To The Compounds The Dipping Tanks Should Be Properly Vented And All Fumes Exhausted To The Outside Atmosphere Since Temperatures Of The Caustic Solutions Exceed The Boiling Point Of Water, Any Splashing Encountered While Adding Make- Up Water Can Cause Serious Bums Always Add Water Slowly And With Extreme Care When The Parts To Be Dipped Are Cold, Caution Should Be Taken To Avoid Splashing That Might Occur When The Cold Parts Come In Contact With The Hot Solutions. A Heavy Wire Screen Type Basket, Suitable For Holding A Quantity Of Injector Bodies, Is Recommended For Dipping The Parts In The Solutions

**WARNING**

Use Extreme Care In The Handling Of These Chemicals To Prevent Serious Injury To The Person Or Damage To Finished Surfaces Wash Off Spilled Fluid Immediately With Clean Water

**WARNING**

The Fuel Spray From An Injector Can Penetrate The Skin Fuel Oil Which Enters The Blood Stream Can Cause A Serious Infection Therefore, Follow Instructions And Use The Proper Equipment To Test An Injector

**WARNING**

This Adhesive Contains Cyanoacrylate Keep Away From Children Irritating Liquid And Vapor Hazardous if Swallowed Use With Adequate Ventilation In Case Of Skin Contact, Flush With Plenty Of Water For Eye Or Mouth Contact, Get Medical Attention

**WARNING**

Never. Use A Caustic Cleaning Solution For Cleaning As This Will Damage Certain Parts Use The Cleaning Solution In An Open Or Well-Ventilated Area Avoid Breathing The Fumes To Avoid The Possible Toxic Effect Of The Cleaning Solvent Keep Away From Open Flames To Avoid The Possibility Of A Fire Do Not Use A Wire Brush or A Steel Blade Scrapper to Clean The Parts

**WARNING**

Be Sure The Engine Is Securely Mounted To The Overhaul Stand Before Releasing The Lifting Sling Severe Injury To Personnel And Destruction Of Engine Parts Will Result If The Engine Breaks Away From The Overhaul Stand

**WARNING**

When Inspecting A Blower On An Engine With The Engine Running, Keep Fingers And Clothing Away From Moving Parts Of The Blower And Run The Engine At Low Speeds Only

**WARNING**

Many Accidents, Some Fatal, Have Resulted From Improper Handling Of Wheels And Tires It Is Of The Utmost Importance That The Following Information Be Carefully Noted And Followed To Prevent Injury.

**WARNING**

Before Removing Tire And Rim Assembly From Vehicle, The Tire Must Be Completely Deflated If Dualed, Both Tires Must Be Deflated Before Mounting Bolts Are Loosened

**WARNING**

Extreme Care Must Be Taken In Removing Wheel Nuts Rim Clamps Can
Snap Off The Rim And Cause Serious Injury

**WARNING**

Fuel Is Very Flammable And Can Explode Easily To Avoid Serious Injury Or Death, Keep Fire Extinguisher Within Easy Reach When Working With Fuel Do Not Work On Fuel System When Engine Is Hot Fuel Con Be Ignited By Hot Engine When Working With Fuel, Post Signs That Read "NO SMOKING WITHIN 50 FEET OF VEHICLE."

**WARNING**

Fuel And Oil Are Slippery And Can Cause Falls To Avoid Injury, Wipe Up Spilled Fuel Or Oil With Rags

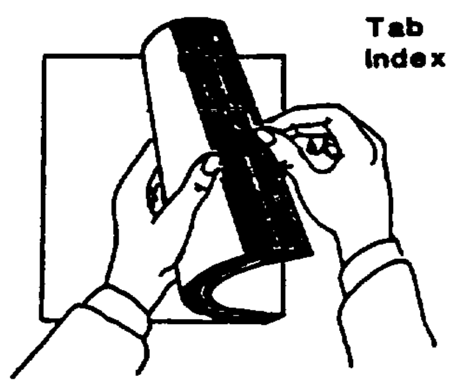
**WARNING**

Remove Rings, Bracelets, Wristwatches, And Neck Chains Before Working Around The Tank Or Other Vehicles.  Jewelry Can Catch On Equipment And Cause Injury, Or May Short Across An Electrical Circuit And Cause Severe Burns Or Electrical Shock

**Service Manual** **Quick Reference System**



How To Use This Manual
The manual is divided into nine major sections as shown on this page. Each section can be located with the tabs on the right hand edge of the page as shown in the picture.



**Warranty**

**Standard Warranty Cable Cranes**

FMC CORPORATION, CABLE CRANE & EXCAVATOR DIVISION is hereinafter called the COMPANY.

The products manufactured by the COMPANY, exclusive of used or re-built machinery or equipment, are subject to the following warranty:

(A) Warranty.

"ALL of COMPANY's products are of high quality and are manufactured in conformity with the best commercial practices in the various lines. The COMPANY warrants all products manufactured by it to be free from defects in material and manufacture at the time of shipment for six (6) months from date of shipment or 1000 hours of operation, whichever shall occur first. The COMPANY will furnish without charge, f.o.b. its factory, replace- ments for such parts as the COMPANY finds to have been defective at the time of shipment, or at the COMPANY's option, will make or authorize repairs to such parts, provided that, upon request, such parts are returned, transportation prepaid, to the factory from which they were shipped.

"This warranty shall not apply to any product which has been subjected to misuse; misapplication; neglect (including but not limited to improper maintenance); accident; improper installation, modification (including but not limited to use of unauthorized parts or attachments), adjustments, or repair. Engines, motors, and any accessories furnished with the COMPANY's products, but which are not manufactured by the COMPANY, are not warranted by the COMPANY but are sold only with the express warranty, if any, of the manufacturers thereof. THE FOREGOING IS IN LIEU OF ALL OTHER WARRANTIES, WHETHER EXPRESS OR IMPLIED (INCLUDING THOSE OF MERCHANT- ABILITY AND FITNESS OF ANY PRODUCT FOR A PARTICULAR PURPOSE), AND OF ANY OTHER OBLIGATION OR LIABILITY ON THE PART OF THE COMPANY.

(B) Limitation of Liability.

"It is expressly understood that the COMPANY's liability for its products, whether due to breach of warranty, negligence, strict liability, or otherwise, is limited to the furnishing of such replacement parts, and the COMPANY will not be liable for any other injury, loss, damage, or expense, whether direct or consequential, including but not limited to loss of use, income, profit, or production, or increased cost of operation, or spoilage of or damage to material, arising in connection with the sale, installation, use of, inability to use, or the repair or replacement of, the COMPANY's products.

The COMPANY reserves the right to make alterations or modifications in their equipment at any time, which, in their opinion, may improve the performance and efficiency of the machine. They shall not be obliged to make such alterations or modifications to machines already in service. Any operation beyond rated capacity expressly prohibited in the operating instructions or safety manual furnished with the machine, or any adjustment, or assembly procedures not recommended or authorized in the operating or service instructions shall void such warranty.

**Special Provisions**

The standard machine warranty is modified by special provisions in solicitation DAAEO7-80-B-5230.

J07 EQUIPMENT WARRANTY

J.7.1 Definitions

Acceptance. The word "acceptance" as used herein means the execution of the Acceptance Block and signing of a DD Form 250 by the authorized Government representative.

Supplies. The word "supplies" as used herein means the end item and all parts and accessories thereof, furnished by the contractor, and any related services required under this contract. The word does not include technical data.

J.7.2 Warranty. Notwithstanding inspection and acceptance by the Government of the supplies furnished under the contract or any provision of this contract concerning the conclusiveness thereof, the contractor hereby warrants that the supplies are free from defects in design, material, and workmanship and will conform with the specifications and all other requirements of this contract for a period of 15 months from date of acceptance, as shown on the Material Inspection and Receiving Report (DD Form 250), or 1500 hours of operation, whichever occurs first. Equipment designated as Production Samples shall be treated as equipment delivered

**Warranty**

at the time as the production units. If a Safety Recall defect occurs during equipment warranty period, the contractor agrees to extend the term of the warranty by the period of time equal to the time period required to make necessary safety defect corrections. Additionally, to the extent of the contractor or his supplier(s) provide to commercial customers a greater warranty for the supplies furnished therein, the contractor hereby likewise provides such greater warranty to the Government. To the extent the terms of such greater warranty are inconsistent with or conflict with this warranty, the provisions of this warranty shall govern.

J.7.3 Remedies.

J.7.3.1 New Replacement Supplies. With respect to defective supplies, wherever located, the warranty shall include the furnishing, without cost to the Government, F.O.B. contractor's plant, branch or dealer facility, or F.O.B. original CONUS destination, or F.O.B. US Port of Embarkation, at the Government's option, new supplies to replace any that prove to be defective within the warranty period.

J.7.3.2 Corrective Action Options. In addition, the Government shall have the option (a) to return the equipment or parts thereof to the contractor's plant, branch or dealer facility for correction, or (b) to correct the supplies itself. When the Government elects to return the equipment or parts to the contractor's plant, branch or dealer facility, the cost of labor involved in the correction of the defective supplies shall be borne by the contractor. When the equipment or parts thereof are returned to the contractor for correction, the contractor shall bear all transportation costs to the contractor's plant and return. With respect to defective supplies, when the Government elects to correct them itself, the cost of labor involved in the correction of defects shall be borne by the Government. If the Government requires the assistance of Contractor personnel in disassembly/reassembly of items removed in connection with repair or replacement of defective parts, the Contractor will be reimbursed for labor at a rate to be negotiated between the Contracting Officer and the Contractor at the time of repairs.

J.7.3.3 Notification. If the Government elects to have warranty repair or replacement performed by the contractor, the Government shall deliver the parts or equipment to contractor's local facility or dealership for warranty corrective repair or replacement. If the Government elects to effect warranty repairs or replacement itself, the contractor shall be notified in writing of repairs required under the warranty within 30 days after discovery of the defect. Within 10 days after receipt of such notices, the contractor shall submit to the Contracting Officer a written recommendation as to the corrective action required to remedy the defect. In any event, the Contracting Officer may, upon the expiration of the 10 day period set forth above, proceed with correction or replacement as set forth in the paragraph, Remedies, above, and the contractor shall, notwithstanding any disagreement regarding the existence of a breach of warranty, comply with the Contracting Officer directions related to such correction or replacement. After the notice, but not later than 30 days after receipt of the contractor's recommendation for corrective action.

The Contracting Officer will, in writing, notify the contractor of the parts used by the Government in repair or replacement and all other costs or expenses required for Government correction of warranty defect as set forth in the paragraph, Remedies, above. The contractor shall respond within 30 days after receipt of this notice, of his intention to furnish identified replacement parts and/or cost reimbursements to the Government. In the event it is later determined that the contractor did not breach the warranty in paragraph, Warranties, above, the contract price will be equitably adjusted pursuant to the terms of the "Changes" clause of the contract. Failure to agree to such an equitable adjustment or upon any determination to be made under this clause shall be a dispute concerning a question of fact within the meaning of the "Disputes" clause of this contract. The Contractor shall furnish with his proposal a listing of distributors, dealers, and franchise outlets where warranty claims may be exercised.

J,7.4 Decalcomania. A synopsis or simplified summary of the warranty coverage and its implementation will be printed on a decalcomania approximately 3" x 4" and shall be mounted in view of the operator as near as possible to the center of the instrument panel of each vehicle. On those vehicles requiring concealed markings and registration numbers said decalcomania shall be placed in a readable position on the engine side of the fire-wall.

J.7.5 Rights. The rights and remedies of the Government provided in this clause are in addition to and do not limit any rights afforded to the Government by any other clause in the contract. Exceptions To Warranty

The following supplies are not covered under the 1500 hour or 15 month warranty: (1) Tires (2) Batteries (3) Light Bulbs (4) Windshield wipers (5) Electrical Wires (6) Lubricants (7) Filters.

**Warranty**
**Preparation Of Warranty Claims**

(1) Use warranty claim no. 531 for all claims over $25. These forms are available at no charge from the factory.
(2) Claims less than $25.00 will not be processed.
(3) Campaigns - A $25.00 minimum will be paid on all claims identified as a campaign and listing the campaign only on the individual warranty claim.
(4) Delivery and applicable follow-up reports must be on file before warranty consideration will be given.
(5) Warranty Claim must be typed and mailed to the manufacturing division where the particular machine was manufactured no later than 45 days after work is completed.
Do not type on the reverse side of the warranty claim form. If additional space is required on the warranty claim form, attach an additional sheet.
(6) The upper right hand corner of the claim must be completely and correctly filled out. Information about description of the job must also be furnished.
(7) Under Section 1 and 2 of the warranty claim, explanation must be given covering problem as diagnosed and corrective action taken.
The statement "installed or replaced" will not be accepted as a satisfactory explanation of the diagnosis of problem and corrective action taken. Neither will the statement making reference to a previous report be accepted in lieu of information correctly filled out explaining the problem and correct action taken.
(8) Section 3 entitled "Name of Part(s) That Failed or Caused Failure" must be completely filled out to enable the factory to determine disposition of defective parts. The serial number of the replacement part is also required to ensure future warranty of the part replaced.
(9) Section 4 of the claim entitled "Other" is reserved tolist things not provided for elsewhere on the form. Examples: A freight bill, outside purchase of parts, outside labor for machine shop, etc. A copy of the paid invoice must accompany each claim.
(10) Section 5 is to list item number of part, description of part, quantity of part, invoice number and cost
(11) If part or parts were supplied from your "stock", type the word "stock" in the invoice section provided
(12) If parts were ordered where a 5 or 10% added cost was assessed for emergency shipment, a copy of the
(13) If a large group of parts were ordered from the factory for warranty repair, a legible copy of the FMC in-voice attached in lieu of filling out Section 5 if preferred.
(14) If an incorrect FMC part number is listed or a part claimed that cannot be identified, it will be eliminated from the claim and will not appear on the credit memo.
(15) Section 6 and 8 are reserved for factory use only. Do not enter any information in these areas.
(16) Section 7 under labor, type hours only.

Returning Defective Or Failed Parts To The Manufacturing Division

(1) Do not send defective parts to the factory. Hold all defective parts until information is received as to their disposition. If and when the parts are needed by the manufacturing division, the manufacturing division will forward instructions wither verbally or in writing and/or both. In all cases an A.T.R. number (Authorization to Return and Authorization to Receive) will be assigned with shipping instructions.

A.T.R. 87 - - - is used by the Bowling Green plant.
FMC Corporation
Crane & Excavator Division
U.S. 31. W. South
Bowling Green, Kentucky 42101

The Receiving Departments have orders not to accept any shipment of warranty parts without an A.T.R. number clearly displayed on all parts, shipping cartons, tags, bills of lading and other papers required by transportation companies.
If the part to be returned is a large item that cannot be crated (Example: boom sections, large hydraulic cylinders, frames, counterweights, etc.) it will be necessary to have the A.T.R. number legibly marked or painted with some waterproof marking device. If it is a part that is apt to be rolled over, it is required that the number be marked on two or more sides of the component.
(2) Parts must be returned in clean condition. Hydraulic parts must be sealed to prevent contamination. Any parts received without covering port plugs, etc., will not be inspected or forwarded to the vendor as vendors refuse any warranty consideration of hydraulic components not properly protected.
(3) Shipping of parts for more than one claim in one shipment is discouraged. However, if for some reason or other, this must be done than each individual part must be identified by item number, claim number and A.T.R. number.

**Warranty**
**Submitting Of Warranty Claims**

(a) Prepare claim as outlined under "PREPARATION OF WARRANTY CLAIMS".
(b) Distribute copies as follows:

| | | |
|---|---|---|
| Copy #1 White | ( | Forward copies to the Manufacturing Division |
| Copy #2 Yellow | ( | responsible for the model involved. For your |
| Copy #3 White | ( | assistance we are listing below the mailing |
| Copy #4 Pink | ( | address of each of the models manufactured. |
| Copy #5 Green | ( | |
| Copy #6 Blue | ( | Government copy. Copy should be retained for your records. |

(c) You will be advised on the disposition of any alleged defective parts.
(d) Approximate time for processing claims that are within the time frame of normal warranty will fall in the following categories:
  (1) If material is not required for inspection, the claim will be accepted or rejected within 45 days of receipt of the #3 copy. The Government will assume the responsibility for destroying and scrapping related parts under the direction of the Warranty Supervisor.
  (2) If material is required for inspection, the claim will be accepted and credit issued within 45 days of receipt of the part or parts at the factory or a designated location. If inspection reveals the part or parts were not defective, the factory will re-invoice the Government to cancel the credit
  (3) Government will be notified by phone followed by confirming letter with shipping instructions for alleged defective parts. If parts not received within 3 days a follow-up letter will be sent to distributor. If parts not received within 30 days after follow-up letter mailed, warranty claim will be
  (4) A disputed warranty settlement must be presented in writing to Construction Equipment Distribution Operation, 2800 Lakeside Drive, Bannockburn, Illinois 60015, Attention: Service Department, no later than 45 days after the warranty claim status report is dated.

If the Government does not reply to FMC within the 45 day time frame, the warranty claim will not be opened to any further discussion at a later date.
Listed below are the mailing addresses and models for the Manufacturing Division. Direct claims to the attention of the Warranty Departments.
FMC Corporation
Crane and Excavator Division
Box 950
Bowling Green, Kentucky 42101

**Campaign Procedures (Safety Recall)**

A. Labor compensation for announced factory modification and retrofits implemented by CCED.
  (1) FMC will compensate the Government 100% of its charge out rate which must be on record with the company at the time the claim is received, for performance of work related to the campaign.
    (a) If FMC has established the work time required to effect the campaign, only the time so established will be recognized in establishing the amount of the claim.
    (b) If FIC has not established the hours required to effect the campaign, the company will accept actual documented time expended by the distributor, provided the time is reasonable and can be substantiated.
B. Travel Time - Per Diem
  (1) FMC will compensate the Government at 100% of their charge out rate, on record with the company, for actual travel time expended in the performance of campaign work up to a maximum of eight hours.
  (2) The standard 10% add-on clause, as found in the warranty labor program, will not apply to computing the credit amount on the warranty claim.
  (3) In addition to travel time, a reasonable per diem will be allowed for living expenses. Per diem receipts must accompany claim.

**Warranty**

C. Overtime

(1) Overtime charges will not be accepted, unless agreed to by the company prior to the performance of the work.

D. Limits of FMC Responsibility

(1) FMC reserves the right to make alterations or modifications in their equipment at any time which in their opinion may improve the performance and efficiency of the machine. FMC shall not be obligated to make such alterations or modifications to machines already in service

(2) FMC will not be under obligation to credit the Government with the price of the new part or to reimburse the Government for the labor cost for repairing or replacing defective part unless, within thirty (30) days of the date of the campaign work performed, the Government submits a typewritten claim list- ing parts used and the R1C allotted time provided in the campaign letter, or if FMC has not established the time, satisfactory proof of the time reasonably expended in repairing or replacing the defective

(3) FMC will issue a minimum of $25.00 per claim.

(4) Claims which cover campaign work performed on more than one machine will not be accepted.

(5) The work must be completed within the time frame stated in the campaign agreement and campaign instructions. If campaign work is not completed within the stated time frame, FMC assumes no responsibility for any damage that might be incurred due to delay of campaign completion.

E. Requirements for Qualification

(1) The Government will utilize only qualified personnel in the performance of campaign work. These personnel must have attended an authorized factory school on the particular product line within the

(2) The Government must maintain properly equipped service vehicles and shop facilities as dictated by past 18 months.

(3) The Government must have any specialized material, equipment, and tools, required by general industry general industry standards.

(4) The Government must maintain a current and updated service library; including service manuals, bulletins standards. tins, policy handbook, parts books, and/or microfilm.

1.1 SM (Service Manual) System

The index is a list, identifying all major components on a machine. It is divided into general areas. The following areas are used with this machine.

Example: 1-1-1.0
General Area

| Area | Description |
|---|---|
| 1 | Rubber Tired Lower |
| 3 | Upper Revolving Frame And Equipment |
| 4 | Vertical Shafts |
| 5 | Horizontal Shafts |
| 6 | Upper Engine & Converter |
| 7 | Speed-o-Matic System |
| 9 | Boom Attachment |
| 18 | Special Equipment |

Each area is divided into numerous sub areas. The following is an alphabetical index of sub areas used on this machine.

Example:: 1-1-1.0
Sub Area

Alphabetical Index



(1 of 24)

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After determining the area, and sub-area, look at the third set of numbers on the parts page code. This is the specific page number.

Example: 1-1-1.0 — Specific Page Number

The SM page code number (Example: 1-1-1.0) appears at the top of each page. The pages are in the book in numerical order, making it easy to find a specific page.

**Notes**

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**Service Manual** SM0-0-1.0 General Information & Indexes

1.3 List Of Illustrations

**Service Manual** SM0-0-1.0 General Information & Index

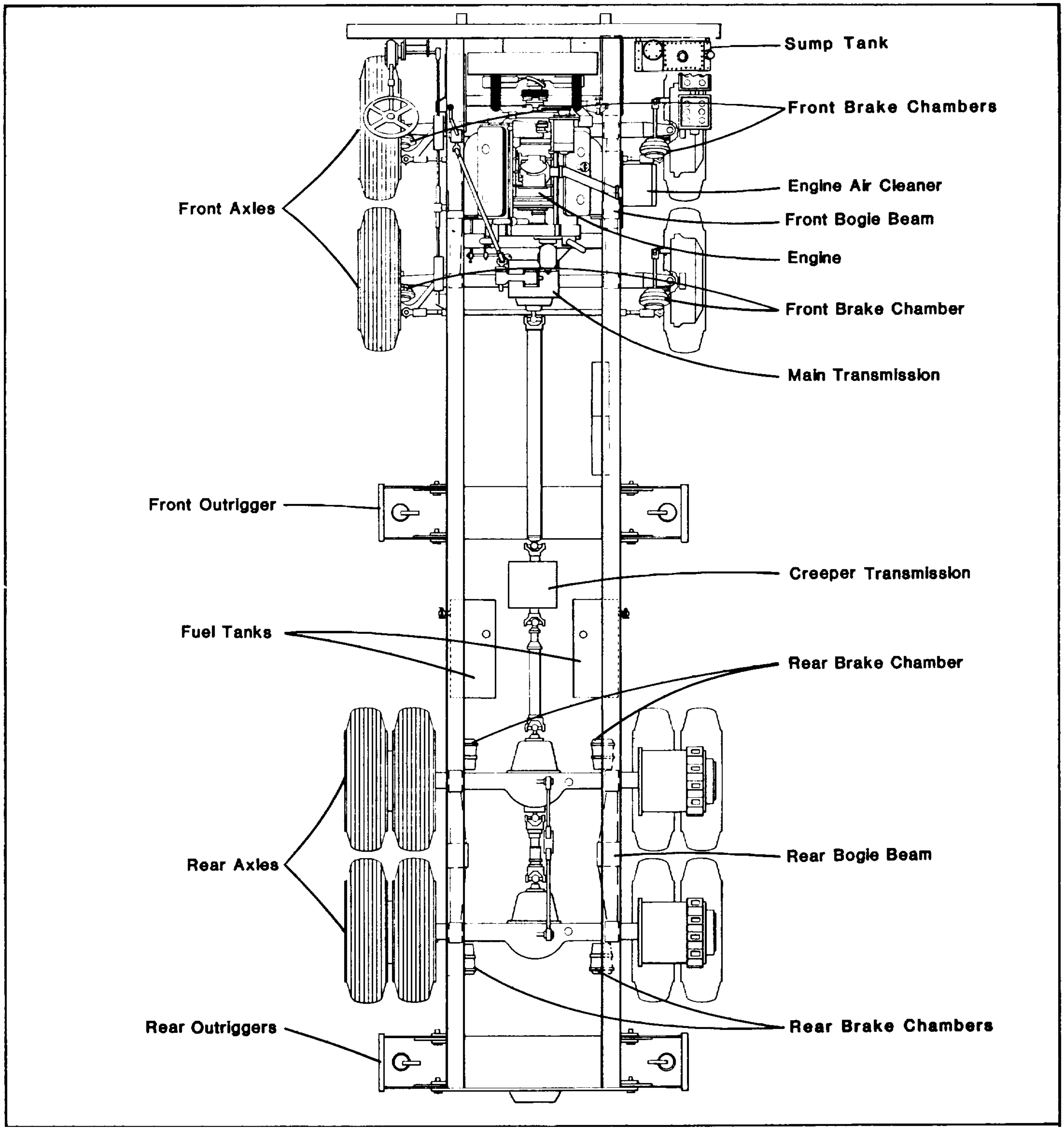


*Fig. 1*
*Truck Carrier* *NA220-D*

The carrier was designed and built by FMC Corporation.
The 238A carrier has 8 x 4 drive.
Engine power is transferred through a 15 speed main transmission, to a two speed creeper transmission, and then to the rear axles.

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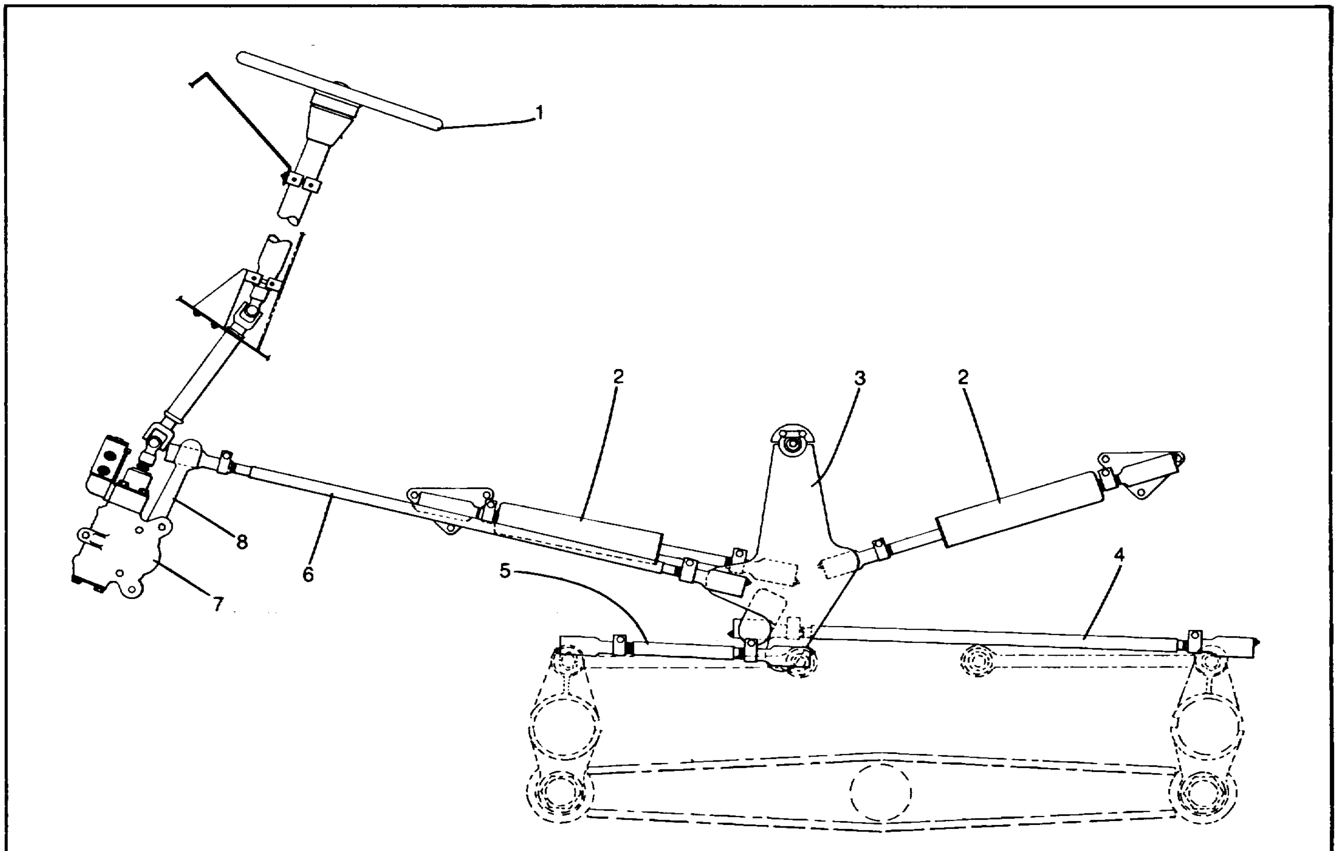


Fig. 1 NA206-D
Steering Mechanism
(1) Steering Wheel (2) Steer Cylinders (3) Ilder Arm (4) 2nd Axle Drag Line (5) 1st Axle Drag Link (6) Pitman Drag Link (7) Steering Gear (8) Pitman Arm

### 3.1 Front Axle Assembly

The front axles are mounted to the carrier frame on equalizer beams, one set on each side of the carrier. The equalizer beams serve two purposes: (1) They reduce bumps and road irregularities. (2) They distribute the loading between the front axles.

The front axles are also supported by torque rods, two per axle. As the name implies, the torque rods absorb any torque caused by the tendency of the axles to turn forwards or backwards on their neutral axis due to the starting or stopping inertia.

3.2 Front Wheel Alignment

To obtain maximum tire life, tire alignment must be checked periodically. This is critical on a tandem axle arrangement. The front axles must be aligned with respect to each other, or excessive tire wear will result. The following procedure outlines the steps necessary for checking front wheel alignment.

a) Jack the carrier up so front wheels clear the

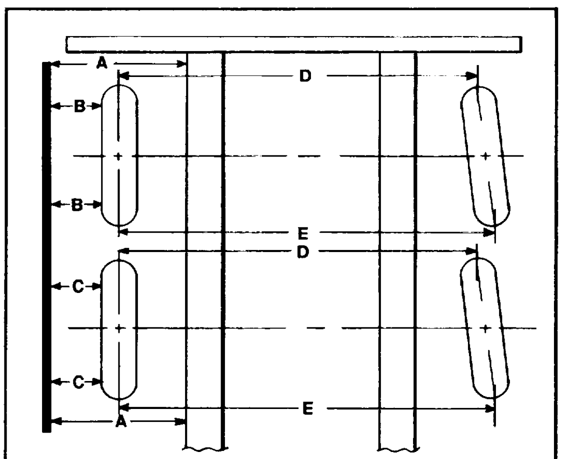


Fig. 2 L234-A
Front Wheel Alignment

ground.

(b) Turn steering wheel until the left tires are in line with each other and are straight ahead with respect to the carrier. Fig. 2 illustrate one method of checking step (b). This involves placing a straight edge parallel to the carrier by measuring a distance (A) at each end of the straight edge. Once the proper position of the straight edge is determined, measure the distance between the straight edge and the milled surface of the wheel hub used to locate the tire lugs. These dimensions are represented by the letters (B) & (C). Distances (B) must equal (B), and (C) must equal (C), but (B) doesn't necessarily have to equal (C). An axle drag link adjustment may be necessary to correct any misalignment. (Fig. 1).

(c) Once the front left tires are lined up, check for proper toe in. Toe in can be checked by scribing a line around the circumference of the tire tread at the centerline of the tire tread. The difference between the distances (D) on the front and (E) on the back (Fig. 2) indicate the amount of "toe in" and should equal 1/8" + 1/32". A tie rod (2) adjustment will correct any toe in variations (Refer to Fig. 3).

(d) Check the stroke of the power steering cylinders and make sure they are centered when the left wheels are straight ahead as established in step (b). A ball socket adjustment on one or both ends of the cylinder may be required (Fig. 1).

(e) To establish a position of the steering wheel when the wheels are straight ahead, mark the steering wheel with relation to some reference point.

(f) Now count the revolutions of the steering wheel from the extreme left to extreme right. Center the steering wheel. Note the position of the mark made in step (e).
It should be within one revolution of its established mark. If not, return the steering wheel to its reference point. (This again aligns the front wheels straight ahead). Remove the pitman arm from the steering gear, center the steering wheel, and reinstall the pitman arm to the steering gear (Refer to Fig. 1).

3.3 Wheel Bearing Adjustment (Fig. 3)
The wheel bearing adjustment must be checked periodically. The carrier should never be operated with the bearings improperly adjusted. Bearing failure can result. The bearings are adjusted as follows:

(a) Jack up one end of the axle until the wheel clears the ground.

(b) Remove the hub cap (3).

(c) Remove cotter pin (4).

(d) Tighten the adjusting nut (5), and at the same time rotate the wheel in both directions until there is a slight bind, thus being sure all bearing surfaces are in contact.

(e) Then back off the adjusting nut (5) 1/6 to 1/4 of a turn, or to the nearest locking hole, or sufficiently to allow the wheel to rotate

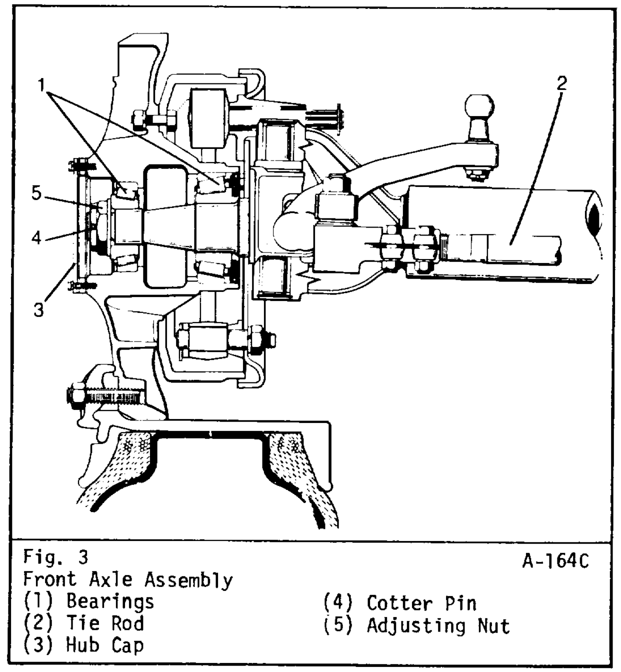


*Fig. 3* *A-164C*
*Front Axle Assembly*
*(1) Bearings* *(4) Cotter Pin*
*(2) Tie rod* *(5) Adjusting Nut*
*(3) Hub Cap*

freely within limits of .001" to .010" end play.

(f) Replace cotter pin (4). Spread the ends of the pin to retain it.

(g) Replace the hub caps(3), being sure that the wheel bearings (1) are packed with sufficient grease, and the hub cap is packed with enough grease to prevent moisture condensation.

3.4 Wheel Bearing Repacking

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

At the interval specified in Section 2 of the Operator's Manual the wheel bearings must be removed, cleaned with kerosene, diesel fuel, or some similar approved solvent, repacked with new grease, and adjusted as explained earlier in this SM. Use only wheel bearing grease that meets or exceeds the specifications listed in Section 2 of the Operators Manual. Pack the hub cap, and the hub between the two bearing cups with grease to the level of the cups smallest diameter. The seal which retains grease in the inner bearing should be examined, and replaced if worn or damaged. The tapered roller bearings, whenever removed from the axle, should be handled with great care and kept free from dirt or water. When reassembling caution should be used to prevent any foreign material from allowing metal to metal contact between the roller bearing cups and cones, the spindles on which they ride, and the shoulders against which they are intended to fit. 3.5 Wheel Torque Procedure: See SM1-69-2.0.

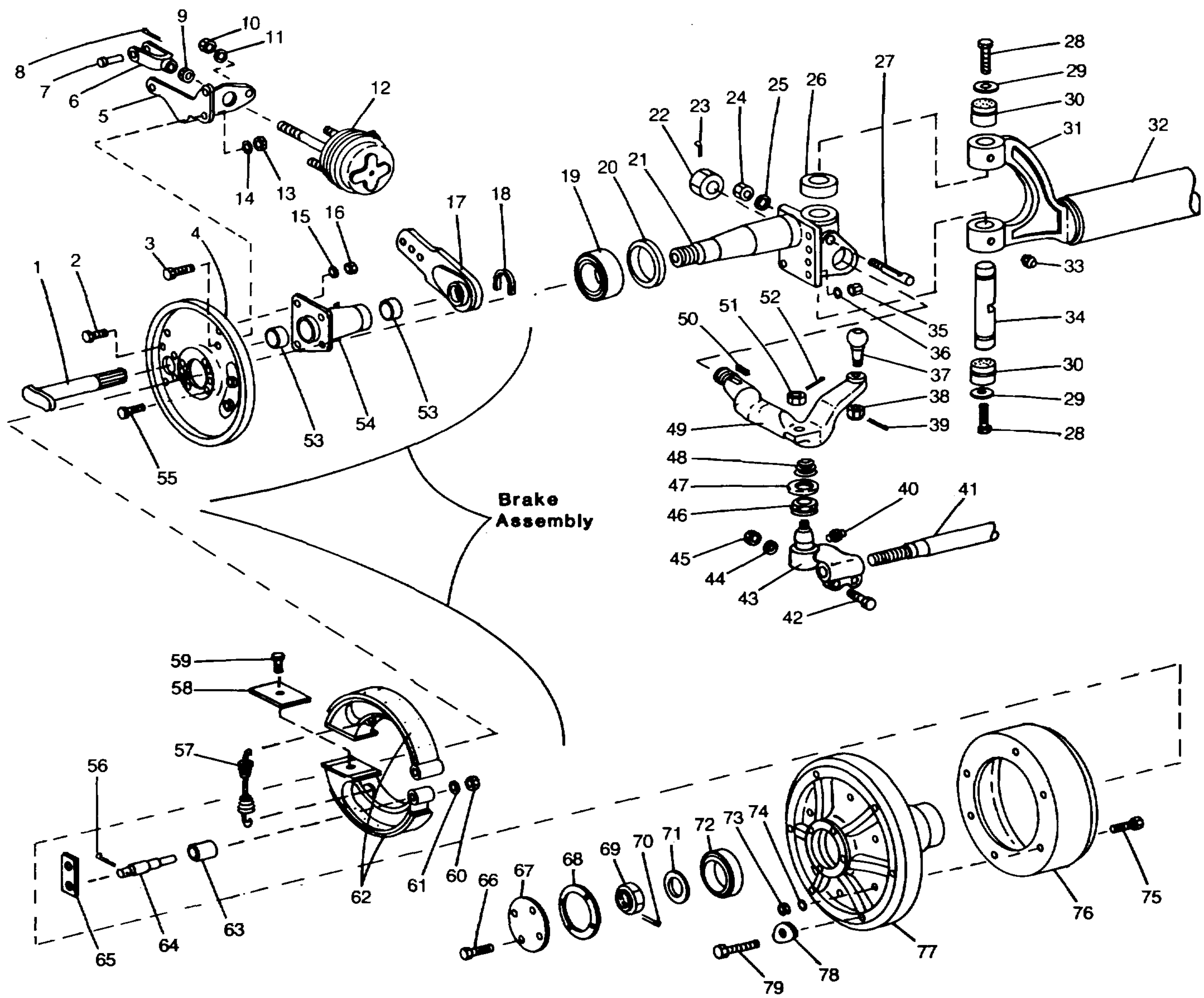


*Fig. 1* *NA388-B*

*Front Axle Disassembly*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (1) | Camshaft | (17) | Slack Adjuster | (33) | Grease Zerk | (49) | Steering Arm | (65) | Plate |
| (2) | Capscrew | (18) | Lock | (34) | Knuckle Pin | (50) | Key | (66) | Capscrew |
| (3) | Capscrew | (19) | Bearing | (35) | Nut | (51) | Nut | (67) | Hub Cap |
| (4) | Backing Plate | (20) | Grease Retainer | (36) | Lockwasher | (52) | Cotter Pin | (68) | Gasket |
| (5) | Bracket | (21) | Steering Knuckle | (37) | Ball Stud | (53) | Bushing | (69) | Nut |
| (6) | Yoke | (22) | Nut | (38) | Nut | (54) | Bracket | (70) | Cotter Pin |
| (7) | Clevis Pin | (23) | Cotter Pin | (39) | Cotter Pin | (55) | Capscrew | (71) | Spindle Washer |
| (8) | Cotter Pin | (24) | Nut | (40) | Grease Zerk | (56) | Cotter Pin | (72) | Bearing |
| (9) | Nut | (25) | Lockwasher | (41) | Cross Rod | (57) | Spring | (73) | Nut |
| (10 | Nut | (26) | Thrust Bearing | (42) | Capscrew | (58) | Wear Plate | (74) | Lockwasher |
| (11) | Lockwasher | (27) | Draw Key | (43) | Cross Rod End | (59) | Screw | (75) | Capscrew |
| (12) | Brake Actuator | (28) | Capscrew | (44) | Lockwasher | (60) | Nut | (76) | Brake Drum |
| (13) | Nut | (29) | Dust Plug | (45) | Nut | (61) | Lockwasher | (77) | Wheel Hub |
| (14) | Lockwasher | (30) | Bushing | (46) | Washers | (62) | Brake Shoe Assy. | (78) | Rim Clamp |
| (15) | Washer | (31) | Axle Yoke | (47) | Cover | (63) | Bushing | (79) | Stud & Nut |
| (16) | Nut | (32) | Axle Tube | (48) | Spring | (64) | Anchor Pin | | |

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5.1 Disassembly

(a) Jack up the front end of vehicle so tires clear floor (use outrigger jacks). Block up securely at this position. Remove wheel and tire assembly (Refer to SM1-69-2.0).

**WARNING**

Do Not Attempt To Disassemble Or Perform Knuckle Pin Repair With Vehicle Supported By Jacks Only.

(b) Remove hub cap (67), gasket (68), cotter pin (70), nut (69) and spindle washer (71).

(c) Remove outer bearing (72).

(d) Remove wheel hub assembly (77).

(e) Remove brake actuator (12) from bracket (5).

(f) Remove brake assembly from steering knuckle (21) by removing capscrews (55).

(g) Remove cotter pin (52) and nut (51) to disassemble cross rod assembly from the steering arm (49). Remove cross rod end (43) from steering arm with a devils fork and hammer.

(h) Remove cotter pin (23), nut (24) and steering arm (49) from steering knuckle (21).

Note: It is not necessary to remove steering arm unless it requires service.

(i) Remove dust plug capscrews (28) and dust plug (29).

(j) Remove nut (24). Tap draw key (27) out by use of brass hammer on threaded end.

(k) Tap out knuckle pin (34) with a bronze drift.

Note: Do not strike the hardened steel knuckle pin directly with a steel hammer.

(1) Remove steering knuckle (21) and thrust bearing (26).

5.2 Bushing Replacement

(a) Remove axle assembly (refer to SM1-4-1.0 for axle removal) and use a press to remove and replace bushings (30).

(b) Install axle assembly.

5.3 Assembly

(a) Make sure knuckle pin holes in axle yoke (31) are clean and dry.

(b) Position and support steering knuckle (21) in axle yoke (31).

(c) Slide thrust bearing (26) between upper face of the steering knuckle (21) and axle yoke (31).

(d) Align steering knuckle hole and thrust bearing hole with axle yoke holes.

(e) Align knuckle pin "flat" to mate with draw key hole, and tap knuckle pin (34) through axle yoke (31), thrust bearing (26) and steering knuckle (21) from the top or bottom side.

(f) Install draw key (27) so the "flat" on the key mates with corresponding "flat" on knuckle pin.

Note: Before setting draw key, center knuckle pin to equalize gap between upper and lower gap mounting surfaces.

(g) Install lockwasher (25) and nut (24).

(h) Install dust plugs (29) and capscrews (28).

(i) Install steering arm (49) into steering knuckle (21), connect key (50) and tighten nut (22). Position cotter pin (23). Install cross rod assembly, tighten nut (51) and position cotter pin (52).

(j) Install brake assembly, brake actuator (refer

(k) Install bearing (72), spindle washer (71), nut (69) and adjust. (Refer to SM1-2-3.0). (1) Install gasket (68) and hub cap (67). Install wheel and tire assembly. See SM1-69-2.0. and grease retainer (20) in wheel hub (77). Install hub on spindle. to SM1-3-4.0 for brake service). Pack bearings (19, 72) with grease. Install bearing (19)

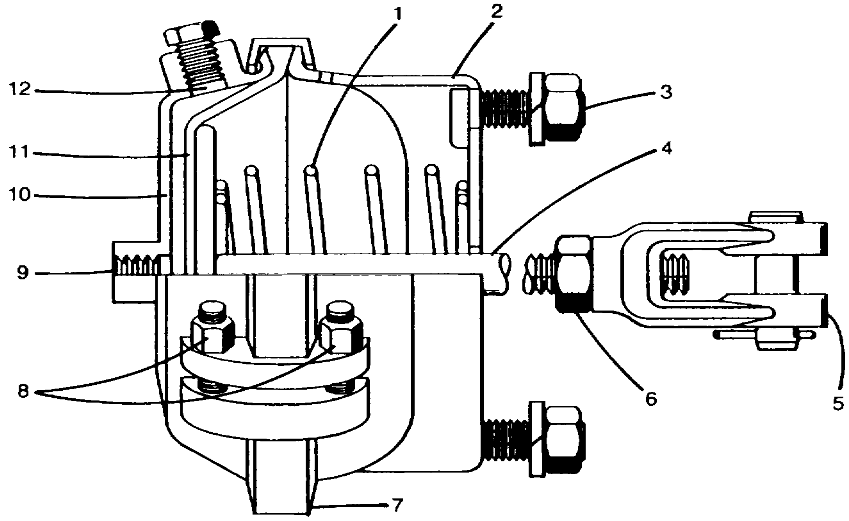



Fig. 1 K11-B
Front Brake Actuator

| | | | | | |
|---|---|---|---|---|---|
| (1) | Spring | (5) | Yoke & Pin | (9) | Inlet Port |
| (2) | Non-Pressure Plate | (6) | Locknut | (10) | Pressure Plate |
| (3) | Mounting Bolts & Nuts | (7) | Clamp Ring | (11) | Diaphragm |
| (4) | Push Rod Assembly | (8) | Clamp Rinq Nuts & Bolts | (12) | Inlet Port |

1.1 Single Diaphragm Actuator
Air under pressure is admitted to port (9) when the foot brake pedal is depressed. The air pressure pushes on the diaphragm (11) and push rod assembly (4) to apply the brakes. When air is released from the actuator, the brake spring and spring (1) disengage the brake and return the diaphragm (11) and push rod assembly to their disengaged position.

1.2 Actuator Disassembly
(a) Block the wheel of the carrier so it cannot move.
(b) Disconnect the air line leading to the actuator.
(c) Remove the pin which connects the yoke (5) to the brake slack adjuster.
(d) Remove the mounting nuts (3), and remove actuator from axle.
(e) Pull out the push rod and clamp it at the non-pressure plate (2) with a vise or vise grips. Cover or tape the vise or vise grip jaws to prevent damage to the push rod.
(f) Remove the clamp ring nuts and bolts (8).
(g) Spread the clamp ring (7) slightly with a screw driver and remove.
(h) Remove the pressure plate(10) and diaphragm (11).
(i) Remove the yoke (5) and locknut (6) from the push rod.
(j) Release the grip on the push rod.
(k) Remove the push rod assembly (4) and spring

(1) Thoroughly clean and inspect all parts. Replace any worn parts. When the diaphragm (11) or spring (1), or both are replaced, they should be replaced' in the other brake chamber on the same axle.

1.3 Actuator Assembly
(a) Install push rod assembly (4) and spring (1). Compress spring, and clamp the push rod in a vise.
(b) Install diaphragm (11) over push rod assembly (4). Install pressure plate (10) over diaphragm (11).
(c) Spread clamp ring (7) and install on actuator. Install and tighten nuts and bolts
(d) Remove assembly from vise. Install locknut (6) and yoke (5).
(e) Install actuator on axle. Connect yoke (5) to slack adjuster.
(f) Connect air line to actuator.
(g) Adjust brakes as explained in SM1-3-4.0.

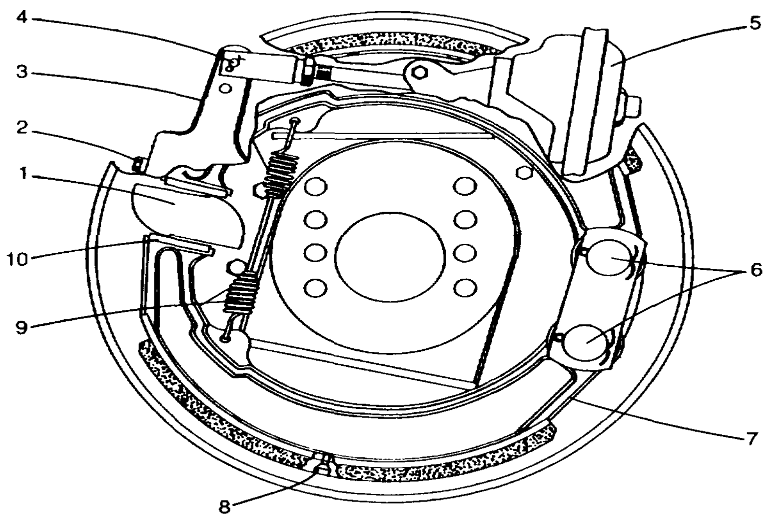



*Fig. 1* *D208-B*
Brake Assembly

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) | Brake Cam | (4) | Pin | (7) | Brake Shoe | (10) | Wear Plate |
| (2) | Adjusting Screw | (5) | Brake Actuator | (8) | Lining Rivet | | |
| (3) | Slack Adjuster | (6) | Anchor Pin | (9) | Shoe Return Spring | | |

4.1 Front Wheel Brakes

The front wheel brakes are of the two shoe eccentric anchor pin design. They require no major adjustment after initial setting and "break in" of new lining. The taking up of wear is by means of the slack adjusters (Fig. 1) throughout the life of the lining. After the initial setting and "break in" of the lining, the eccentric adjustment is not changed. Changing the eccentric adjustment during the life of the lining will create an out of round condition resulting in uneven and short lining life, poor braking, unusually high temperatures, and heat cracked drums.

As is the case of any brake, worn linings must be replaced before the heads of the lining rivets (8) start to rub and score the brake drums. When relining, check brake drums for scoring or heat cracking. Wear plates (10) anchor pins (6), bushings, and springs (9) must be cleaned and examined for replacement if necessary.

4.2 Adjustment (Fig. 1)

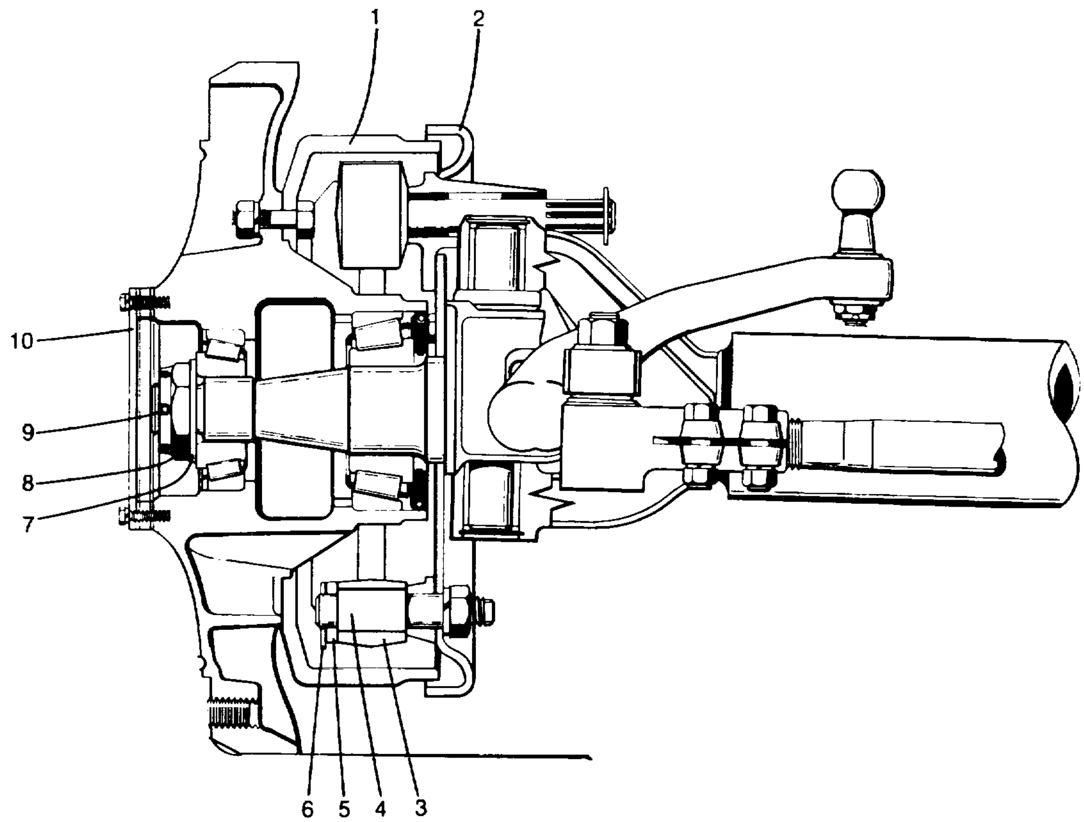
After the brakes have been relined, the following initial adjustment is required.

(a) Jack up front wheels.
(b) Adjust slack adjuster (3) until toe of shoes (7) contacts brake drum and prevents wheel from turning.
(c) Release the slack adjuster (3) just enough to free the wheel.
(d) Expand each anchor pin (6) in the same manner, releasing each of them just enough to allow the wheel to turn freely.
(e) Continue this procedure a second and third time, if necessary, to obtain the best possible brake adjustment. After relining there are always high spots which must be eliminated before there is full and perfect contact between the lining and the drum. Maximum brakes are not obtained until these high spots are worn off. These high spots can be removed while the vehicle is in use by careful, gradual braking. Excessive braking during this break in period may start drum trouble. Each application of the brake increases the contacting surface until full contact between lining and drum is obtained. At this point, any additional adjusting of the brake is to be done with the slack adjusters only.

4.3 Front Brake Removal (Fig. 2)

The front wheel brakes may be removed from the machine for inspection or repair as follows:

(a) Jack up the machine until the front wheel clears the ground.
(b) Unbolt and remove the hub cap (10) from the wheel.
(c) Remove the cotter pin (9), adjusting nut (8), and lockwasher (7) from the spindle.
(d) Remove the front wheel assembly (1) from the spindle to expose the brakes. It may be




Fiq. 2 A164-C

Front Axle Assembly

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) | Wheel Assembly | (4) | Anchor Pin | (7) | Lockwasher | (10) | Hub Cab |
| (2) | Backing Plate | (5) | Anchor Plate | (8) | Adjusting Nut | | |
| (3) | Brake Shoe | (6) | Cotter Pin | (9) | Cotter Pin | | |

(d) necessary to back off on the brake adjustment to remove the wheel assembly.
(e) Remove the shoe return spring (9) (Fig. 1).
(f) Remove cotter pins (6) from brake anchor pins (4). Remove anchor plate (5) from pins.
(g) Remove brake shoes (3) from backing plate (2).

4.4 Brake Cam Removal (Fig. 1)

(a) Remove brakes as explained previously.
(b) Remove pin (4) which connects actuator to slack adjuster (3).
(c) Remove snap ring which retains slack adjuster on cam.
(d) Remove cam (1) from backing plate.

4.5 Reassembly

Follow above procedures in reverse. Adjust wheel bearings as explained in SM1-2-3.0. Adjust brakes as explained earlier in this SM.

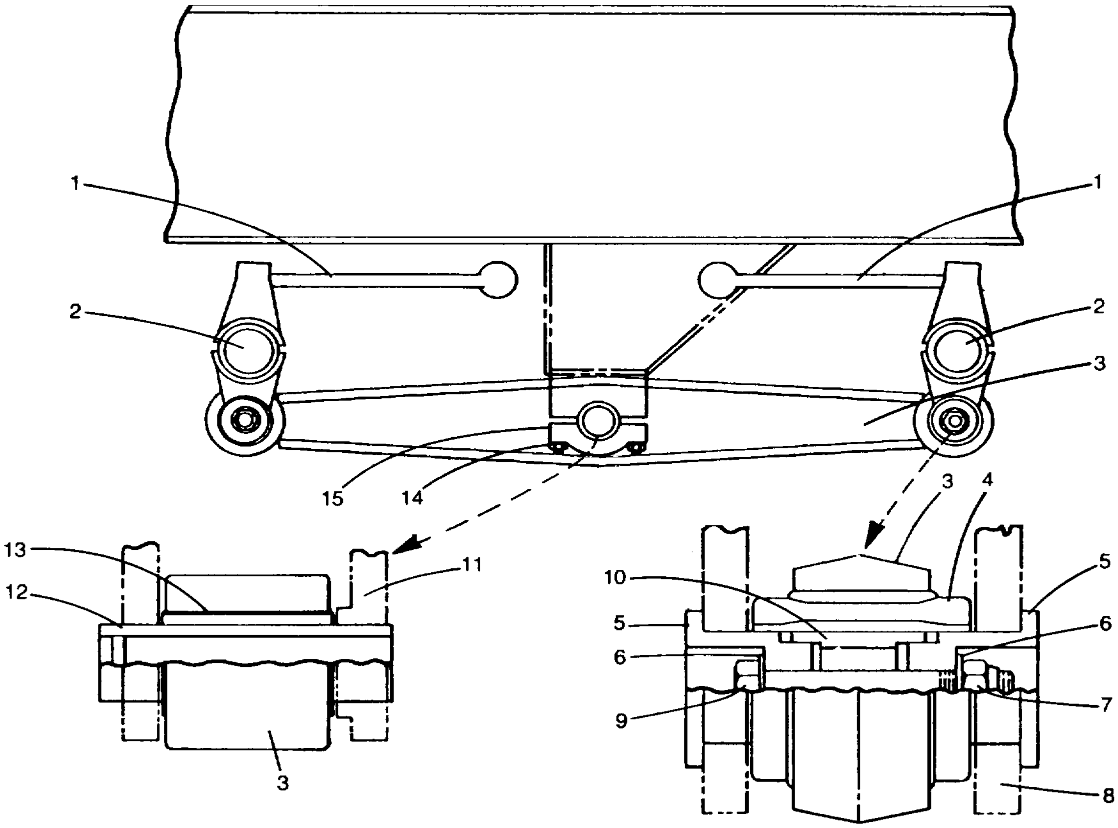



*Fig. 1* *LA744-C*
*Front Suspension*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (1) | Torque Rod | (4) | Bushing | (7) | Nut | (10) | Intermediate Tube | (13) | Bushing |
| (2) | Front Axle | (5) | Adapter | (8) | Axle Bracket | (11) | Saddle Legs | (14) | Nut |
| (3) | Equalizer Beam | (6) | Washer | (9) | Bolt | (12) | Cross Tube | (15) | Saddle Cap |

The carrier uses a solid mount suspension system which is very stable, since the only factor affecting stability is the deflection of tires. Effects of shocks are reduced by using large rubber bushings at all three pivot points in the equalizing beam, The upper torque rods are also rubber-bushed. These rubber bushings eliminate the need for lubrication. Removal of torque rods, equalizer beams, axles and bushings will be discussed in this SM.

4.1 Disassemble

(a) Park machine on a firm level surface. Apply emergency brake.

(b) Jack machine up until tires clear the ground. The hydraulic outriggers can be used for this purpose. Block securely under the frame so machine cannot fall.

(c) Remove tire and wheel assemblies (refer to SM1-69-2.0).

(d) Use jacks and blocks to hold axles stationary.

**WARNING**

When Disassembling, Take Care When Disconnecting Torque Rods Or Equalizer Beams Because Axles Assemblies May Roll Or Pivot If Not Securely Blocked.

(e) If removing rear axle assemblies the drive shaft must be disconnect (refer to SM1-22-2.0).

(f) Remove equalizer beams.

(a) (1) Front suspension (refer to Fig. 1):

(aa) Remove saddle caps (15).

(bb Disconnect beam end mountings: Remove bolt (9). Wedge out one adapter (5) using a chisel (a relief is provided on each side of the adapter for chisel entry), drive chisel first on one side then the other. After one adapter is removed the opposite adapter can be driven out with an impact hammer or heavy bar and hammer.

(2) Rear suspension: Remove the end stud (13 refer to Fig. 2).

(3) Separate beam from cross tube by pulling apart by hand.

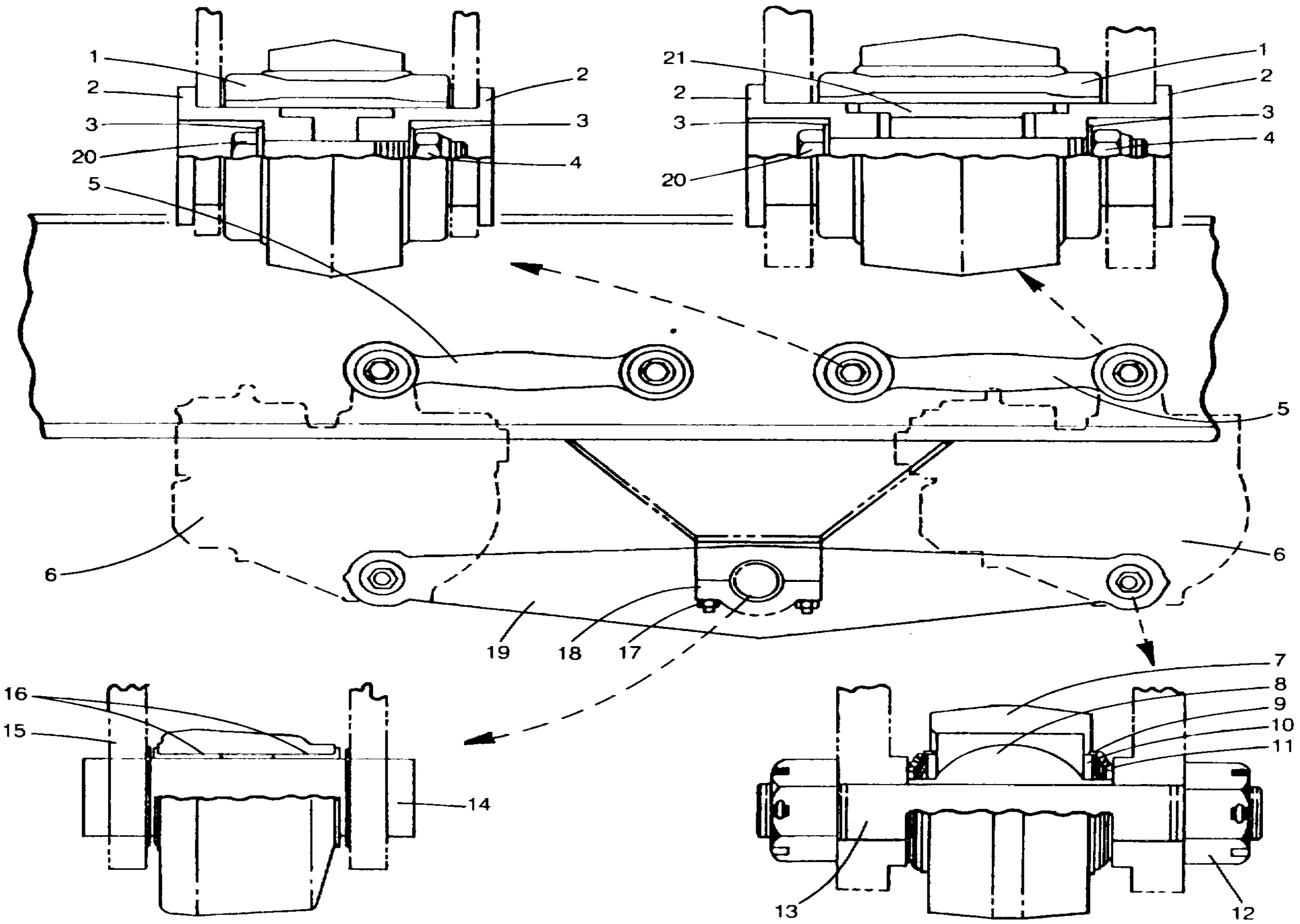



*Fig. 2*
*Rear Suspension*

*L744-C*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) | Bushing | (7) | Beam Socket | (13) | End Stud | (19) | Equalizer Beam |
| (2) | Adapter | (8) | Beam Ball | (14) | Cross Tube | (20) | Bolt |
| (3) | Washer | (9) | Retainer | (15) | Saddle Legs | (21) | Intermediate Tube |
| (4) | Nut | (10) | Felt Washer | (16) | Bushings | | |
| (5) | Torque Rod | (11) | Spring | (17) | Nut | | |
| (6) | Rear Axle | (12) | Nut & Cotter Pin | (18) | Saddle Cap | | |

(g) Remove torque rods.

(1) Front suspension (refer to Fig.,3):

(aa) Remove nuts.

(bb) Strike top of torque rod bracket with hammer to break stud free of brackets.

(2) Rear suspension (refer to Fig. 2):

(aa) Remove bolt (20).

(bb) Wedge out one adapter (2) using a chisel (a relief is provided on each side of the adapter for chisel entry), drive chisel first on one side then the other. After one adapter is removed the opposite adapter can be driven out with an impart hammer and or heavy and hammer.

(h) Disconnect air brake lines.

(i) Disconnect steering drag links from axle steering arm, if removing front axles.

(j) Remove axles from under machine.

4.2 Cleaning and Inspection

(a) Clean all dirt from suspension parts.

(b) Inspect all parts for cracks, wear or damage. Replace if required.

(c) Inspect rubber bushings for damage or deterioration.

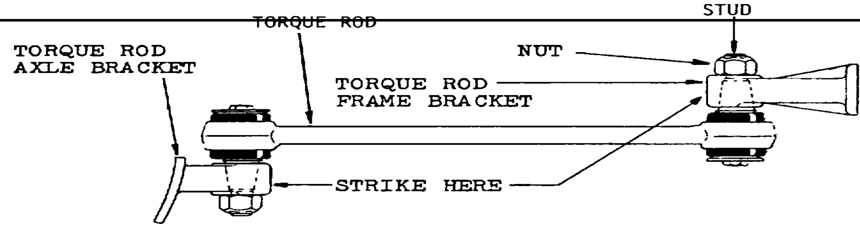



*Fig. 3*
*Torque Rod*

4.3 Replace Bindings
- (a) Remove bushings by pressing or pulling them out.
- (b) Apply a thin coat of white lead to outside diameter of new bushings and press new bushings in.

4.4 Assemble
- (a) Position and block axles up under machines.
- (b) Install cross tube into equalizer beam.
- (c) Lay equalizer beams in position under axles.
- (d) Raise and place the same end of each beam into axle brackets of one axle.
- (e) Align the beam end rubber bushings to the axle bracket and apply rust proofing compound inside of bushing, outside of adapters, outside and inside of intermediate tube and axle bracket holes.
- (f) Connect equalizer beam ends.
- (1) Front suspension: Install adapters with intermediate tube (10) (apply rust proofing compound) bolt (9), washer (6) and nut (7), but do not lock nut tight at this time (refer to Fig. 1).
- (2) Rear suspension: Install felt washer (10), retainers (9), retainer springs (11), end stud (13) and nuts (12) (applying rust proofing compound), but do not lock nuts tight at this time (refer to Fig. 2).
- (g) Install opposite end of equalizer beams to other axle using same procedure as above.
- (h) With beams attached to axles, making sure center bushing of each beam is lined up with center of the saddle legs, position beam center bushings in centering saddle and install the saddle caps and nuts. Do not tighten until torque rods are level with frame, then tighten to 225-275 ft/lbs (300-367 N-m) torque.
- (i) Install torque rods to axle brackets and frame brackets.
  - (1) Front suspension (refer to Fig. 3).
    - (aa) Lubricate stud threads with S.A.E. 20 oil before assembling.
    - (bb) Position stud in bracket.

Note: <u>Stud and bracket hole must be free of all foreign matter before assembling.</u>

- (cc) Tighten nuts to 175-225 ft/lbs (233330 N-m) torque.
- (dd) After initial tightening, rap torque rod bracket with hammer for drive fit of stud.
- (ee) Retighten nuts to above specified torque.

Note: <u>Be sure flat section of the adapter flange is in a vertical position.</u>

- (j) Tighten front beam end adapter bolt nuts and rear beam stud nuts to 375-400 ft/lbs (501534 N-m) torque.
- (k) Connect air brake lines.
- (l) If assembling rear axles, connect drive shafts (refer to SM1-22-2.0).
- (m) If assembling front axles connect steering drags to axle steering arms. Check front wheel alignment (refer to SM1-2-3.0).
- (n) Install tire and wheel assemblies (refer to SM1-69-2.0).

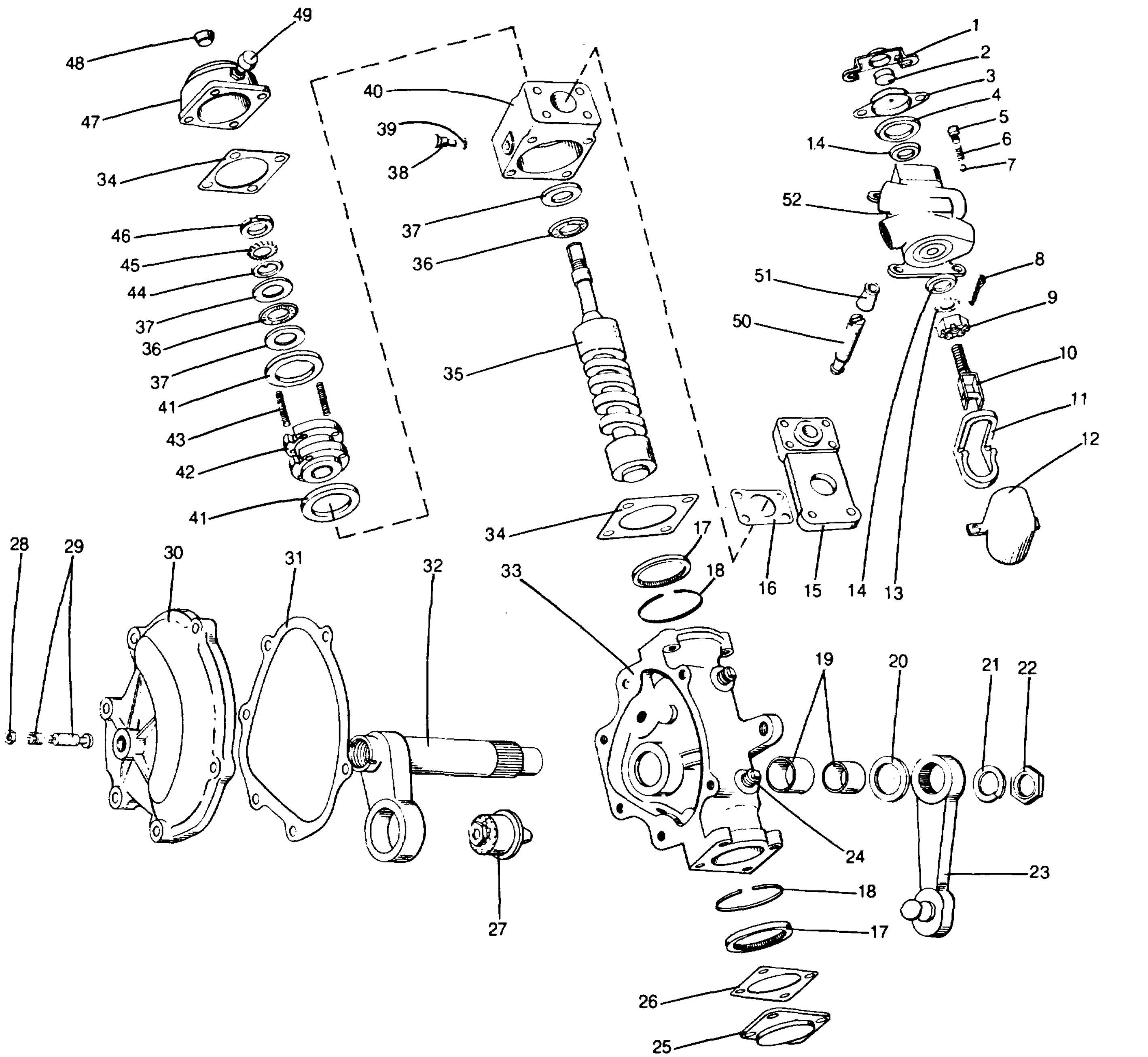



Fig. 1 L162-D

Steering Gear

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) | Cover | (14) | "O" Rings | (27) | Stud Roller Bearing Unit | (40) | Actuator Housing |
| (2) | Water Seal | (15) | Bracket | (28) | Locknut | (41) | Centering Washers |
| (3) | Valve Spool Cover | (16) | Gasket | (29) | Adjusting Screw W/Retainer | (42) | Actuator |
| (4) | "O" Ring | (17) | Bearing | (30) | Side Cover | (43) | Centering Springs |
| (5) | Plug | (18) | Retaining Ring | (31) | Gasket | (44) | Tongued Washer |
| (6) | Spring | (19) | Bushing | (32) | Levershaft | (45 | Lockwasher |
| (7) | Steel Ball | (20) | Oil Seals | (33) | Housing | (46) | Adjusting Nut |
| (8) | Cotter Pin | (21) | Lockwasher | (34) | Gasket | (47) | Upper Cover |
| (9) | Nut | (22) | Nut | (35) | Cam & Wheel Tube Assy. | (48) | Seal |
| (10) | Clevis Rod | (23) | Pitman Arm | (36) | Thrust Bearing | (49) | Vent Plug |
| (11) | Seal | (24) | Plug | (37) | Thrust Washer | (50) | Actuator Lever |
| (12) | Cover | (25) | End Cover | (38) | Retainer Screw | (51) | Seal |
| (13) | Lockwasher | (26) | Gasket | (39) | Washer | (52) | Valve Body & Spool |

HC238A

1.1 Operation

The action of the steering gear is both manual and hydraulic. When the same is turned left or right by the drivers effort on the steering wheel, the stud of the inner lever is moved through the groove of the cam (worm) thus rotating the lever shaft and providing angular movement of the steering gear pitman arm. Whenever the drivers effort at the steering wheel exceeds the preload of the centering springs the control valve is actuated and the hydraulic power is applied to provide the drive with power steering.

Hydraulic reaction is the feedback force due to inlet port pressure acting on a small area of the valve spool which resists the drivers' effort. As the pressure in the hydraulic cylinder builds up, the hydraulic centering force increases. Thus, the driver's effort on the steering wheel in turning a corner is greater than in a straight ahead road correction condition. Because the hydraulic pressure is low in the straight ahead driving conditions, it is necessary to add centering springs to assist the hydraulic reaction in giving the system "road feel".

The feel and steering effort created by the centering springs valve are constant for any steering condition and are generally tailored to suit the vehicle application by changing the spring load to give the degree of steering effort desired.

When the valve is in the center position, the oil pressure at its two cylinder ports is low and equal and produces ineffective forces in the cylinder. This results in no movement of the piston and no circulation of oil in the lines to the cylinder, however, oil is circulating from the pump through the control valve to the reservoir with sufficient pressures only to overcome friction of lines and fittings.

Whenever the driver's effort at the steering wheel overcomes the centering effect of the springs and/ or hydraulic reaction, the valve spool is moved axially restricting one of the return passages to the outlet port thus causing an immediate increase in pressure at one of the cylinder ports and in one end of the cylinder. At the same time, the other return passage is enlarged, allowing the oil from the discharging end of the cylinder free passage to the outlet port and return to the reservoir. The immediate effect is increased pressure in one end of the cylinder to actuate the piston which applies hydraulic power directly to the steering gear pitman arm or linkage part to which the cylinder is attached. Full pressure is obtained with a spool travel of about sixty-five thousandths of an inch. The slightest movement results in a pressure differential.

Whenever the effort at the steering wheel is released, the valve spool is returned to the center position.

If the steered wheels are subjected to shock loads, the pitman arm, acting through the inner lever of the gear, shifts the cam and control valve spool axially in the appropriate direction thus directing the fluid to the proper side of the piston to resist the shock forces. This blocking action prevents kick-backs at the steering wheel.

1.2 Adjustment Procedures

On the manual section, there are two principal adjustments and a supplemental adjustment on the stud roller bearing unit (27) in the levershaft (32). Neither of the adjustments is indexed, but can be set at the most desirable point. The principal adjustments are: (1) Adjustment of needle thrust bearings on the cam shaft on each side of the valve actuator. (2) Adjustment of tapered stud in cam groove for backlash. When making adjustments free the steering gear of all load, preferably by disconnecting the drag link from the steering gear arm and loosen the instrument board bracket clamp on steering gear column to make sure the steering column is not binding, preventing the valve from centering. Loosen any clamp on column that is located over the bearing in upper end of column tube. There is an adjustment on the valve.

1.3 Adjustment No. 1: (Thrust Bearing 36)

It is preferable to have the gear removed from the vehicle. If the gear is readily accessible on the carrier, it is only necessary to disassemble those parts which will permit the removal of the upper cover (47) so that adjusting nut (46) on the cam shaft is accessible.

(a) Before adjusting thrust bearings turn gear off its center position to free the stud (27) in the cam groove (35).

(b) Remove capscrews holding upper cover (47). Remove cover.

(c) Reassemble screws in actuator housing (40) with 3/8" thick spacers under heads of screws. This is to hold the actuator and cam assembly in the gear when making the adjustment.

(d) Straighten prong of lockwasher (45). Remove adjusting nut (46), tongued washer (44), and upper thrust washers and thrust bearing (36 &3'7).

(e) Be sure that the threads of the nut (46) and cam shaft (35) are free of interference by running the nut onto the cam shaft using only your fingers to turn the nut. If the nut cannot be driven all the way with finger torque, the threads are fouled and must be cleaned with a thread file or other means until the nut goes on easily.

(f) Reassemble thrust washers and thrust bearings (36 & 37), tonqued washer (44), and pronged lock- washer (45), and adjusting nut (46).

(g) Drive on nut (46) and tighten to 10 ft./lbs (13 N'm) torque. Back off nut 100 - 200. This can be done by moving the nut relative to the pronged lockwasher approximately 1-1/2 width of a lug.

Bend the lug, nearest in alignment with a notch in the adjusting nut (46), tight against the notch root.

1.4 Adjustment No. 2: (Stud In Cam Groove)

Note: Backlash of the stud in the cam groove shows up as backlash at steering wheel and also at ball on steering arm.

The groove of the cam is purposefully cut shallower and narrower in the mid position range of the stud travel to provide close adjustment where usually the straight ahead driving action takes place.

Adjust through mid position to the high spot. Do not adjust in an end position. Backlash in the end position is normal and not objectionable.

*Fig. 2*
*Adjusting Valve Spool*

1.5 Adjustment Of Stud Roller Bearing Unit

The above adjustments will suffice in most cases. In some cases it may be necessary to adjust the stud roller bearing unit (27) in the levershaft (32). In order to make this adjustment the shaft must be removed from the gear.

The roller bearing must be preloaded at all times. Adjust to a noticeable drag.

Factory adjustments are set to 1 to 4 inch pounds torque to revolve the stud. Used or replacement units should be set to the same torque.

Note: Operation of a correctly adjusted unit may feel rough to the hands, but under steering load it will be smooth. Rotate the stud several full turns and reverse before checking rolling torque.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(a) Wash bearings in clean solvent and lubricate with oil used for lubrication of gear.
If any roller is damaged or lost, replace with a complete new set or bearing unit. Do not make a partial replacement.
(b) Use a new locking washer. If old washer must be used, break off bent prong to prevent using again.
(c) Tighten nut as required. Hold stud from turning by using a spanner wrench on the washer.
(d) Revolve stud several complete turns and reverse and test adjustment.
(e) Lock adjustment by bending over locking washer prong that is 90° to a side of the nut. Do not use the washer twice unless the used prong has been removed.
(f) Lubricate with lubricant used in gear.

1.6 Adjustment Of Valve

The purpose of this adjustment is to center the valve spool in the valve (52). Make this adjustment each time the valve is removed from its position on the gear and at any other time the valve seems to be maladjusted. The adjustment is made with the valve mounted on the gear.

(a) Remove cover (12) and seal (11) from lever end of valve.
(b) Remove, from other end of valve, water seal cover (1), rubber water seal (2), cover (3), and "0" Ring (4).
(c) Remove cotter pin (8), then loosen slotted nut (9) on clevis rod (10).
(d) Using screw driver in slot on valve spool, thread spool in or out until the slotted end of spool is flush with the end of valve body (52), refer to Fig. 2.

Note: In the event of steering drift (self steering to the left or right) adjust valve slightly off center to overcome it.

(e) Tighten slotted nut (9) but maintain position of valve spool in relation to clevis rod by keeping screw driver in slot as slightest change will affect adjustment. Lock adjustment with cotter pin (8). See Fig. 3.

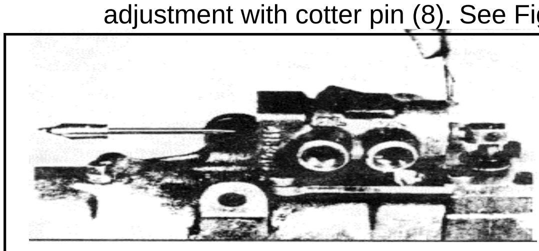


*Fig. 3*
*Tighten Slotted Nut*

(f) Be sure spool actuates (moves axially in both directions) before assembling end covers. This can be done as follows:
(1) Place steering gear arm on lever shaft.
(2) Place steering wheel on wheel tube.
(3) Turn steering wheel to move steering arm against a stop.
(4)Apply sufficient effort to actuate spool.
(5) Reverse arm against an opposite stop to actuate spool in other direction.
(g) Replace "O" Ring (4), cover (3), water seal (2), and cover (1).
(h) Replace cover (12) and seal (11).

1.7 Removal Of Gear From Chassis

Before removing the gear, note the hookup of hydraulic lines. Identify by tagging lines and noting the ports each connect to.

The following is a general procedure.

(a) Remove steering gear arm (23) from levershaft (32). Use arm puller if possible. Do not hammer off arm without using support against the end of the shaft. Use light blows as they are more effective. Heavy blows may cause brinelling of the cam lead.

(b) Disconnect the hydraulic lines at control valve Tag to identify ports each connects to.

(c) Plug all ports to keep out dirt.

(d) Remove mounting flange bolts. Remove gear front chassis.

1.8 Disassembly of Gear

The following procedure applies to complete disassembly of gear after removal from chassis. For partial disassembly the procedure may differ depending upon the parts involved.

(a) Removal Of Levershaft:

(1) Loosen locknut (28). Unscrew adjusting screw (29) a few turns.

(2) Remove housing side cover (30).

(3) Slide levershaft (32) from housing (33) having first made sure there are no burrs on outer end of shaft to damage the bushing (19) and seal (20) in the housing.

(b) Removal Of Control Valve:

(1) Remove four screws holding valve (52) to bracket (15) and remove valve.

(2) Remove rubber seal (51) from actuator lever (50) and pull out lever.

(3) Remove two remaining mounting screws and remove bracket (15).

(4) Remove screws holding upper cover (47) and actuator housing (40) to gear housing (33).

(5) Slide cover (47) off cam shaft (35) taking care not to damage oil seal in counterbore of upper cover.

(c) Removal Of Cam And Tube Assembly:

(1) Unlock actuator retainer screw (38) and remove actuator housing (40).

(2) Remove whole assembly of cam and wheel tube and valve actuator assembly as a unit from housing (33).

(3) Remove adjusting nut (46) after straightening bent prong of lockwasher (45). Remove tongued washer (44) and upper thrust washer and needle bearings (36 & 37).

(4) Remove upper centering washer (41) from end of actuator (42). Remove actuator taking care not to lose springs (43) that are in the actuator.

(5) Remove lower centering washer (41) thrust washer (37) and thrust bearing (36).

1.9 Inspection:

Careful visual inspection of the steering gear parts is very important. These visual checks may uncover conditions not evident during operation. T (a) Cam and shaft (35):

(1) Check the cam groove for chipping, scoring, or brinelling. (The cam is copper plated for initial service. The operation of the stud in the cam groove will wear away the copper plating. This is a normal condition).

(2) Check condition of bearing surface on O.D. at each end of cam tube.

(3) Check conditions of splines and threads on tube.

(b) Levershaft (32):

(1) Check for burrs on splines, twisted splines, wear on bearing surfaces.

(2) Check lever shaft stud for nicks, flat spots, or spalling.

(3) Check adjustment of stud roller bearing.

(c) Housing (33):

(1) Check for strain at mounting flanges.

(2) Check condition of needle bearings (17) in each end of housing.

(3) Check fit of cam in needle bearings.

(4) Check bushings (19) in housing for wear or out of round.

(5) Check levershaft oil seal (20).

(d) Control Valve (52):

(1) The valve is the control center of the hydraulic system. The housing and spool are M individually fitted and are not separately replaceable. If either part needs replaced, replace the whole unit.

(2) Be careful when handling valve parts to prevent damage. Sealing edges of the valve sleeve and the spool should not be broken. The result would be excessive leakage and reduced hydraulic power.

(e) Internal Inspection Of Valve:

(1) Remove water seal cover (1), rubber washer seal (2), spool cover (3) and "0" Ring (4) from valve.

(2) Remove clevis rod (10) from end of valve spool as follows:

(aa) Take out cotter pin (8).

(bb) Loosen nut (9).

(cc) Unscrew clevis rod from spool.

(3) Push spool out clevis rod end (about ½ inch) until "O" Ring (14) is exposed and removable. Remove "O" Ring. Use pointed instrument but be careful not to damage seal.

(4) Push spool in opposite direction to expose "O" Ring for removal from that end of spool.

(5) Remove spool and inspect. Inspect body internally. Check for scoring by dirt in system. It is impractical for a field service station to measure wear. Wear should be negligible because the spool operates in circulating oil. Performance determines usability.

### 1.10 Cleaning

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Cleanliness is very important. Use dry-cleaning solvent or volatile mineral spirits to clean or wash grease, oil or dirt from all metal parts of assembly. Do not steam clean parts. Clean machined parts individually to avoid damage due to "bumping" together of parts.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Use lint free cloths soaked in approved solvent to clean all machined surfaces.

After parts are cleaned, dry with compressed air. Don't use compressed air to dry bearings.

Note: Some cleaning solvents or volatile mineral spirits will deteriorate rubber parts.

### 1.11 Reassembly Of Gear

(a) Replace all gaskets and seals.
(b) If needle bearings (17) in ends of housing (33) have been removed, replace them. Take care not to press bearings too hard against retaining ring (18).
(c) Pre-assemble actuator assembly on cam and wheel tube assembly and adjust.
- (1) First be sure that the threads of the nut and cam shaft are free of interference by running the nut on to the cam shaft using only fingers to drive the nut. If the nut cannot be driven all the way with the fingers the threads are fouled. Clear them with a thread file until the nut goes on freely.
- (2) Assemble thrust bearing (36) over wheel tube and seat against upper end of cam.
- (3) Assemble other parts in this order:
  - (aa) Thrust washer (37).
  - (bb) Centering washer (41).
  - (cc) Actuator (42).
  - (dd) Springs (43) in actuator.
  - (ee) Centering washer (41).
  - (ff) Thrust washer (37).
  - (gg) Thrust bearing (36).
  - (hh) Thrust washer (37).
  - (ii) Tongued washer (44).
  - (jj) New lockwasher (45) with thirteen external lugs.
  - (kk) Adjusting nut (46).
- (4) Adjust as explained earlier under "Thrust Bearings".

(d) Assemble cam (35) in housing (33). Be certain cam rotates and oscillates freely in housing.
(e) Assemble gasket (34) on top of housing (33).
(f) Assemble actuator housing (40) over actuator.
(g) Position actuator housing for location of valve mounting. Assemble retainer screw and washer (38 & 39). Be sure screw engages horizontal slot in actuator.
(h) Assemble gasket (34) to upper face of actuator housing.
(i) Assemble upper cover (47).
(i) Fasten upper cover (47) and actuator housing (40) to gear housing (33) with long mounting screws.
(k) Install levershaft in housing (33). Use care not to damage oil seal (20) in end of housing (33).
(l) Assemble gasket (31) and side cover (30) to housing (33).
(m) Assemble adjusting screw (29) and locknut (28).
(n) Adjust as explained earlier under "Adjustment No. 2 (Stud in Cam Groove)".

### 1.12 Control Valve Reassembly

(a) Assemble spool in valve body, being sure spool end for clevis rod is in right end of valve. When assembling spool in body a twisting motion applied to the spool will be helpful. Before assembling be sure all parts have been thoroughly cleaned. Apply light lubricating oil to the valve spool and "O" ring.
(b) Place "O" Ring (14) in groove on end of valve spool that is slotted (not clevis rod end).
(c) Assemble spool in valve body by pushing the clevis body end through. Push spool through far enough to uncover "O" Ring groove in clevis rod end of spool.
(d) Assemble "O" Ring (14) in this groove and push spool back into body until "O' Ring just enters the body.
(e) Screw nut (9) onto clevis rod (10).' Assemble lockwasher (13) next to nut. Screw clevis rod into end of spool.
(f) Assemble valve mounting bracket (15) to top of actuator housing (40).
(g) Assemble actuating lever (50) in bushing in bracket (15) making sure that stud end of lever seats in circular groove of actuator (42).
(h) Assemble rubber seal (51) on top end of actuating seal, anchoring seal around shoulder of bushing in bracket (15).
(i) Assemble valve to mounting bracket (15), making certain slot of actuator lever engages pin in
(j) Adjust valve spool as explained earlier in this Service Manual.
(k) Assemble "O" Ring (4) in spool cover (3), water seal (2), cupped end toward spool, and against cover (3). Tighten end cover screws.
(l) Assemble cover and seal (11 & 12).

### 1.13 Installation In Chassis

(a) Place gear in chassis and clamp securely.

(b) Install steering wheel. Draw nut tight to 55-65 ft/lbs (73-86 N-m) torque.
(c) Center steering wheel. Count number of turns of steering wheel from right to left. Turn the wheel back half of this distance to mid position.
(d) Set front wheels straight ahead, parallel to the carrier frame. Measure from frame rail to a point on each side of each wheel. Make sure the dimension is the same on each side. e) Connect drag link to ball on steering arm.
(f) Install steering arm on lever shaft of gear. If arm does not line up with splines on shaft, turn wheel right or left, no more than 1/4 turn to align splines. Install lockwasher. Tighten nut to 250 ft/lbs torque.
(g) Install hydraulic lines. Refer to SMI-10-1.0 for information on filling hydraulic system.
(h) Fill steering gear with lubricant. Consult lubrication chart in Operators Manual for proper lubricant to use.

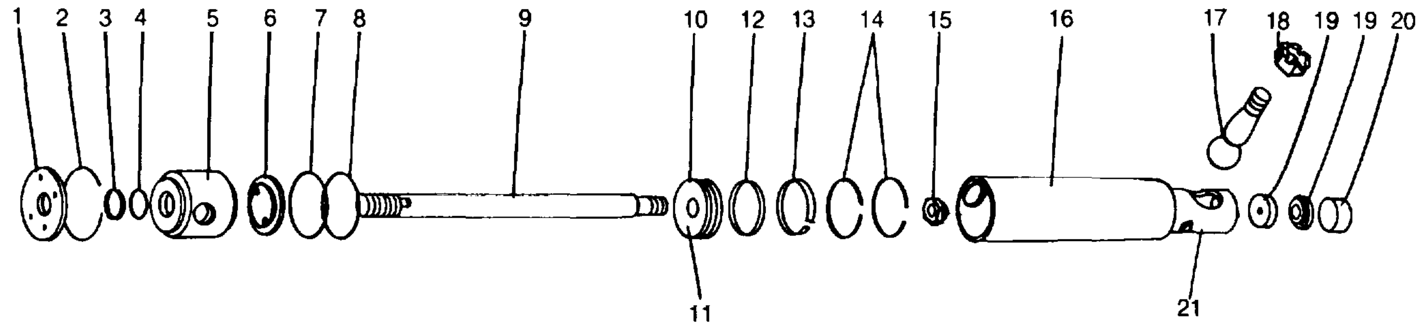



*Fig. 1 Power Steer Cylinder* D115-A

| | | | | | |
|---|---|---|---|---|---|
| (1) | End Cover | (8) | "0" Ring | (15) | Nut |
| (2) | Retaining Ring | (9) | Piston Rod | (16) | Cylinder Barrel |
| (3) | Seal | (10) | Piston | (17) | Ball Stud |
| (4) | "0" Ring | (11) | Poppet Valve | (18) | Slotted Nut |
| (5) | Head | (12) | Seal | (19) | Ball Seat |
| (6) | Stop Ring | (13) | Shim | (20) | Adjusting Plug |
| (7) | Back Up Ring | (14 | Piston Rings | (21) | Socket Shell |

The power steer cylinder is a double acting cylinder. Oil under pressure is directed to a control valve which directs the oil to the cylinder to turn the carrier wheels.

2.1 Steer Cylinder Removal

(a) Block the carrier wheels so it will not roll.

(b) Disconnect the hydraulic lines leading to the steer cylinder. Cap or plug all openings to prevent entry of foreign material.

(c) Disconnect cylinder from steering linkage and remove from machine. Thoroughly clean exterior of cylinder before disassembling.

Some cylinders have a poppet valve in the piston. The poppet valve is held closed by the hydraulic fluid force on the piston. At the end of the stroke the poppet contacts the end of the cylinder and is pushed open allowing fluid to flow through the piston preventing full hydraulic force at the end of the stroke. It is an "unloading valve". The poppet valve will not function if the cylinder is too long for the stroke used.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames. Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Handle parts with care and wash them clean. Wash parts in a suitable clean solvent and blow dry with compressed air. (Do not steam clean).

2.2 Disassembly Procedure

Drain oil from cylinder by moving piston rod in and out from one extreme end of its travel to the other.

(a) Remove end cover (1).

(b) Remove retaining ring (2). To remove ring (2),push head (5) into cylinder barrel (16) approximately 1/4", compress retaining ring (2) with a punch entered through knock out hole of cylinder barrel, and remove ring.

(c) Pull on piston rod (9), to remove internal parts from barrel (16). If replacement seals are not available, take care to not damage "O" ring (8) when sliding past retaining ring groove and large port hole in wall of cylinder barrel.

(d) To remove head (5) from piston rod, slide off piston end of rod.

(e) Remove nut (15). (Hold rod by the two wrench flats near outer thread end to pre- vent damage to polished finish on rod O.D.).

(f) Slide off piston (10) and remove piston rings (14) shim (13) and seal (12).

(g) With gland removed from rod remove sealing parts in gland by first removing oil seal (3), and "0" ring (4). From O.D. of gland disassembly "0" ring (8) and back up ring (7). Note: Replace stop ring_(Q) only if damaged.

(h) Check action of poppet valve (11) (if used) for leakage. If not in good condition, re- place with new piston assembly (10).

**2.3 Assembly Procedure**

(a) It is suggested that all old seals and "0" rings be discarded and new ones used when reassembling.

(b) Lubricate all seals and "0" rings with light oil before assembling.

(c) Assemble "O" ring (4) to inside of head (5), with sealing lip toward inside.

(d) Assembly back-up ring (7) on O.D. of head (5), then "O" ring (8). To prevent damage to "O" Ring (4) assemble head assembly to the rod (9) from the piston end of the rod. Slide head over rod toward outer end of rod, but prevent from sliding over threads.

(e) Assemble new seal (12) in piston ring groove of piston (10) shim (13) over seal and new piston rings (14).

(f) Assemble piston (10) to end of rod (9) with nut (15). Tighten to 175-200 foot pounds torque. (Hold piston rod by wrench flats).

(g) Slide piston (10) into cylinder barrel (16). Push assembly into cylinder half way and slide head (10) into cylinder taking care to not damage "O" ring (8) as it slides past retaining ring groove in end of cylinder.

(h) Assemble scraper seal (3) with lip out, over piston rod and into head (5).

(i) Lock head in place with retaining ring (2) in cylinder groove.

(j) Check for bind by moving piston rod in and out full stroke.

(k) Assemble end cover (1). Torque screws to 100-120 inch pounds.

(l) Install cylinder on machine.

(m) Start engine and turn wheels as far as possible in each direction. Check system for leaks, and repair if any are evident.

(n) Check fluid level in power steering system. Replenish if necessary. See Section 2 of Operators Manual for the proper fluid to use.

2.4 Servicing Ball Socket And- Ball Stud

(a) Disassemble: Remove cotter pin and unscrew adjusting plug (20), remove ball stud (17) and ball seats (19).

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(b) Inspection: Thoroughly wash parts and socket shell (21) with solvent. Examine parts and ball stud for flats, scoring galls and excessive wear. Replace parts as necessary. Note: Flats worn on ball stud can cause a bind and erratic steering.

(c) Assembly: Assemble ball seats (19) and adjusting plug (20). Insert lubricated ball stud (17) into socket shell (21) opening and tighten adjusting plug tight, back off to nearest lock point and insert cotter pin.

Note: After complete assembly and installation of cylinder, lubricate socket assembly with conventional lubricant.

**Service Manual** **SM1-10-1.0 Power Steer Pump**

## 1.1 Power Steer System

**Checking Pump Pressure:**

(a) Install a pressure gauge of at least 2,000 P.S.I. (13,790 kPa) capacity somewhere in the pressure line leading from pump.
(b) Shift truck transmission to neutral. Engage park brake.
(c) Start engine and allow it to idle for a few minutes. Check reservoir. Add fluid until reservoir is full.
(d) Accelerate engine to full speed. Turn steering wheel until steering bottoms out. Read pressure on gauge with steering bottomed. Pressures should be 1500 P.S.I. (10,343 kPa).

**CAUTION**

Don't Bottom Out Steering Over A Few Seconds At A Time. This Can Result In Shortened Pump Life.

(e) Relief valve is preset at the factory and cannot be adjusted. Disassemble relief valve as explained later in this section and clean. Reassemble and recheck pressure setting. If setting is wrong, relief valve subassembly and spring must be replaced.

## 1.2 Pump Disassembly (Fig. 2)

(a) Disconnect return hose from reservoir. Catch oil draining from reservoir in a pan. Disconnect pressure hose from pump body. Cap hose ends to keep dirt out of hydraulic system.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(b) Remove pump from engine. Clean exterior of pump and reservoir with solvent or diesel fuel.
(c) Remove wing nut (1) and cover (4). Remove cotter pin (5). Remove spring (7), retainer (8) and filter element (9).
(d) Loosen nut (13). Remove stud (12). Remove cap- screw (10), and baffle (11). Remove reservoir (14) and gasket (15) from pump cover (36).
(e) Remove pin (38). Remove plug (32), control valve (34) and spring (35) from pump cover (36).
(f) Remove capscrews (37). Separate body (24) from cover (36).
(g) Pump may be L.H. or R.H. rotation. Note direction of rotation of pump before proceeding. One edge of pump vanes is chambered. This chamber trails rotation.
(h) Remove ring assembly from cover. Remove pressure plate (17) and spring (16).
(i) Remove snap ring (31) which holds shaft (29) in place.
(j) Remove seal (26) from body. Clean and inspect all parts. If any parts are worn, damaged, scored, etc., they must be replaced.

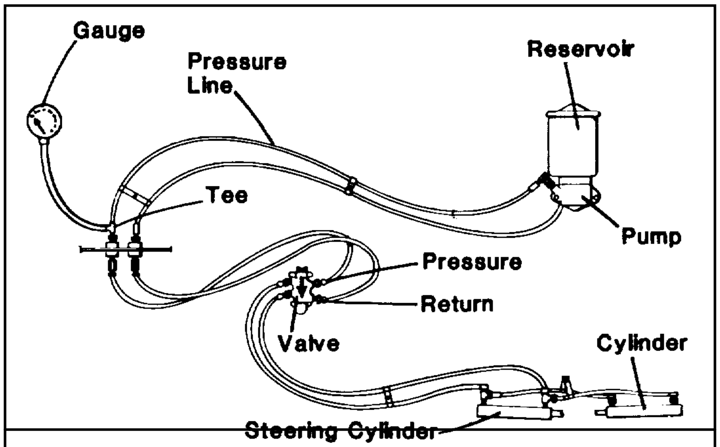



*Fig. 1 Power Steering System* N-66B

## 1.3 Pump Reassembly

(a) Soak the shaft seal (26) in clean hydraulic oil. Install seal in body (24). Install with lip to inside.
(b) Install bearing (28) on shaft (29). Install retaining ring (27) to hold bearing on shaft.
(c) Install shaft in body. Be careful not to damage seal.
(d) Install snap ring (31) in body.
(e) Assemble rotor and vanes inside ring (19). Make sure components are assembled for correct rotation. Vanes have one chambered edge. This edge trails rotation. If in doubt, turn engine over on the starter and check rotation of pump drive. Assemble pieces accordingly.
(f) Set cover (36) on bench with opening up. Install spring (16) pressure plate (17), and pin (18) in-side cover.
(g) Install ring assembly inside cover. Ring must fit over pin (18) to hold it against rotation.
(h) Install new "0" rings (22 & 23) on body (24). Set body in place on cover. Splines on shaft must go through splines in rotor.
(i) Install capscrews (37). Tighten to 25-30 ft/lbs (33-40 N-m) torque.
(j) Rotate pump shaft in the correct direction sever-al times by hand to make sure of complete rotary freedom.
(k) Set gasket (15) and reservoir (14) in place on cover.
(l) Thread nut (13) onto stud (12). Thread stud into place in cover. Tighten nut to 6-8 ft/lbs (8-11 N-m) torque. Install baffle (11) and cap- screws (10) and tighten to 7.5-8 ft/lbs.
(m) Install filter element (9), retainer (8), spring (7) and washer (6) over stud (12). Compress spring and install cotter pin (5).
(n) Install spring (35), control valve (34), "0" ring (33) and plug (32) in cover assembly. Install pin (38) to retain control valve subassembly.
(o) Install pump assembly on engine. Connect hoses to pump assembly.
(p) Fill reservoir with fluid to full mark. Loosen pressure hose where it connects to pump body. Turn engine over on starter until oil comes out hose connection. Tighten hose connection. (q) Refill reservoir. Start engine and allow it to idle for several minutes.

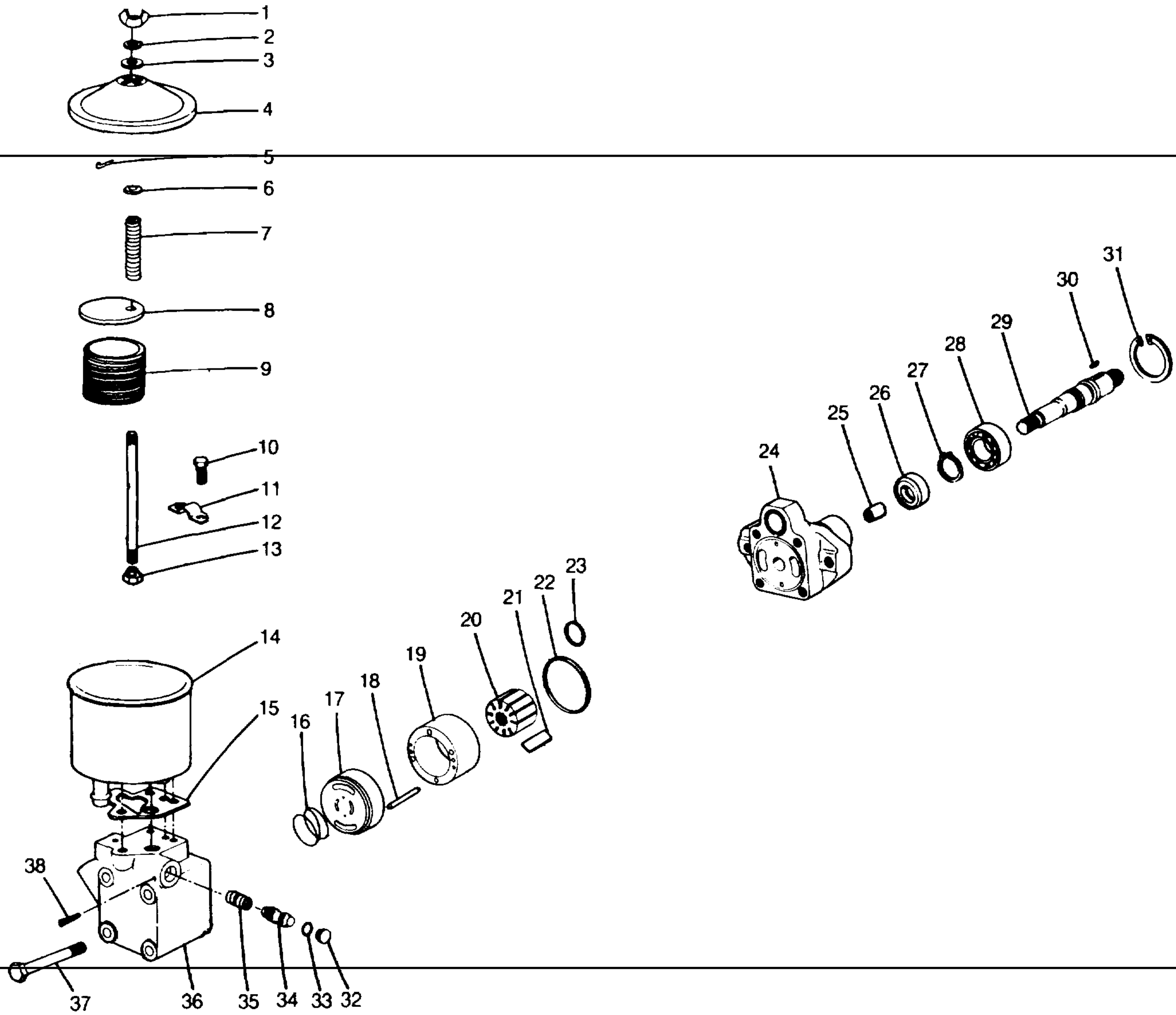



*Fig. 2 Power Steering Pump* L617-B

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) | Wing Nut | (11) | Baffle | (21) | Vane | (31) | Snap Ring |
| (2) | Lockwasher | (12) | Stud | (22) | "O" Ring | (32) | Plug |
| (3) | Washer | 13) | Nut | (23) | "O" Ring | (33) | "0" Ring |
| (4) | Cover | 14) | Reservoir | (24) | Body | (34) | Control Valve |
| (5) | Cotter Pin | (15) | Gasket | (25) | Bearing | (35) | Spring |
| (6) | Washer | (16) | Spring | (26) | Shaft Seal | (36) | Cover |
| (7) | Spring | (17) | Pressure Plate | (27) | Retaining Ring | (37) | Capscrew |
| (8) | Retainer | (18) | Pin | (28) | Bearing | (38) | Pin |
| (9) | Filter Element | (19) | Ring | (29) | Shaft | | |
| (10) | Capscrew | (20) | Rotor | (30) | Key | | |

(r) Slowly turn wheels all the way to the right and then the left to purge air from system. Center the wheels and refill the reservoir.

(s) Install cover (4), washer (3), lockwasher (2), and wing nut (1). Tighten wing nut.

This clutch assembly requires no maintenance other than maintaining release bearing clearance which is accomplished by normal linkage adjustment.

### 2.1 Operation

The clutch flywheel ring (cover) is attached to the engine flywheel and drives the pressure plate by means of driving lugs in the flywheel ring (cover) and matching slots in the pressure plate.

Depressing the clutch pedal disengages the clutch, by allowing the release bearing to contact and move the release levers toward the engine flywheel resulting in the pressure springs being compressed and the pressure plate being retracted away from the disc assembly; thereby disengaging the clutch.

Releasing the clutch pedal engages the clutch by allowing the release bearing and release levers to move away from the engine flywheel and the pressure springs to expand and exert pressure against the pressure plate, resulting in the disc assembly being gripped between friction surfaces of engine flywheel and pressure plate; thereby completely engaging the clutch.

### 2.2 Clutch Removal

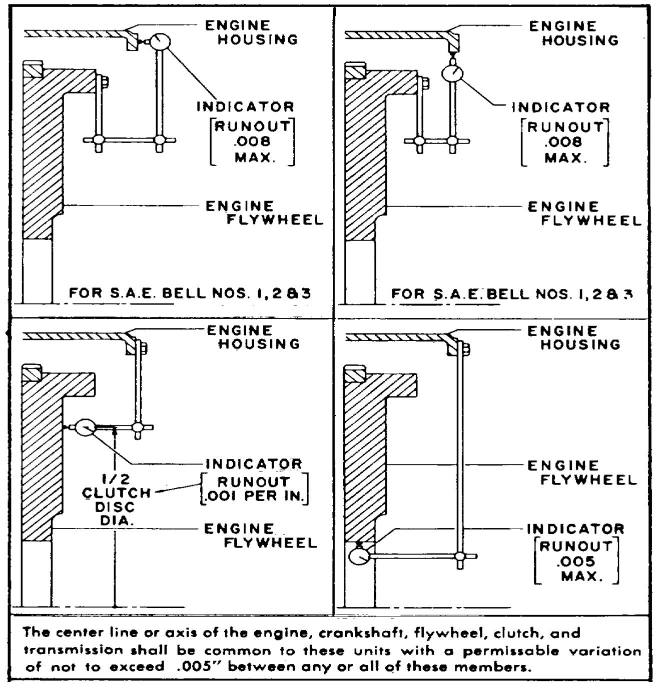
(a) Remove transmission, refer to SMl-18-10.0 for procedure .
(b) Gradually loosen clutch cover mounting capscrews until clutch tension is relaxed. Remove cover.

### 2.3 Inspection

(a) Check flywheel for following:
  (1) Scoring, heat cracks and taper. Resurface if sufficient stock is available or replace.
  (2) Inspect for correct depth, 1.093" (± .005").
  (3) Check bolt hole counterbores.
  (4) Check clutch pilot rim for galling.
  (5) Check drive pin condition and alignment with tool.
  (6) Check alignment with housing and vice-versa (see Fig. 1).
  (b) Check pilot bearing, if worn replace and lubricate.
  (c) Check facing thickness 5/32" and intermediate plate thickness .754" (+ .000" or - .003"). If worn replace.

### 2.4 Clutch Installation

(a) The intermediate plate has driving lugs which fit into mating slots of the flywheel. Before installing clutch assembly, the intermediate plate should be set into the driving slots of the flywheel and clearance checked. A minimum of .006" is recommended to allow for free movement of the intermediate plate. Refer to Fig. 2.
(b) The clutch has 2 disc assembles. They are not interchangeable and will be marked either flywheel side or pressure plate side (refer to Fig. 2).
(c) Install disc assemblies using a splined shaft or aligning shaft with a key to properly align the two disc assemblies.




The center line or axis of the engine, crankshaft, flywheel, clutch, and transmission shall be common to these units with a permissible variation of not to exceed .005” between any or all of these members.

*Fig. 1Checking for Misalignment*

Note: Do not allow the hubs to approach pilot bearing or come together within 5/32".

(d) Bolt the cover assembly to the flywheel, tightening each SAE Grade 8 capscrew gradually until the cover is drawn up tight using 45 ft/lbs (60 N-m) torque. Note: Care must be taken to make sure flywheel ring or cover is seated in piloting rim.
(e) Check "A" Dimension: The distance from the top of the clutch flywheel ring (cover) to ends of release levers. A straight edge and scale provide a means of checking the "A" Dimension (see Fig. 3) which should measure 15/16". If the "A" Dimension does not check out to within 1/32", the cover is not seated properly.
(f) Install transmission, refer to SMl-18-10.0 for procedure.
(g) Connect clutch pedal linkage.
(h) Adjust release bearing carrier clearance (distance between the clutch release levers and release bearing) to 1/8" when clutch is in the engaged position, the release bearing must move forward 1/8" to take up this clearance before it contacts the release levers and then move 1/2" to disengage the clutch.
(i) Check clearance after 5,000 miles and before 10,000 miles.

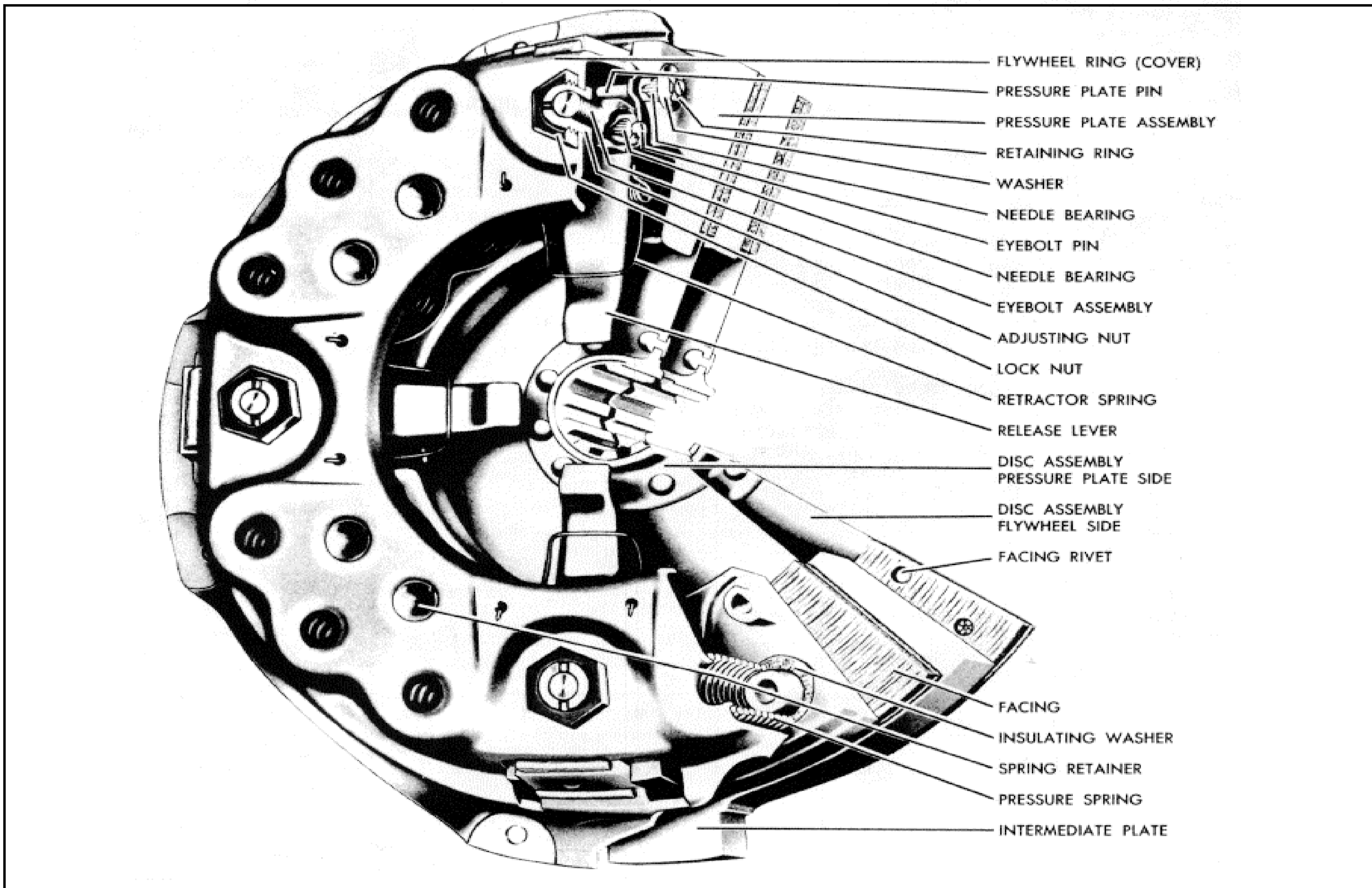



*Fig. 2 Clutch Assembly*

**2.5 Clutch Pedal Adjustment**
(Refer to Fig 4 & 5)
When the clutch linkage is properly adjusted, there will be a small amount of free pedal travel. This free pedal travel results from clearance between the clutch release bearing and the clutch release fingers. This clearance is necessary to remove all loadings from the release bearing when the clutch is disengaged. On this clutch, the clearance must be 1/8" (3.17mm). As the clutch facing wears, this clearance will decrease. If allowed to decrease excessively, the release bearing may contact the release fingers, and cause the clutch to slip, resulting in eventual clutch failure.

Never wait for a clutch to start slipping before adjusting it. Once the clutch starts to slip, it is too late to make an adjustment. Once the facings are burned by slippage, they quickly wear out.

The clutch is adjusted as follows:
(a) Disconnect the clutch linkage.
(b) Place cross shaft in its most forward position

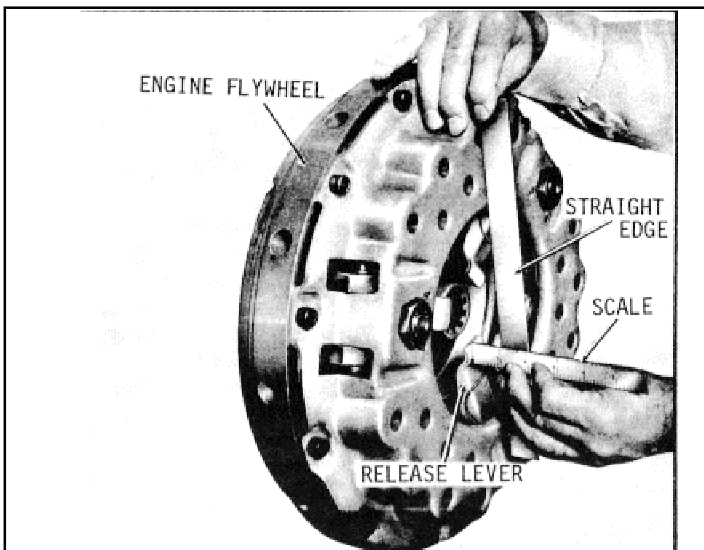



*Fig. 3 Checking Dimension "A"*

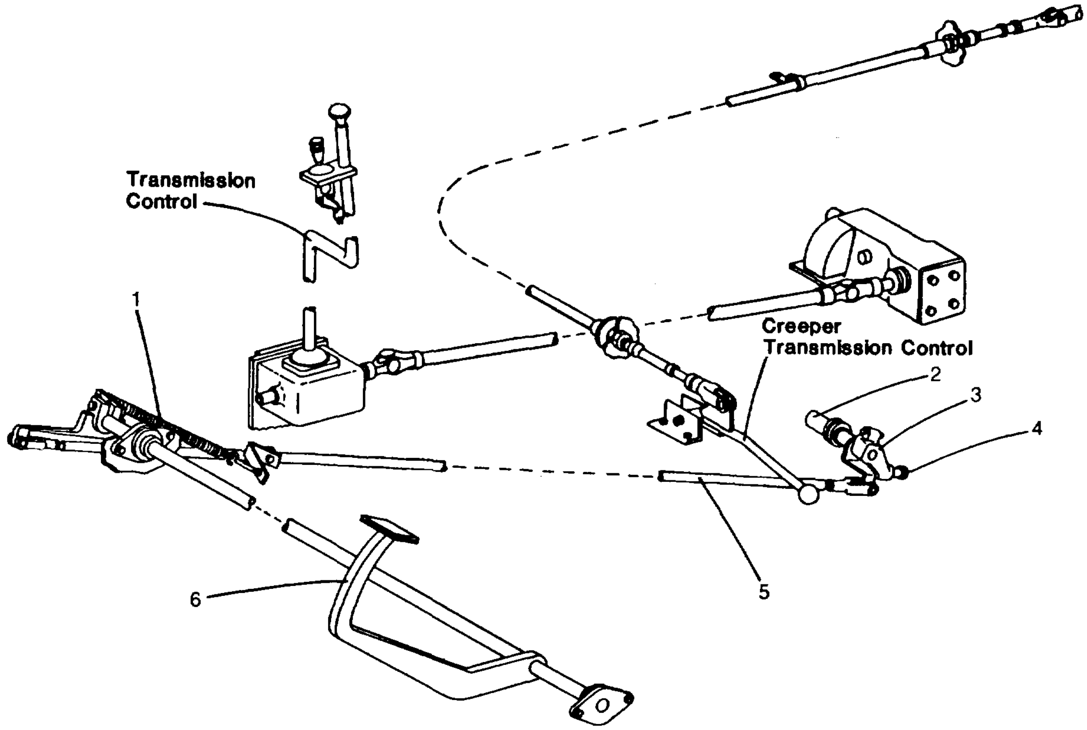



*Fig. 4 Clutch Controls*

| | | |
|---|---|---|
| (2) Return Spring | (3) Adjusting Lever | (5) Clutch Linkage |
| (2) Cross Shaft | (4) Adjusting Screw | (6) Clutch Pedal |

(c) Check the overall length of the clutch linkage (5). It must be adjusted so the clutch pedal (6) is tight against the floorboard when the adjusting lever (3) is in its most forward position.

(d) Reconnect the clutch linkage (5) and check the return spring (1) tension. Make sure the tension is such that the clutch pedal remains tight against the floorboard.

(e) Remove the clutch cover plate (2) from the clutch housing (1) (Fig. 5).

(f) Check the release bearing clearance (A). It should be 1/8" (3.17mm) (Fig. 5).

(g) To increase this clearance back off on the adjusting screw (4).

Note: <u>Excessive release bearing clearance may prevent complete clutch engagement. On the other hand, insufficient clearance may cause slippage and shorten clutch life.</u>

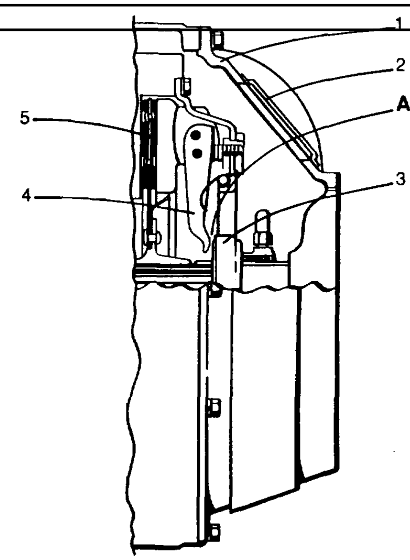



*Fig. 5 Release Bearing Clearance* L189-A

| | |
|---|---|
| (A) Clearance = 1/8" | (3) Release Bearing |
| (1) Clutch Housing | (4) Release Fingers |
| (2) Cover Plate | (5) Clutch |

**2.6 Trouble Shooting**

| Problem | Cause | Remedy |
|---|---|---|
| Chatter | 1. Loose, broken or worn engine mounts. | 1. Tighten or replace. |
| | 2. Pedal linkage worn. | 2. Replace linkage. |
| | 3. Loose or cracked clutch housing. | 3. Tighten or replace. |
| | 4. Spring shackles and mountings loose, worn or broken. | 4. Tighten or replace. |
| | 5. Misalignment. | 5. Realign. See Fig.1. |
| | 6. Oil or grease on facings. | 6. Install new facings or disc ass'y. |
| | 7. Warped or bent driven disc assy. | 7. Install driven disc ass'y. |
| | 8. Improper disc facing thickness (5/32"). | 8. Install proper disc ass'y. |
| | 9. Worn pilot bearing. | 9. Replace. |
| | 10. Wrong spring pressure in cover assy. | 10. Replace with proper cover ass'y. |
| | 11. Release levers not parallel. | 11. Recheck installation. |
| Aggressive | 1. Worn or loose pedal linkage. | 1. Replace or tighten. |
| | 2. Excessive backlash in power train. | 2. Adjust or replace worn parts. |
| | 3. Warped driven disc. | 3. Install new disc ass'y. |
| | 4. Worn hub splines. | 4. Install new disc ass'y. |
| | 5. Worn splines on splined shaft. | 5. Replace shaft. |
| | 6. Improper facing material | 6. Install proper driven disc ass'y. |
| Insufficient Release | 1. Broken or loose motor mounts. | 1. Replace or tighten. |
| | 2. Worn or loose pedal linkage. | 2. Replace or tighten. |
| | 3. Excessive idling speed. | 3. Adjust to factory specs. |
| | 4. Loose or worn facings. | 4. Replace facings or install new driven assy. |
| | 5. Improper facing thickness (5/32"). | 5. Install proper driven disc assy(s). |
| | 6. Warped or bent driven disc assy. | 6. Install recommended driven disc assy properly. |
| | 7. Lever settings wrong. | 7. Check "A" dimension and recheck installation. |
| | 8. Worn splines. | 8. Replace with new driven disc ass'y. |
| | 9. Worn or rusty splines on splined shaft. | 9. Repair or replace. |
| | 10. Worn pilot bearing. | 10. Replace. |
| Hard Pedal | 1. Worn pedal linkage. | 1. Replace with new linkage. |
| | 2. Binding in pedal linkage. | 2. Lubricate and adjust. |
| | 3. Excessive spring pressure in cover ass'y. | 3. Install proper cover ass'y. |
| | 4. Contact pad of release bearing carrier worn by shifter yoke. | 4. Replace carrier and shifter yoke. Also check for proper hook-up to provide best linkage operating positions. |
| . Slippage | 1. Oil or grease on facing. | 1. Replace facing or install new driven disc assy and correct oil leak. |
| | 2. Loose or worn facings (5/32"). | 2. Replace facings or install new driven disc assy. |
| | 3. Flywheel burned, checked or cracked. | 3. Replace or regrind. |
| | 4. Insufficient plate pressure. | 4. Install new cover assembly. |
| | 5. Binding in pedal linkage. | 5. Lubricate and adjust. |
| | 6. Improper facing material. | 6. Use correct facing or replace disc |
| Vibration | 1. All or part of power train out of balance. | 1. Check each unit individually and recheck as a complete assy. |
| | 2. One or more units in power train out of alignment. | 2. Check and align (replace faulty component). |
| | 3. Worn splined shaft. | 3. Replace. |
| | 4. Worn crankshaft bearings. | 4. Replace. |
| | 5. Worn or loose engine mounts. | 5. Replace or tighten. |
| | 6. Loose or out of balance universal joint. | 6. Tighten or replace - check for |
| | 7. Clutch out of balance. | 7. Install balance unit. |
| | 8. Worn disc splines. | 8. Replace disc. |

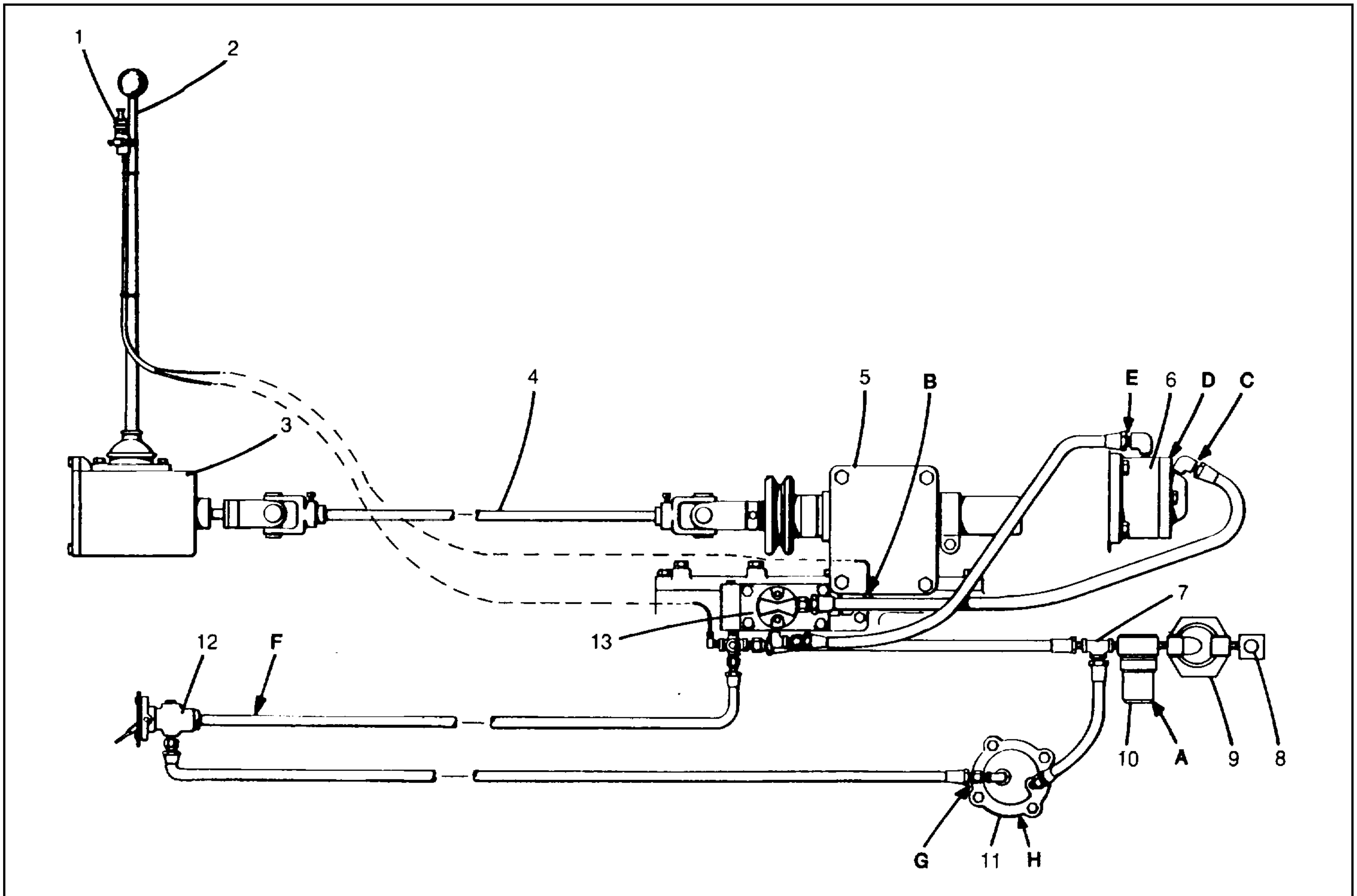



*Fig.*1 *Transmission Controls* NA388-C

(A) thru (H) Trouble Shooting Check Points(9) Air Filter

| | | | | | |
|---|---|---|---|---|---|
| (1) | Control Valve | (5) | Slave Control Assembly | (10) | Regulator |
| (2) | Shift Lever | (6) | Shift Cylinder | (11) | Deep Reduction Shift Cylinder |
| (3) | Master Control Assembly | (7) | Tee | (12) | Deep Reduction Valve |
| (4) | Shift Rod | (8) | Air Supply Port | (13) | Air Valve |

The transmission shift controls are illustrated in Fig. 1. A single lever (2) is used to shift through all speeds. The transmission is shifted from low range to high range with a control button which is mounted on the shift lever (2). The button controls a shift cylinder (6) which shifts the high or low range gears into engagement.

The 5 deep reduction ratios are selected by the same shift lever as the other 10 speeds. The deep reduction gear set is shifted into and out of engagement by an air cylinder (11) which is controlled by a valve (12) on the dash. See Section 1 "Operating Instructions" for shifting, in the Operators Manual.

Note: <u>This SM is concerned with trouble shooting and repair of air shift system only. For repair of transmission assembly, refer to SMl-18-4.0.</u>

2.1 Range Shift Air System

The system consists of an air filter (9), regulator (10), air valve (13), control valve (1), shift cylinder (6), fittings and connecting lines.

Constant pressure is supplied to the bottom port of the air valve, and to the "in" port of the control valve. With the control button down, air passes through the control valve to the end port of the air valve. This permits pressure from the supply to flow through the low range port in the front of the air valve, and on to the shift cylinder. This shift cylinder piston moves to the rear, engaging the low range gear set.

When the control button is up the control valve is closed, and air is exhausted from the end of the range shift air system, plus a deep reduction valve mounted on the carrier dash, and a gear shift cylinder mounted on the transmission.

Constant regulated air is supplied to the end port of the deep reduction valve and to the air port in the lower right inside of the reduction gear shift cylinder cover.
over.

The deep reduction valve lever has two positions, "in" and "out". With the lever moved to the "in" position, the valve is off. Thus, constant air channels through the shift cylinder port of the air valve. This permits pressure from the supply to enter the high range port of the air valve, and flow to the shift cylinder cover port. The air pressure moves the shift piston forward, and engages the high range gear set.

When the control valve is moved from one position to the other, air from the previously charged line exhausts through the breather on the air valve.

### 2.2 Deep Reduction Shift Air System

This system uses the air filter and regulator and cover to the front of the shift piston moves the piston and shift bar to the rear to engage the reduction gear. As the reduction gear is engaged, the range mainshaft is disengaged from the output shaft, removing the low and high range sections from the power flow.
With the deep reduction valve lever moved to the "out" position, air flows out of the side port of the valve and to the air port near the center of the reduction gear shift cylinder cover. This air, pushing against a larger piston area than the constant air supply, moves the shift piston and bar forward to disengage the reduction gear. As the reduction gear is disengaged, the range mainshaft is engaged to the output shaft, permitting use of the low and high range sections.

### 2.3 Trouble Shooting Range Shift Air System

The following checks are to be made with normal vehicle air pressure but with the engine off. Refer to Fig. 1 for check points.

(a) Incorrect Hook-Up: With normal vehicle air pressure and gear shift lever in the neutral position, move the control button up and down, from one range to another.
  (1) If lines are crossed between the control valve and the air valve on transmission, there will be a steady flow of air from the top exhaust in the control valve if the button is held in the up position.
  (2) If lines are crossed between the air valve on transmission and the air or shift cylinder, the transmission gearing will not correspond with the button position. Low range, down position of button, will result in high range gear engagement in the transmission and vice versa.

(b) Air Leaks: With normal vehicle air pressure and gear shift lever in the neutral position, coat all lines and fittings with soapy

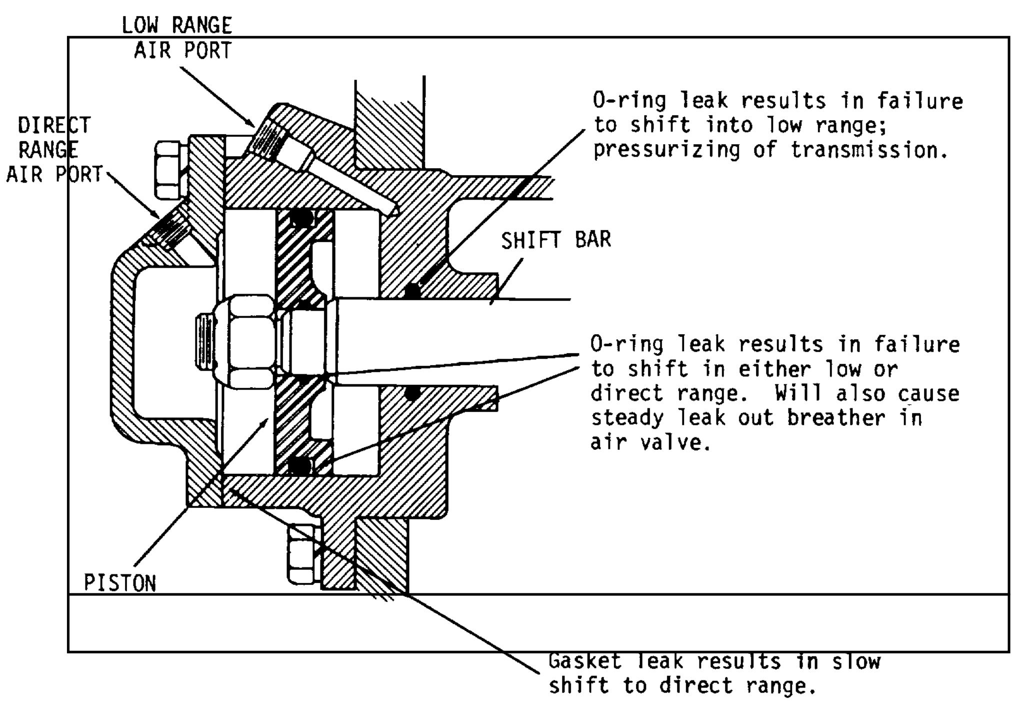



*Fig. 2 Range Shift Cylinder*

water and check for leaks, moving control button to both positions.

(1) If there is a steady leak out exhaust of control valve, there are defective parts or 'O' rings in the control valve.

(2) If there is a steady leak out breather on air valve: there is a defective 'O' ring in the air valve; or there is a leak past 'O' rings on the shift cylinder piston (see check point E and Fig. 2).

(3) If transmission fails to shift into low range or is slow to make the shift and the transmission case is pressurized, see check point E and Fig. 2.

(4) Tighten all loose connections and replace defective parts or '0' rings.

(c) Air Regulator (see check point A): With normal line pressure and gear shift lever in neutral, check exhaust port on bottom of air regulator. There should be no leak from this port.

(1) If there is a steady leak from exhaust port this indicates a defective air regulator and should be replaced. Cut off the vehicle air pressure and install air gauge in line at output port of air regulator. Bring vehicle air pressure to normal. Regulated pressure should be 57.5 to 62.5. If correct pressure readings are not obtained, replace regulator.

(d) Control Valve (see check point B): With the gear shift lever in neutral, pull the control button up to high range and disconnect the 1/8" black nylon air line at air valve.

(1) When control button is pushed down, a steady blast of air should flow from the disconnected line. Air will shut off when button is pulled up. This indicates control valve is operating correctly. Reconnect air line. If control valve doesn't operate correctly, check for leaks. restrictions and

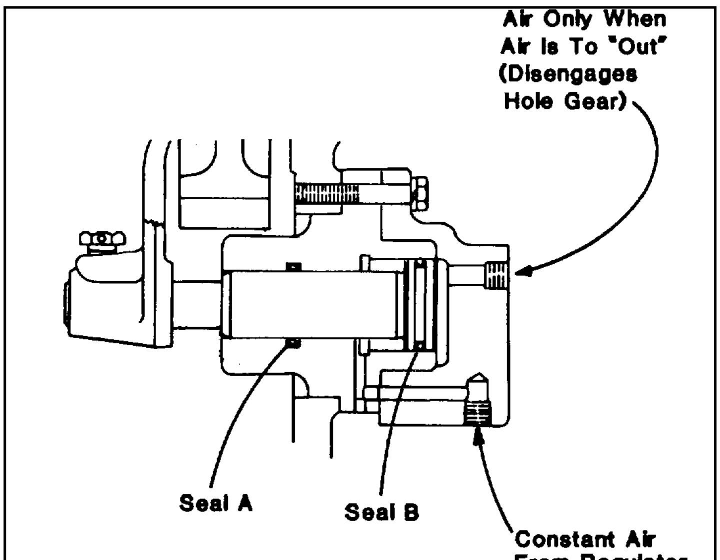



*Fig. 3 Deep Reduction Shift Cylinder*

defective '0' rings.

(e) High Range (see check point C): With the gear shift lever in neutral, push the control button down and disconnect the high range air line from the shift cylinder cover.

(1) Pull the control button up. There should be a steady flow of air from the high range air line. Push button down to shut off air.

(2) Make sure vehicle engine is off, then move the gear shift lever to a gear position. Pull button up; there should be no air at high range line. Move the gear shift lever to neutral; there should now be a steady flow of air from the high range line. Push button down to shut off air and reconnect line.

(3) If air system operating incorrectly, this indicates air valve is defective or actuating parts in shifting bar housing are jammed or defective.

(f) Low Range (see check point D): With the gear shift lever in neutral, pull the control button up and disconnect the low range air line at shift cylinder.

(1) Repeat procedure under check point C, reversing the position of the control button, in order to check the low range operation.

(g) Range Shift Cylinder (see check point E): If any of the seals in the range shift cylinder are defective, the range shift will be affected. The degree of lost air will govern the degree of failure, from slow shift to complete failure to shift. Refer to Fig. 2 for location of seals. Make sure cylinder bore is clean to prevent damage to shellac or Permatex on cover gasket to prevent clogging cylinder. Tighten cover capscrews securely.

2.4 Trouble Shooting Deep Reduction System

The following checks are to be made with normal vehicle air pressure but with the engine off. It is assumed air lines have been checked for leaks and the air regulator has been checked and the correct reading obtained. Refer to Fig. 1 for check points.

(a) Air Input (check point F): With gear shift lever in neutral and normal vehicle air pressure, loosen the connection at input (end port) of the deep reduction valve until it can be determined that there is a constant flow of air at this point. Reconnect line. If there is no air at this point, there is a restriction in the line between the deep reduction valve and air valve. Also check to make sure this line is connected to a constant supply.

(b) Deep Reduction Valve (check point G): With the deep reduction valve lever to "in", remove the line from the deep reduction valve at the port in reduction gear shift cylinder; there should be no air at this point. Move the deep reduction valve lever to "out". There should now be a constant air flow from line. Move lever to "in" to shut off air. If the above conditions do not exist, deep reduction valve is faulty or there is a restriction in air line.

(c) Deep Reduction Shift Cylinder (check point H): If any of the seals in the reduction shift cylinder are defective, the reduction gear shift will be affected. The degree of lost air, of course, will govern the degree of failure to shift. Refer to Fig. 3 for location of seal.

(1) Leak at Seal A: Failure to engage reduction gear; pressurizing of transmission; reduction gear can be disengaged.

(2) Leak at Seal B: Failure to engage reduction gear; leak from deep reduction valve exhaust port when valve is "in".

**4.1 General Precautions for Disassembly**

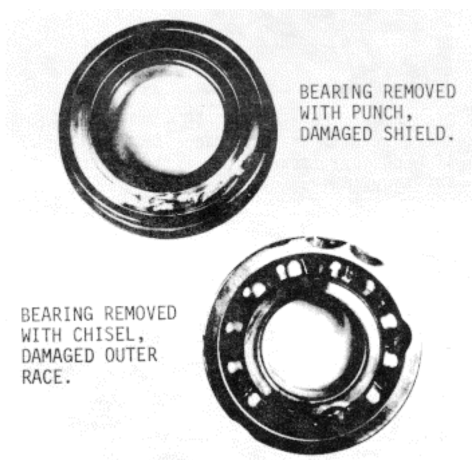
Note: Read this section before starting the detailed disassembly procedures.

It is assumed in the detailed disassembly instructions that the lubricant has been drained from the transmission, the necessary linkage and air lines removed and the transmission has been removed from the chassis. Removal of the gear shift lever housing assembly is included in the detailed instructions; however, this assembly must also be removed from transmission before removing unit from vehicle.

Air lines from the hole-gear switch in cab must be disconnected at the transmission before removing unit from vehicle.

Follow each procedure closely in each section, making use of both the text and pictures.

(1) Bearings: Carefully wash and relubricate all bearings as removed and protectively wrap until ready for use. Remove all bearings with pullers designed for this purpose--do not remove bearings with hammer and punch.




(2) Mainshaft: In the following instructions, two procedures for removing the front section mainshaft are given. The first method is given to facilitate field repair where only partial disassembly is contemplated; it provides for the removal of the mainshaft with-out removing the clutch housing or countershaft bearings. In the second procedure, the mainshaft can be easily lifted from case; however, the clutch housing must be removed along with countershaft bearings.

(3) Snap Rings: Remove snap rings with pliers designed for this purpose. Rings removed in this manner can be reused.

(4) Input Shaft: The clutch or input shaft can be removed on most models without removing the countershafts, mainshaft or drive gear. See SM1-18-8.0.

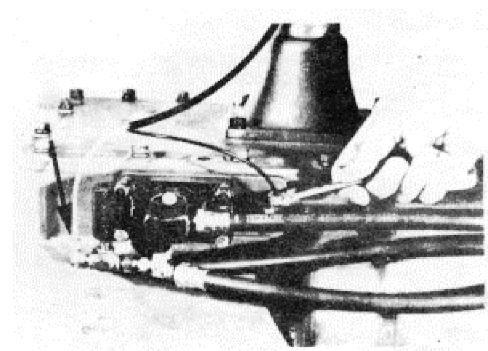
(5) Cleanliness: Provide a clean place to work. It is important that no dirt or foreign material enters the unit during repairs. The outside of the unit should be carefully cleaned before starting the disassembly. Dirt is abrasive and can damage highly polished parts such as bearings, sleeves, and bushings.

(6) When Driving: Apply force to shafts, housings etc., with restraint. Movement of some parts is restricted. Do not apply force after the part being driven stops solidly. Use soft hammers and bars for all disassembly work.

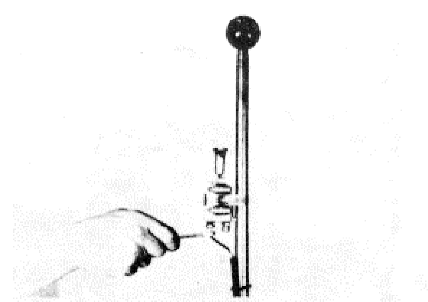
**4.2 Disassembly Instructions**

**4.3 Range Shift Air System**

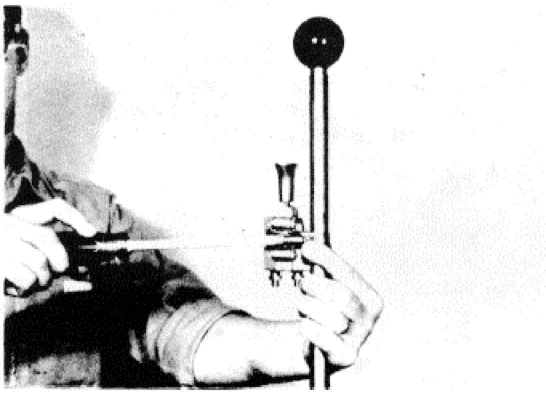
**4.4 Removal of Range Shift Control Valve**



(1) Disconnect the two 1/8" OD air lines at the air valve on the transmission.

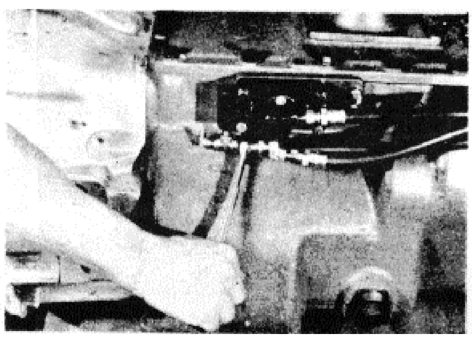


(2) Disconnect the two 1/8" OD air lines at the control valve on the gear shift lever.

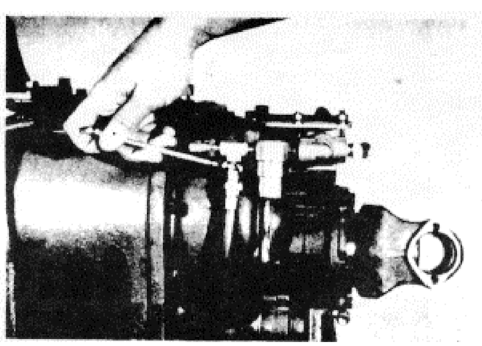


(3) Loosen the mounting clamp and remove the control valve and clamp from the lever. Remove the ball grip, air lines, sheathing and "0" rings from the lever.
Note: For disassembly of the control valve refer to SM1-18-5.0.

**4.5 Removal of the Air Filter and Regulator Assembly**



(1) Disconnect the 1/4" ID air line between the air valve and the regulator.

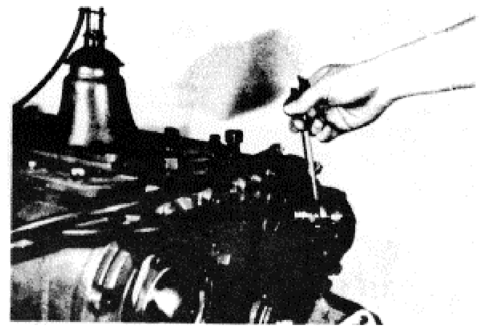


(2) Remove the 1/4" ID air line between the filter regulator assembly and the deep reduction shift cylinder.

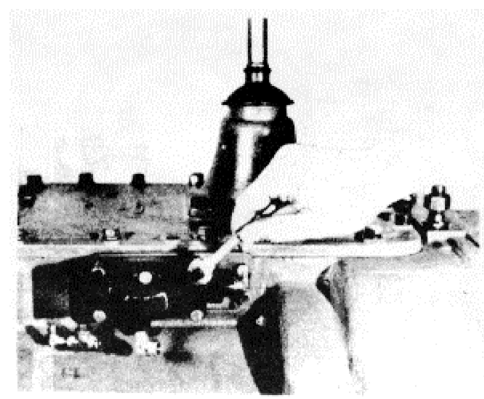
(3) Turn out the two capscrews and remove the filter/regulator assembly from the transmission.

Note: For further disassembly of the filter/ regulator assembly refer to SM1-18-6.0. .6

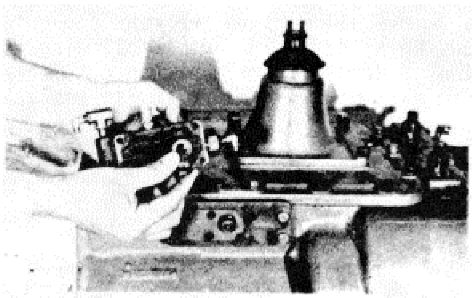
4.6 Removal of the Air Valve



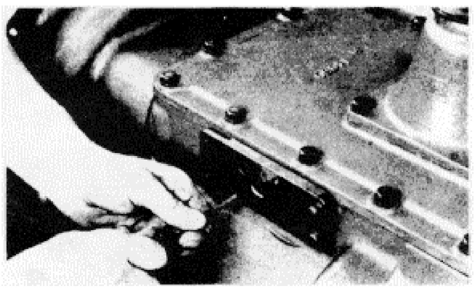
(1) Disconnect the two 1/4" ID air lines between the air valve and the range shift cylinder. If necessary, remove the fittings from the shift cylinder.



(2) Turn out the four capscrews and remove the air valve from the adapter plate.

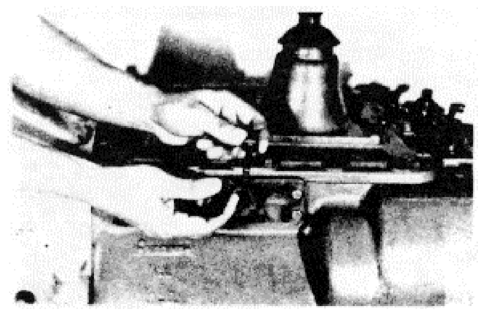


(3) Remove the alignment sleeve from the air valve or bore in the adapter plate.



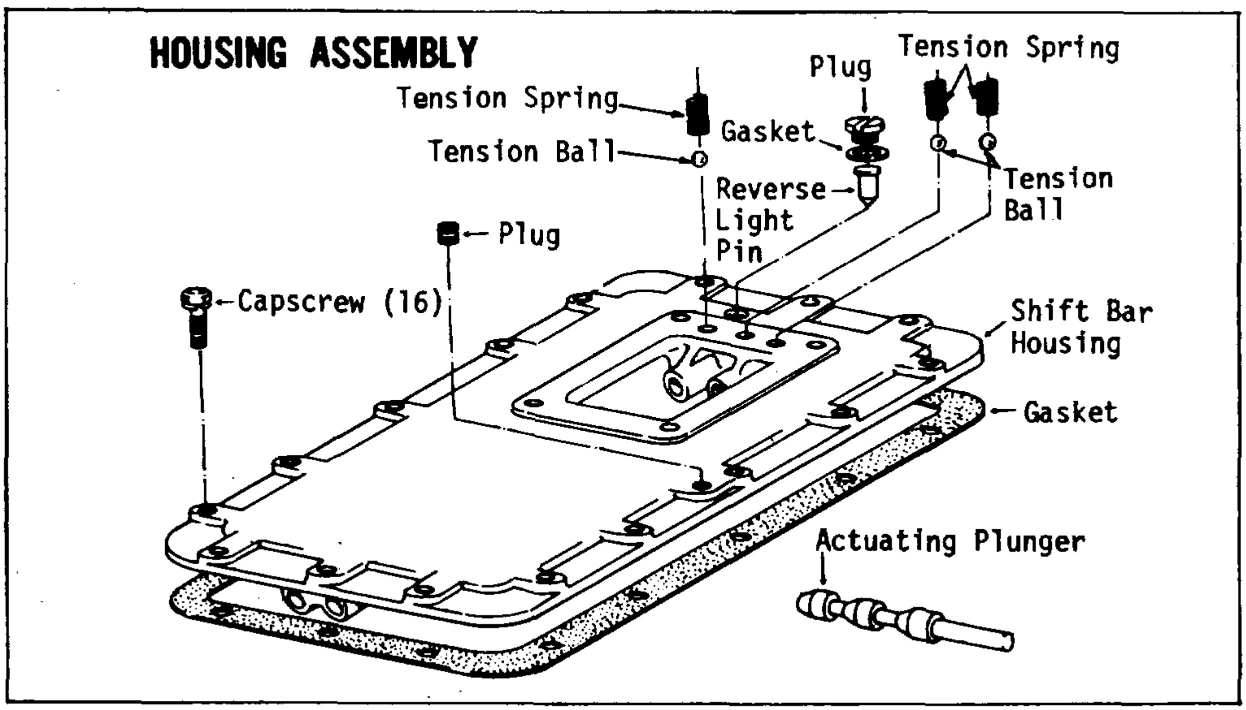
(4) Remove the spring and actuating plunger from the bore in the adapter plate.

### 4.7 Shifting Bar Housing Assembly

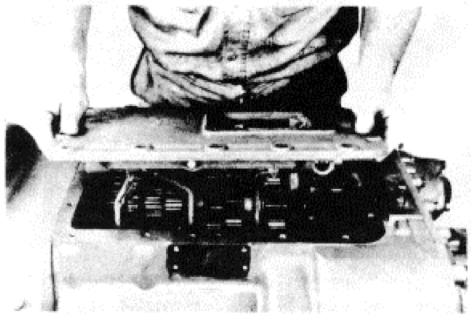


(5) Turn out the two capscrews and two Allen head screws and remove the adapter plate from the transmission. If necessary, remove the fittings from the air valve.

Note: For further disassembly of the air valve, refer to SM1-18-7.0.

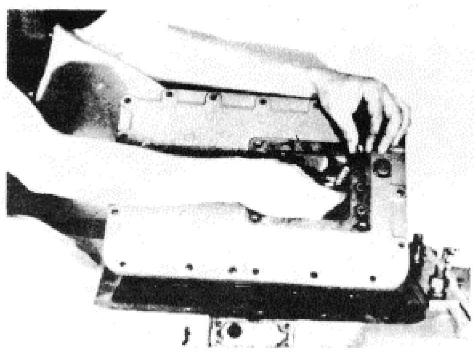


### 4.8 Removal of the Housing

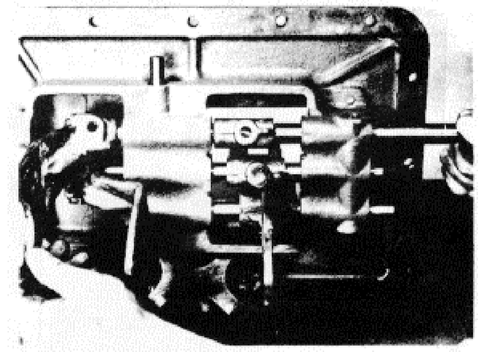


(1) Turn out the attaching capscrews, jar to break gasket seal and lift the housing from the transmission.

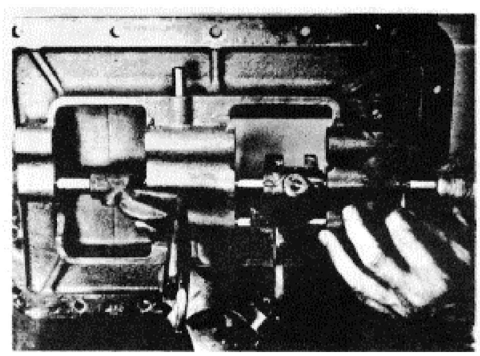
### 4.9 Disassembly of the Shifting Bar Housing Assembly



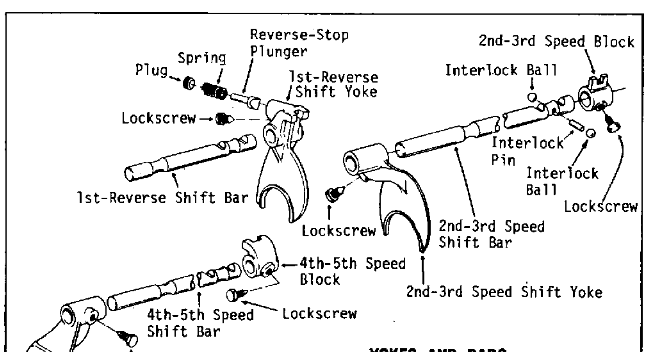
(1) Tilt the housing and remove the three sets of tension springs and balls in the top of the housing. Secure the housing in a vise with the plunger side up. Starting with the upper bar, move all bars to the rear and out of the housing as detailed in the following instructions. Cut lockwire and turn out lockscrews from each bar just prior to its removal.



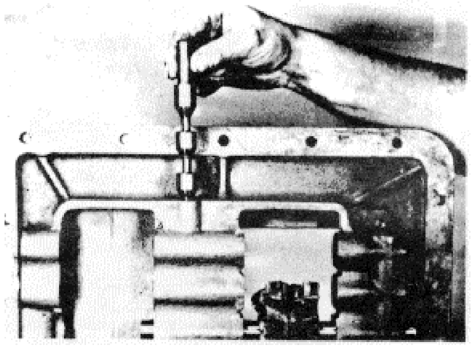
(2) Move the 4th-5th speed shift bar (top) to the rear and out of housing, removing the shifting yoke and block from the bar.



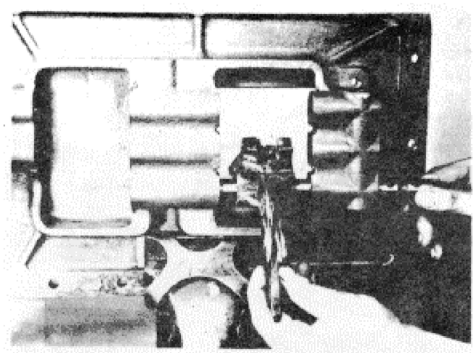
(3) Move the 2nd-3rd speed shift bar (center) to the rear and out of housing, removing yoke and block from bar. As the neutral notch clears the housing boss, remove the interlock pin from the notch.



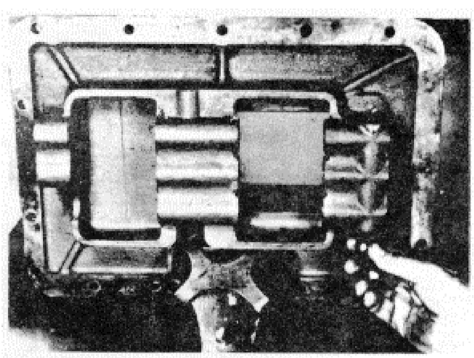

**YOKES AND BARS**



(4) Remove the actuating plunger from the bore in the housing.



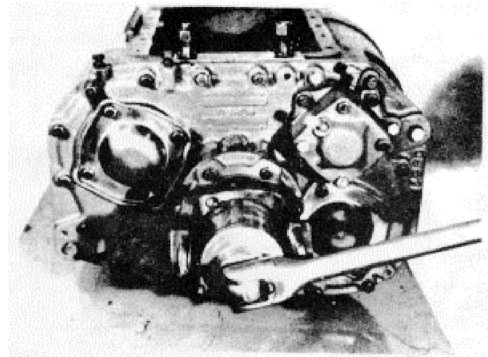
(5) Move the 1st-reverse speed shift bar (lower) to the rear and out of housing, removing the yoke from the bar.



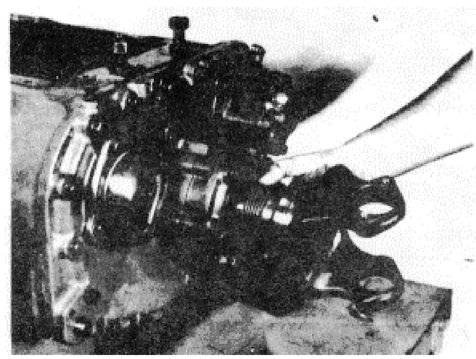
(6) As the 1st-reverse bar is removed, two interlock balls will fall from the opening in the side of the housing.

### 4.9 Companion Flange, Auxiliary Section and Clutch Housing

### 4.10 Removal of the Universal Joint Companion Flange or Yoke

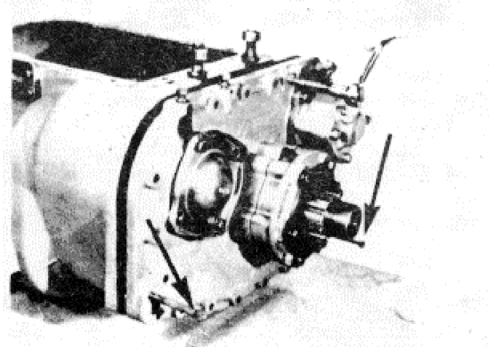


(1) Lock the mainshaft in two gears and turn the elastic stop nut from the output shaft.

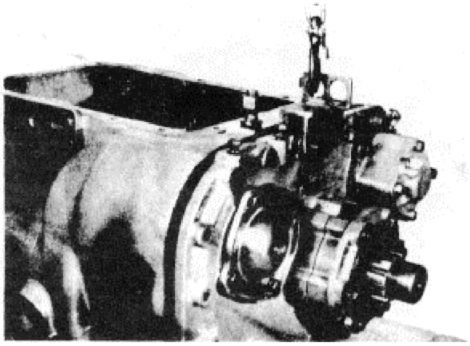


(2) Pull the flange or yoke straight to the rear and off the shaft and remove the speedometer drive gear or replacement spacer from the hub of the flange or yoke.

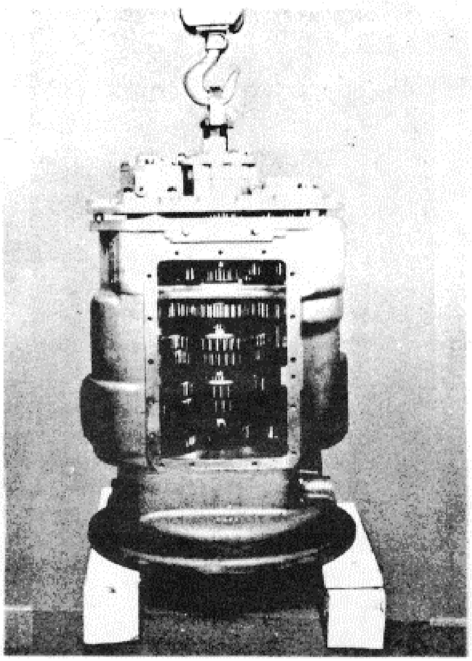
### 4.11 Removal of the Auxiliary Section



(1) Turn out the attaching capscrews and insert three puller screws in the tapped holes in the rear housing. Tighten the puller screws evenly and move the housing far enough away from the front section to break the gasket seal.



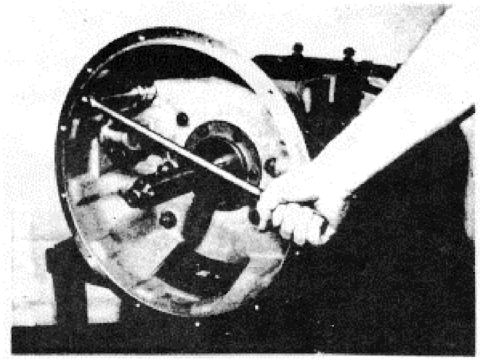
(2) Attach a chain hoist to the rear housing an move the assembly to the rear until free of the transmission.



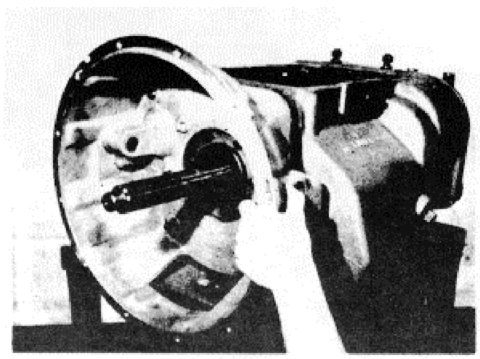
(3) Transmission can also be set vertically to remove the rear housing. Block under the clutch housing to prevent damage to the input shaft and lift the auxiliary housing upwards and from the front section.

### 4.12 Removal of the Clutch Housing

Note: The clutch housing need not be removed unless the countershafts or drive gear are to be removed from the transmission. The mainshaft can be removed without the removal of the clutch housing.



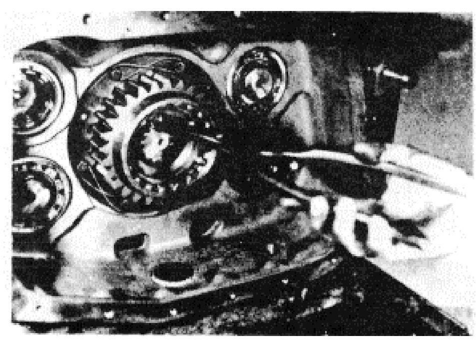
(1) If so equipped, remove the clutch release mechanism and turn the four bolts and six nuts from the clutch housing.



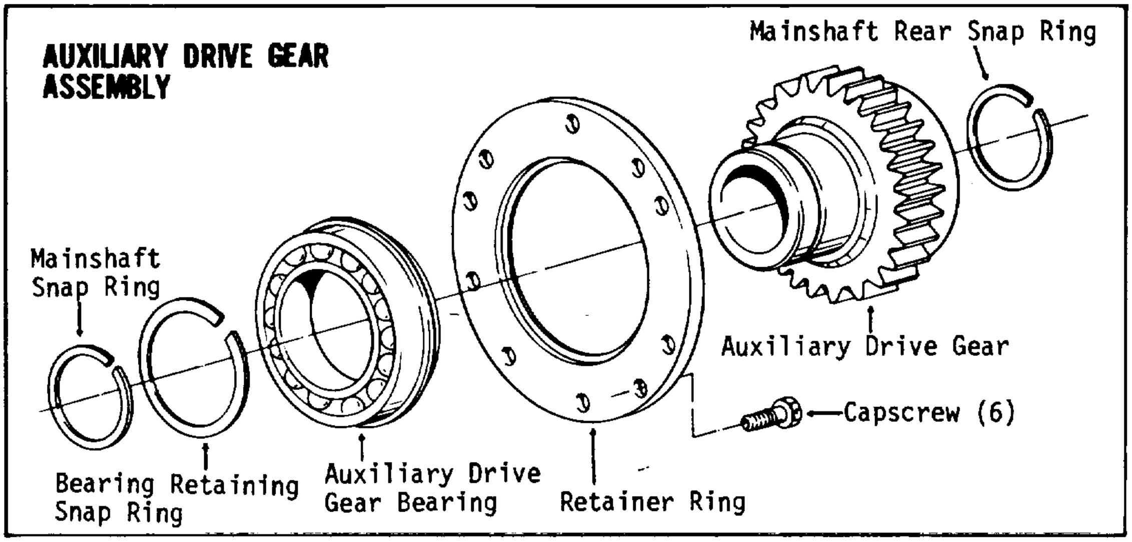
(2) Pull the clutch housing straight forward and off the case. It will be necessary to break the gasket seal by jarring the housing with a soft hammer. The clutch housing is piloted on the drive gear bearing cover.

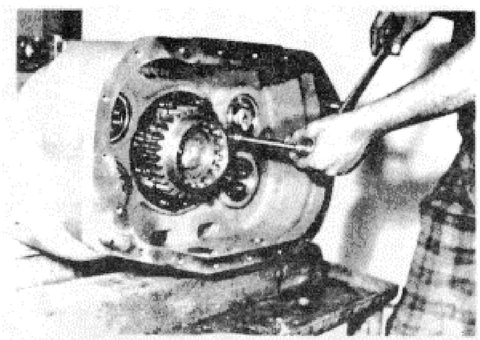
### 4.13 Front Section

### 4.14 Removal and Disassembly of the Drive Gear Assembly

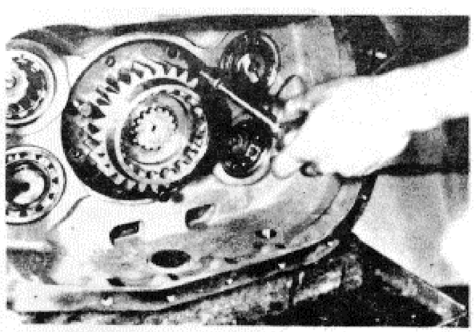


(1) Remove the mainshaft rear snap ring from the groove in the mainshaft.

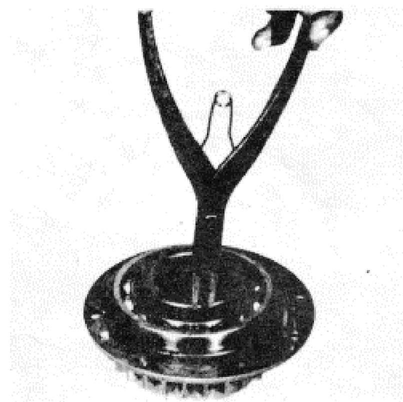


(2) Cut the lockwire and remove the six capscrews from the bearing retainer ring.

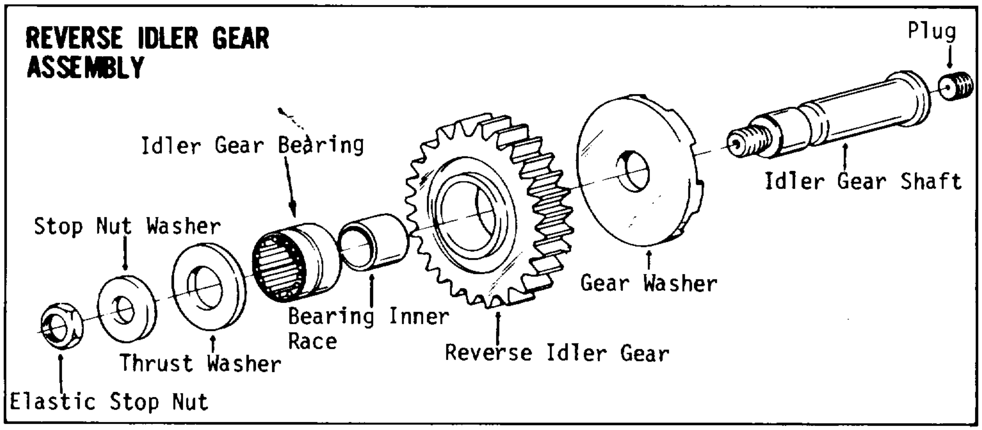


(3) Use three puller screws to pull the assembly from the case bore.

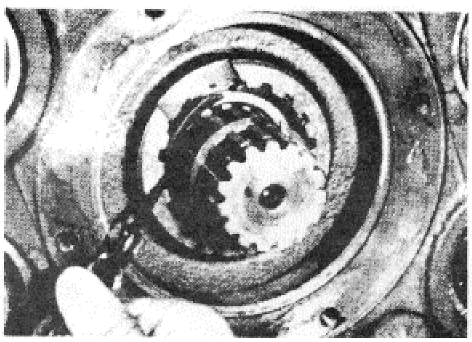


(4) Remove the snap ring from the hub of the auxiliary drive gear; press retainer ring and bearing from drive gear.

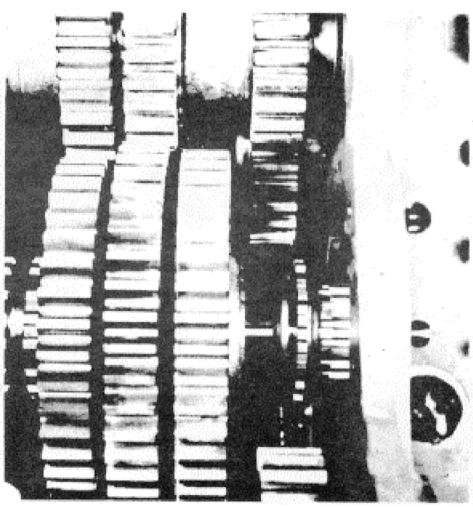
**4.15 Removal and Disassembly of the Left Reverse Idler Gear Assembly**



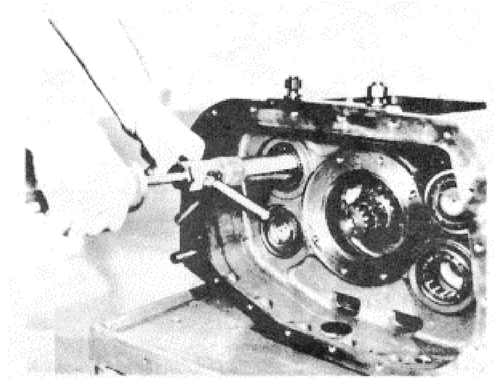

Note: To remove the left reverse idler gear, the reverse gear on the mainshaft must be moved forward to provide the necessary clearance; this procedure is included in the following instructions.



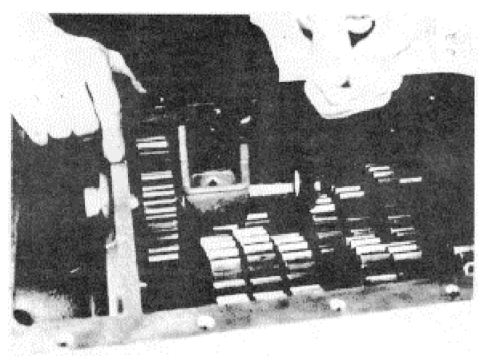
(1) Move the mainshaft reverse gear to the rear as far as possible and remove the snap ring from the ID of the gear.



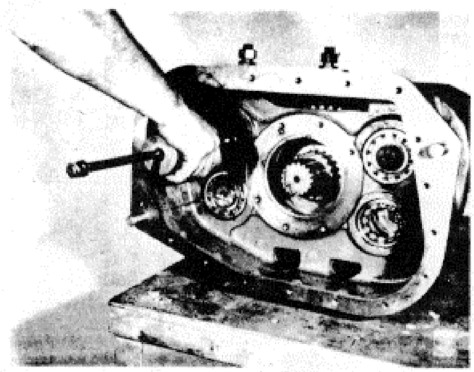
(2) Move the reverse gear forward and against the low speed gear, engaging the splines of the sliding clutch gear.



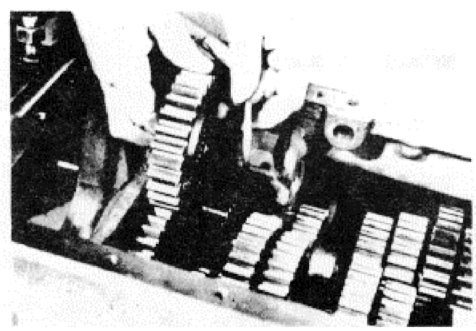
(3) Remove the auxiliary countershaft front bearing from left reverse idler gear bore; use inside jaw pullers.



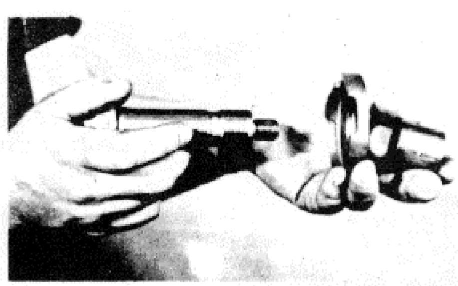
(4) Inside the case, turn the elastic stop nut from the idler shaft and remove the washer.



(5) Remove the plug from the bore in the rear of the idler shaft, insert an impact puller (threaded 1/2-13) and remove the idler shaft.

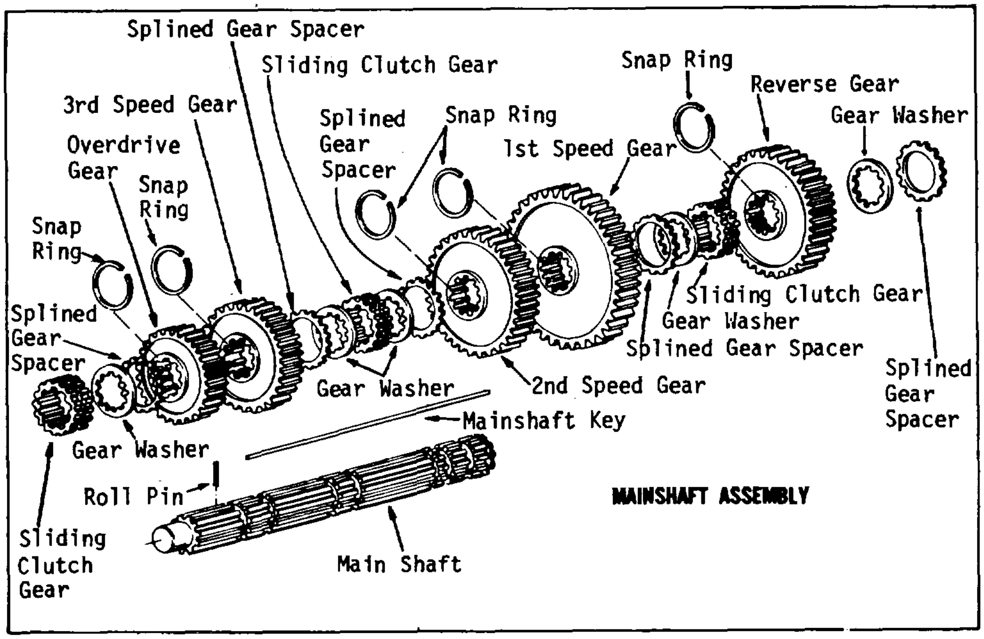


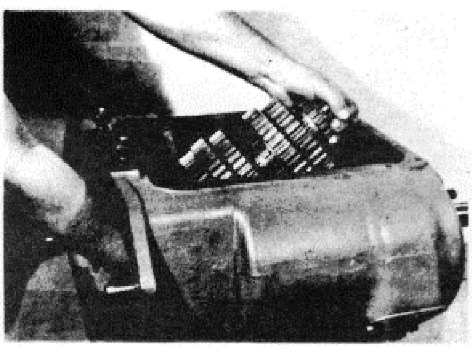
(6) As the shaft is moved to the rear, remove the gear and washer from the shaft and case.



(7) If necessary, remove the bearing inner race and rear washer from the shaft. This is a slip fit. If necessary, press the bearing from the bore of the reverse idler gear.

## 4.16 Removal of the Mainshaft Assembly

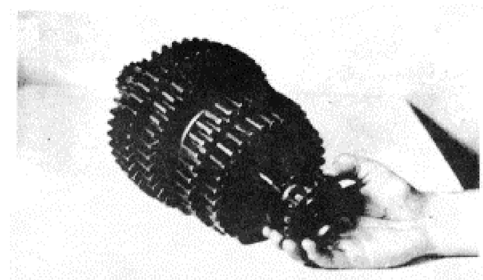


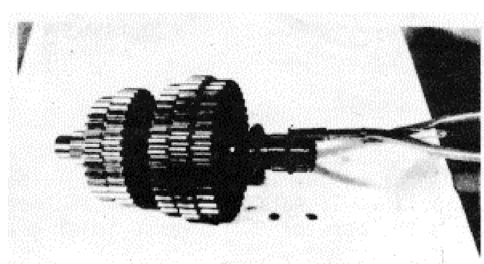
(1) Move the mainshaft assembly to the rear as far as possible to unmesh the mainshaft gears from the countershaft gears. Tilt the front of the mainshaft up and remove the assembly through the top of the case. It will be necessary to work the assembly past the countershaft gears and reverse idler boss in the case. Keep mainshaft to the rear as far as possible and reverse gear next to the first speed gear for full clearance.

Note: Use caution during removal as the reverse gear is free and can fall from the assembly.

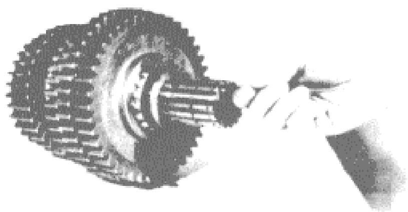
## 4.17 Disassembly of the Mainshaft Assembly



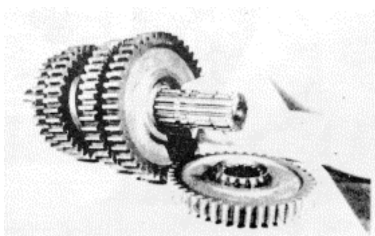
(1) Remove the 4th-5th speed sliding clutch.



(2) Remove the snap ring from the rear of the mainshaft.

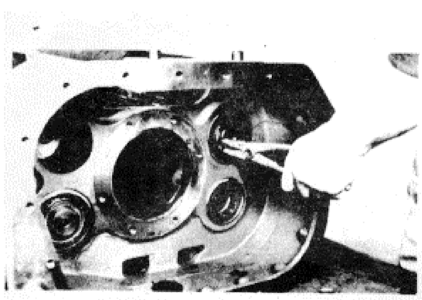


(3) Remove the reverse gear and spacer and pull the key to the rear and from the mainshaft.
Note: When removing washers, spacers and gears, note their location to facilitate the reassembly of the mainshaft. Keep washers and spacers with the gear from which they were removed; there is one spacer and one washer for each gear. The spacers have external splines and the washers have internal splines.



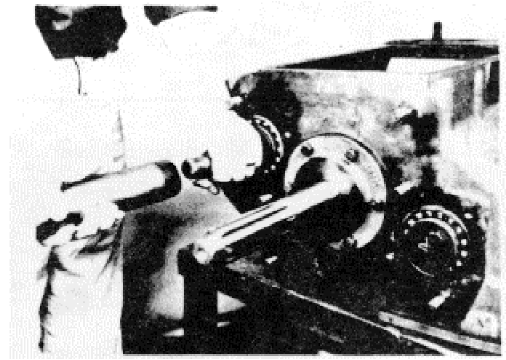
(4) Work washers, spacers and gears from the. mainshaft. It will be necessary to turn washers, located under each gear, to align with splines of mainshaft. If necessary, remove snap rings from ID of each gear.

4.18 Removal of the Countershaft Bearings



(1) Remove the snap ring from the rear of the countershaft and using a blunt punch from inside the case, move the countershaft rear bearing to the rear and off the shaft.
Note: Removal procedures will most likely damage the bearing and removal of the bearing should not be attempted unless replacement is planned.

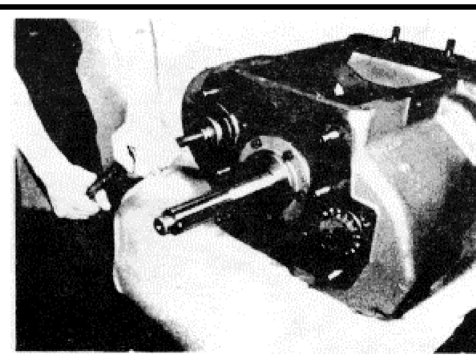
(2) Cut the lockwire, turn out the two capscrews and remove the bearing retainer plate from the front of the countershaft.



(3) Move the right countershaft to the rear as far as it will go, using a soft bar and mallet against the front of the countershaft. This will partially unseat the front bearing from the shaft and unseat the rear bearing from the bore.

**CAUTION**

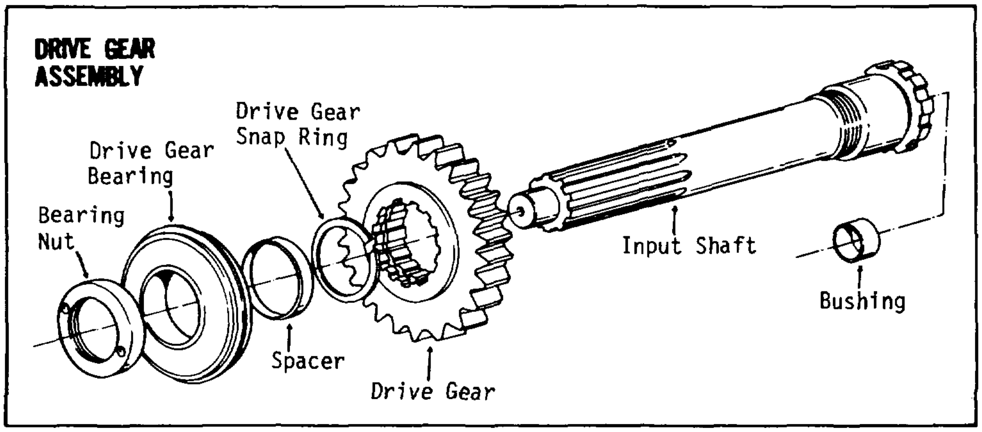
Use A Soft Bar With A Large, Flat End To Prevent Damage To The Capscrew Holes In The Front Of The Countershaft.



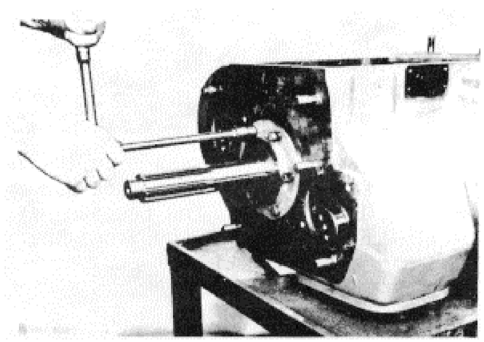
(4) Move the countershaft forward until the front bearing is clear of the case and pull or pry the front bearing from the shaft Note: Remove the retainer plate and bearings from the left countershaft in the same manner as those removed from the right.

**Service Manual** SM1-18-4.0 Main Transmission Repair

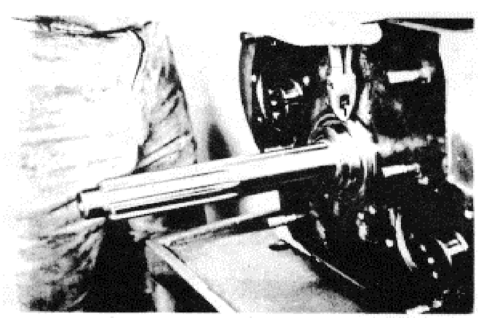
4.19 Removal of the Drive Gear Assembly



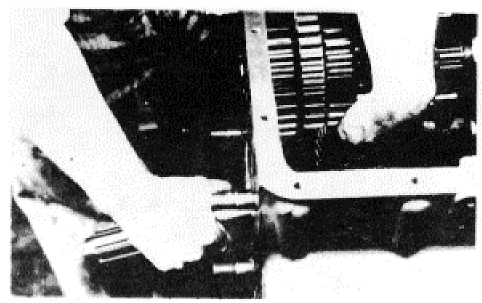

Note: See SM1-18-8.0 for procedure to remove input shaft without removal of the drive gear, countershafts or mainshaft.



(1) Turn out the capscrews from the front bearing cover and from inside the case, move the drive gear forward, removing the cover as the gear pushes it forward. Use a soft bar and mallet to move the drive gear.

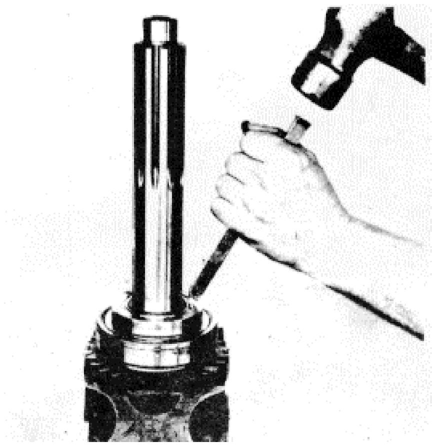


(2) Remove the snap ring from the drive gear bearing.

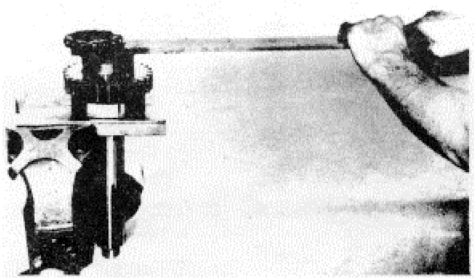


3) Move the drive gear to the rear and into the case and remove from the case, working past the countershaft gears.

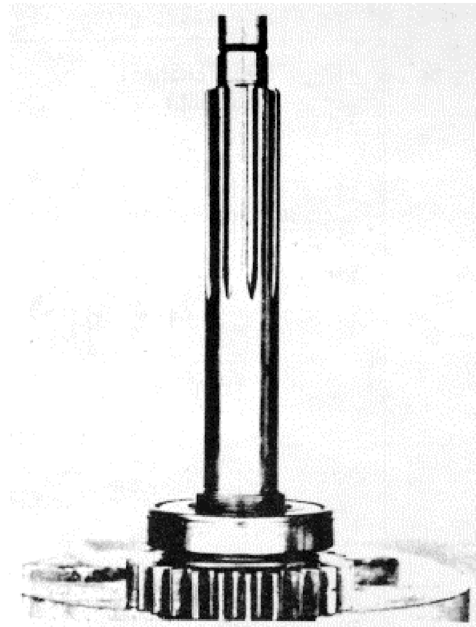
4.20 Disassembly of the Gear Assembly



(1) Relieve the drive gear bearing nut at the points where it is peened into the milled slots of the shaft.

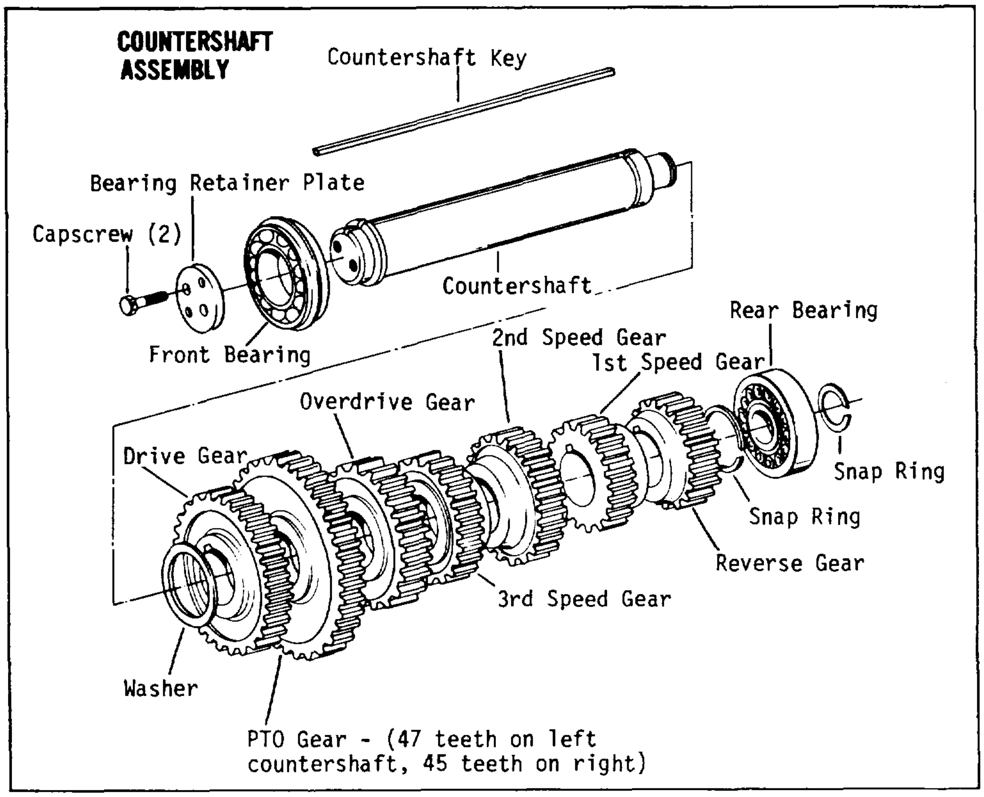


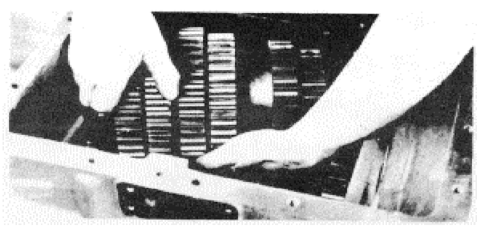
(2) Turn the bearing nut from the shaft (L.H. thread).



(3) Using the rear face of the drive gear as a base, mount the assembly in a press and press the shaft through the gear to unseat the bearing from the shaft. This will free the bearing, spacer and drive gear from the shaft. If necessary, remove the snap ring

4.21 Removal of the Countershaft Assemblies

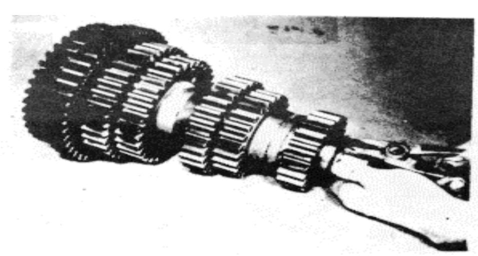


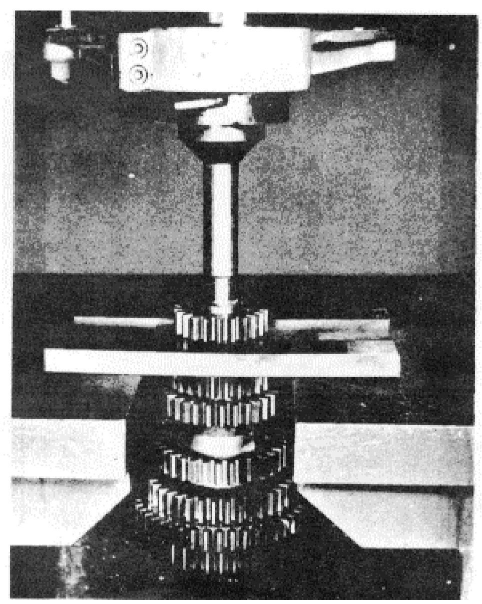
(1) Move the front of the right countershaft towards the center of the case and upwards and remove from the case. Repeat procedure for the left countershaft.

4.22 Disassembly of the Countershaft Assemblies

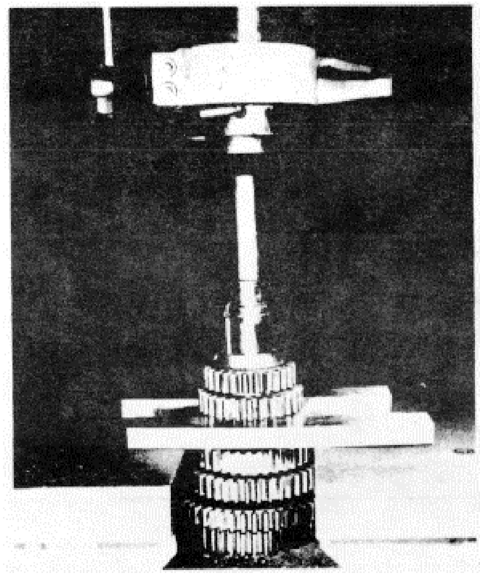
Note: Except for the number of teeth on the PTO gear, both countershafts are identical and disassembled in the same manner.



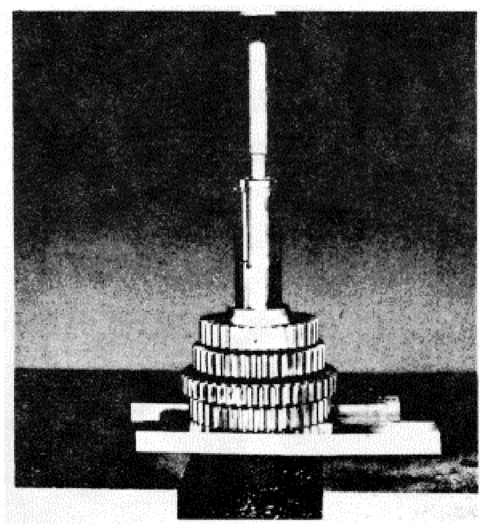
(1) Remove the snap ring from the rear of the countershaft.



(2) Press the reverse gear from the countershaft.



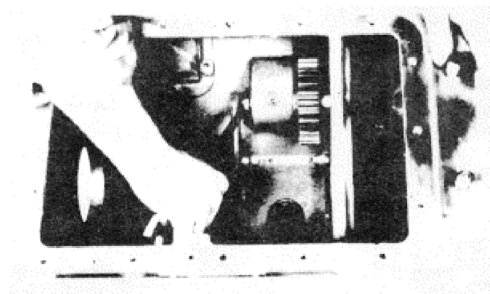
(3) Press the 1st and 2nd speed gears from the shaft.



(4) Press the remainder of the gears from the shaft. This will require a press of at least 25 ton capacity. Use metal shield on press as a safety precaution. If necessary, remove key and front spacer from countershaft.

4.23 Removal and Disassembly of the Right Reverse Idler Gear Assembly

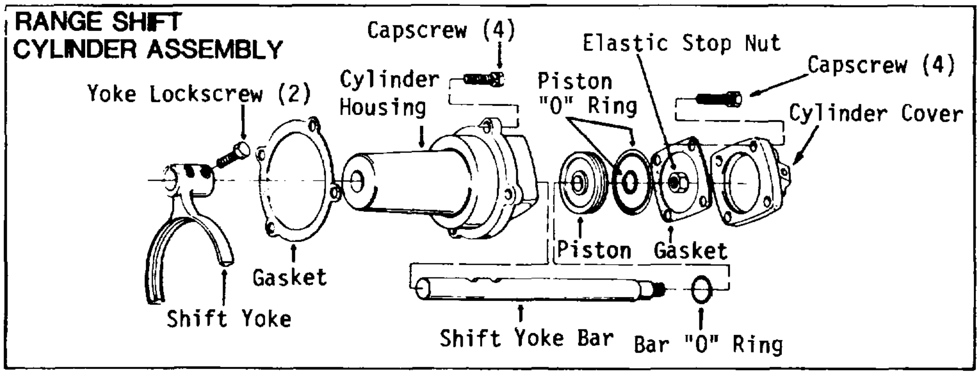
Note: The right reverse idler gear assembly is identical to the left and disassembled in the same manner.

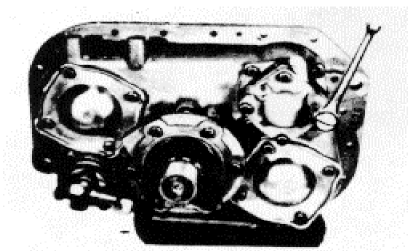


(1) Remove nut and washer from end of idler shaft. Complete removal and disassembly in the same manner as the left reverse idler gear assembly, see paragraph 4.15.

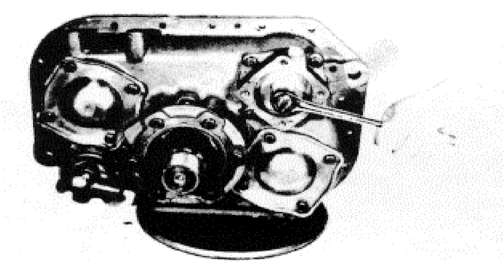
4.24 Auxiliary Section

4.25 Removal and Disassembly of the Range Shift Cylinder Assembly

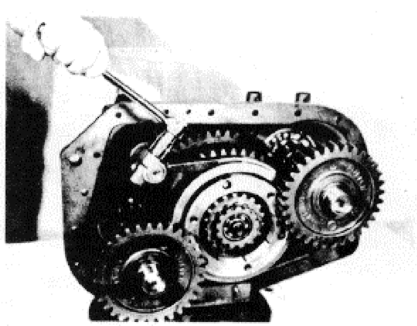


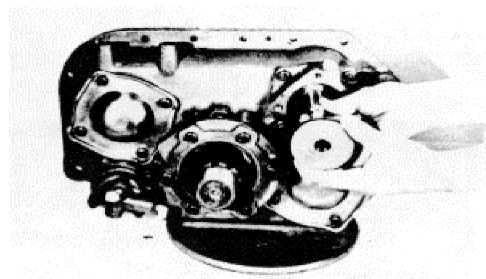
(1) For ease of disassembly, mount the housing upright in a vise. Turn out the capscrews and remove the cylinder cover.



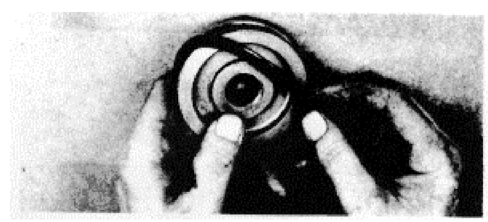
(2) Turn the elastic stop nut from the end of the shift shaft.



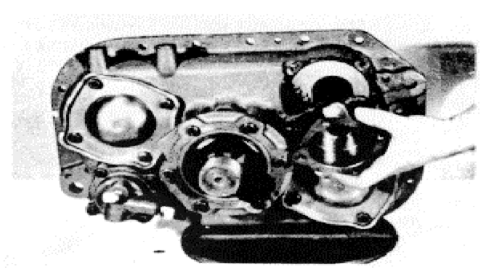
(3) Cut the lockwire and turn out the two yoke lockscrews.



(4) Push the shaft and piston to the rear and out of the shift cylinder. Remove the piston from the shaft.

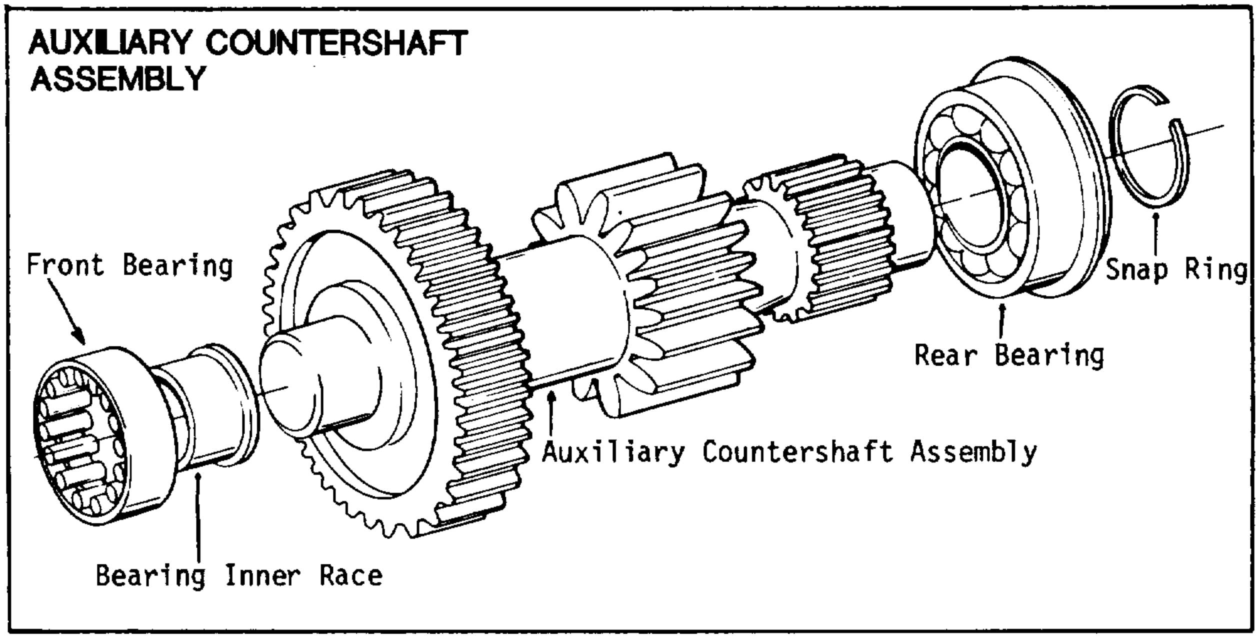


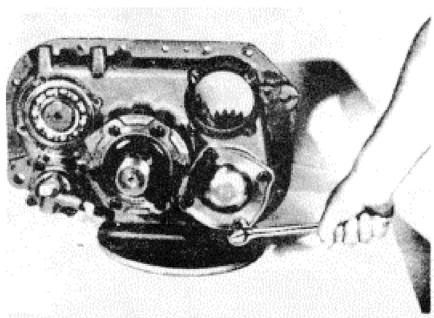
(5) Remove the "0" rings from the ID and OD of the piston and from the bore in the shift cylinder.



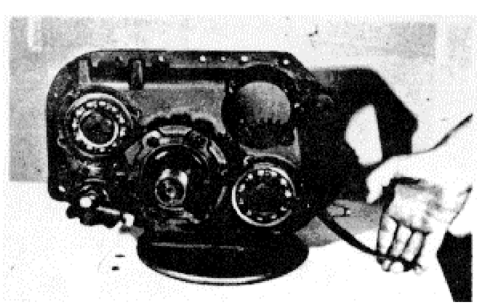
(6) Turn out the capscrews and remove the shift cylinder housing. Remove the yoke from the sliding clutch gear of the synchronizer.

4.26 Removal of the Auxiliary Countershaft Assemblies

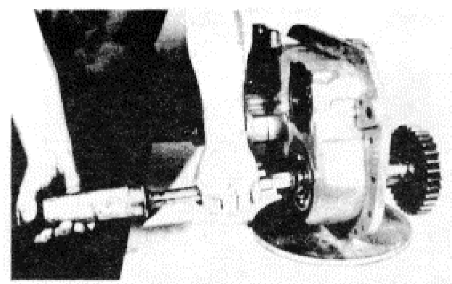


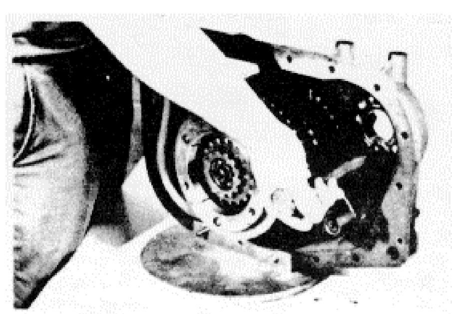
(1) Turn out the capscrews and remove the two rear bearing covers.



(2) Remove the snap ring from the rear of both countershafts.

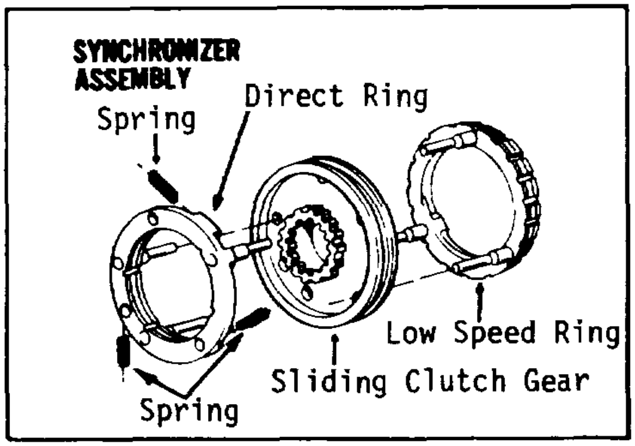


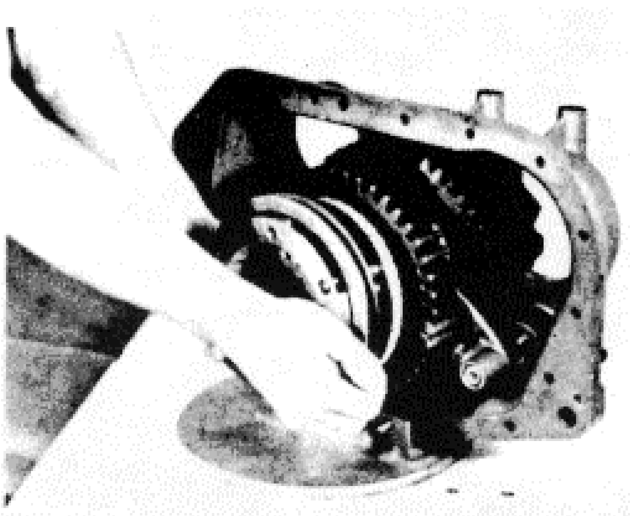
(3) Use a soft bar and mallet to drive the countershafts forward and from the rear bearings.



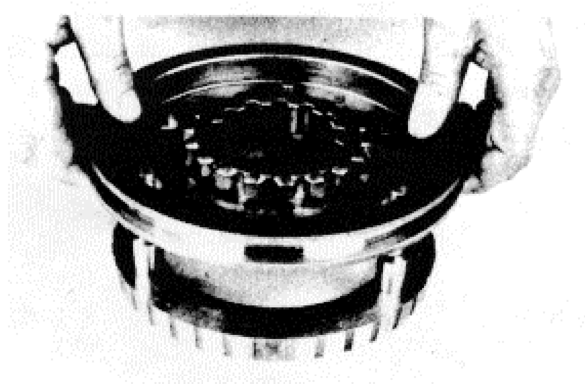
(4) Remove the rear bearings by tapping lightly and evenly to the rear with a soft bar.

4.27 Removal and Disassembly of the Synchronizer Assembly

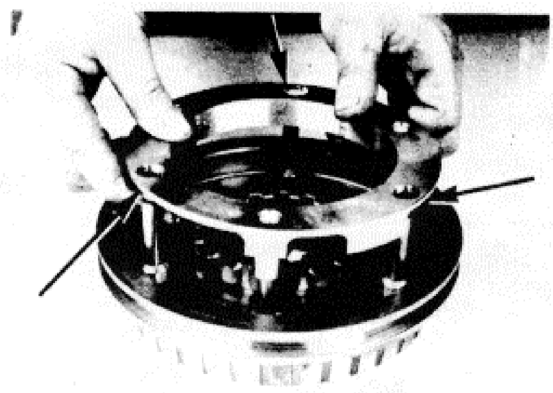


(1) Pull the synchronizer assembly from the splines of the range mainshaft.

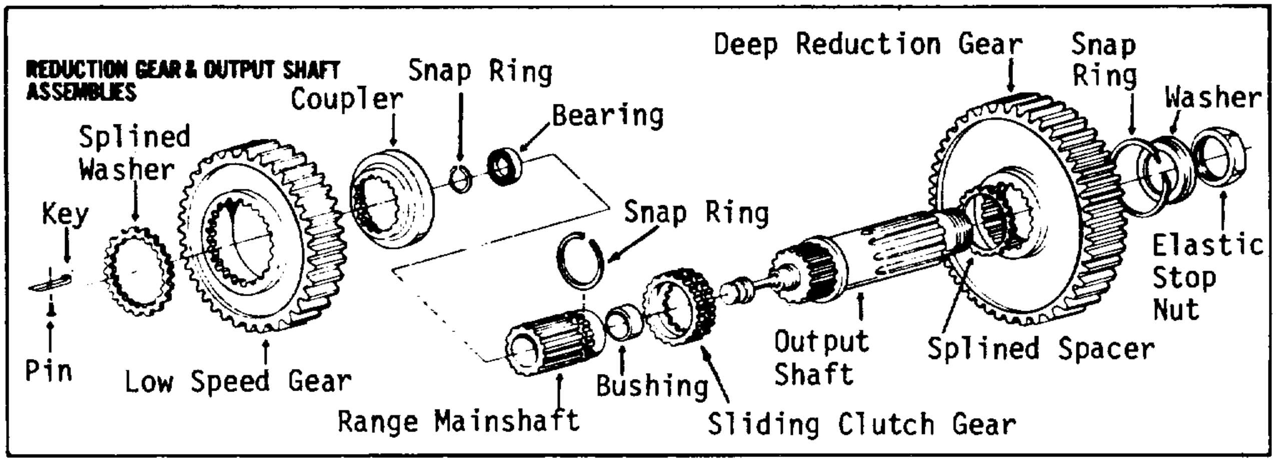


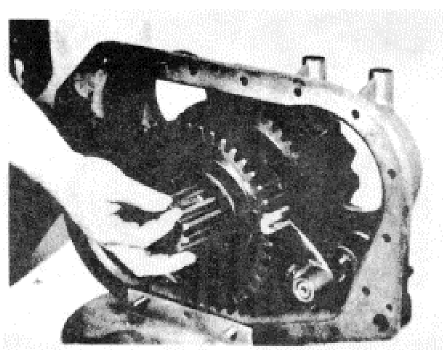
(2) Pull the direct (high range) ring from the blocker pins of the low speed ring. Cover with a cloth as the three springs will be released at the blocker pin locations.



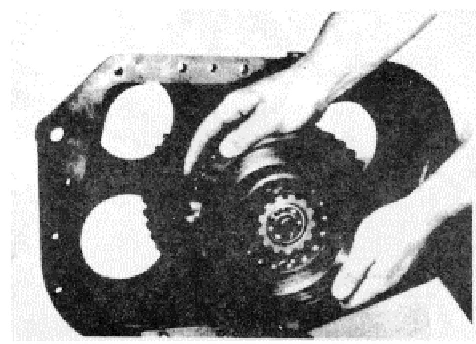
(3) Remove the sliding clutch gear from the pins of the low speed ring.

4.28 Removal of the Low Range Gear



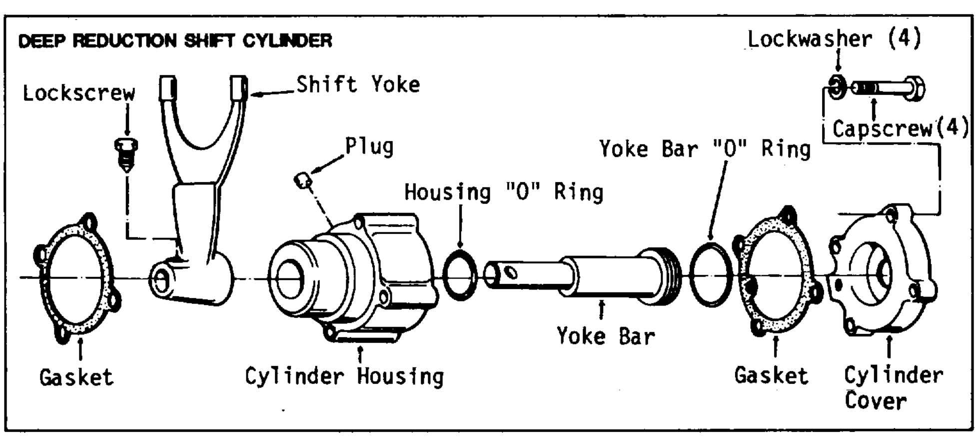



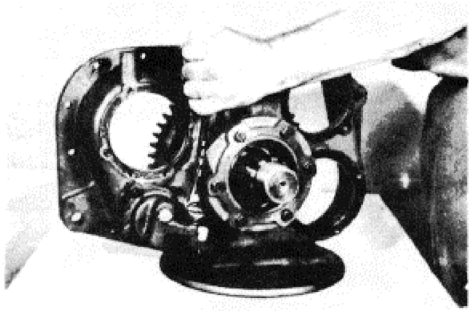
(1) Remove the key from the keyway between the splines of the range mainshaft.



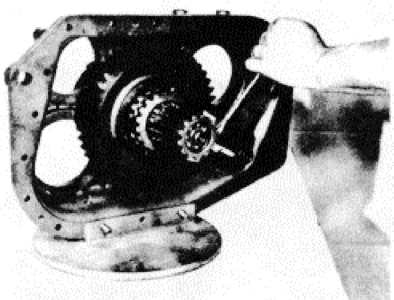
(2) Turn the splines of the low speed gear washer located in the hub of the gear, to align with the splines of the shaft. Remove the gear, washer and coupler from the shaft.

4.29 Removal and Disassembly of the Deep Reduction Shift Cylinder

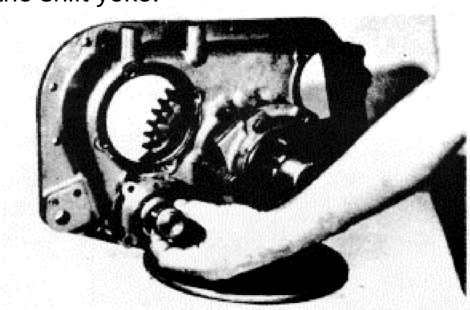




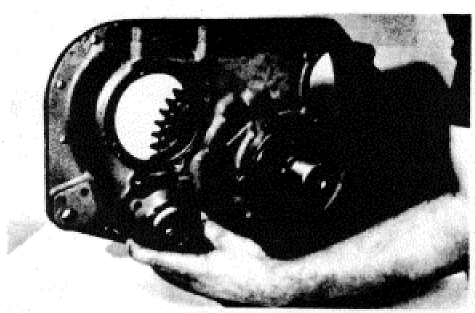
(1) Remove the cover from the shift cylinder.



(2) Cut the lockwire and turn out the lockscrew from the shift yoke.

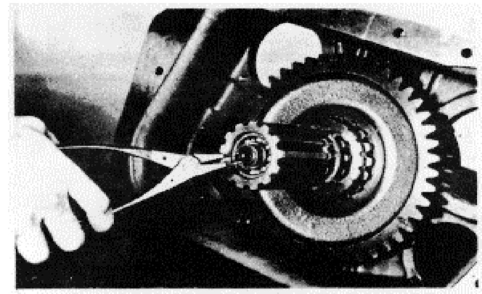


(3) Push the yoke bar to the rear and remove from the housing. If necessary, remove the "0" ring from the large OD of the bar.

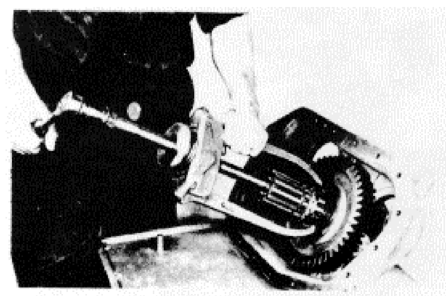


(4) Remove the shift yoke and cylinder housing from the rear housing. If necessary, remove the "0" ring from the bore in the cylinder housing.

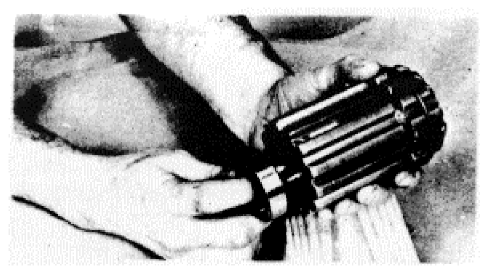
4.30 Removal of the Range Mainshaft



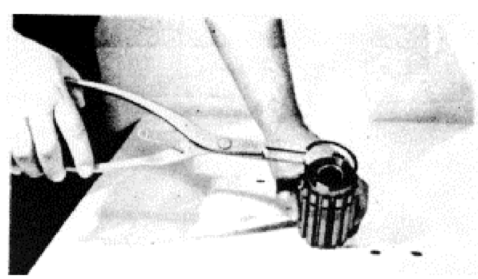
(1) Remove the snap ring from the front of the quill.



(2) Move the sliding clutch forward and against the snap ring of the range mainshaft. Insert jaws of puller behind sliding clutch gear and pull the mainshaft from the quill.

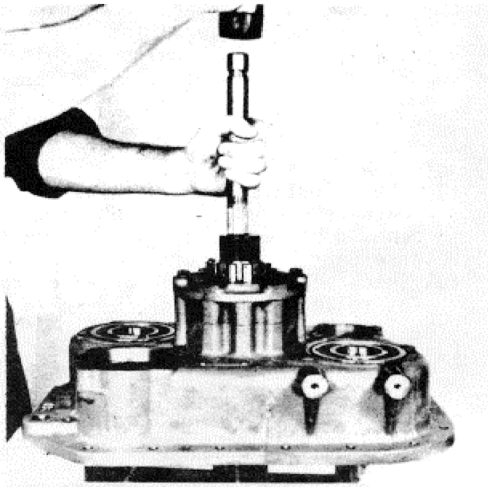


(3) Remove the front bearing from the shaft. If necessary, use an inside jaw impact puller.

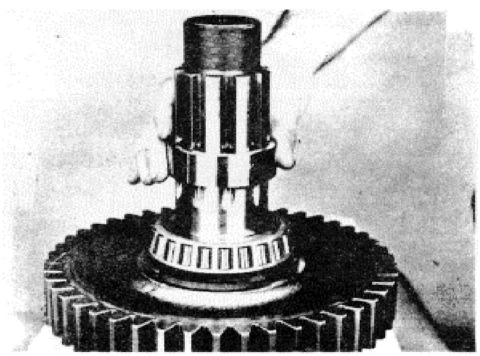


(4) Remove the snap ring from the OD of the main-shaft and, if necessary, press the bushing from the mainshaft.

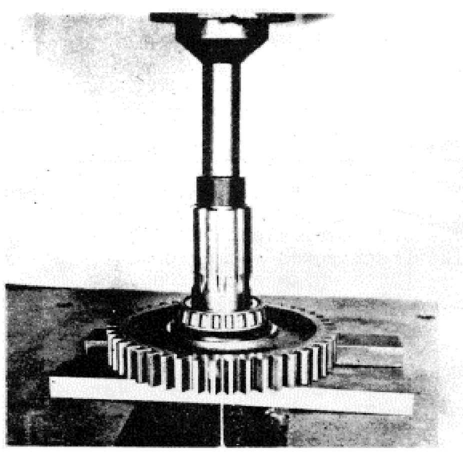
4.31 Disassembly of the Deep Reduction Gear and Output Shaft Assembly



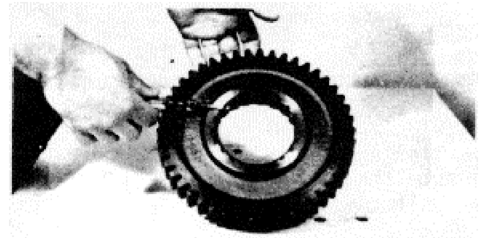
(1) Use a soft bar and mallet to drive the output shaft forward and from the rear bearing.



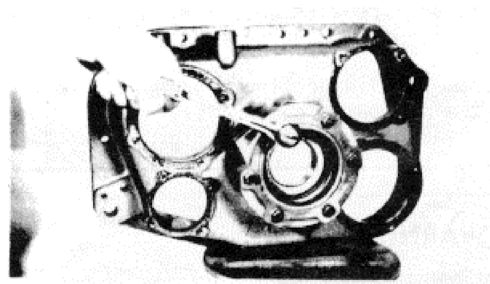
(2) Remove the bearing inner spacer from the shaft.



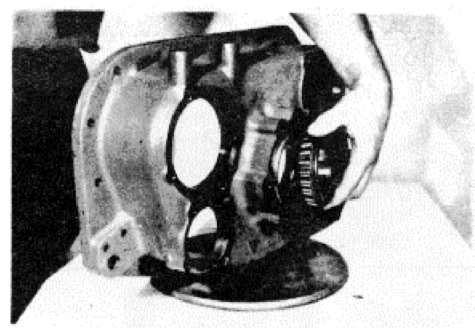
(3) Using the front face of the deep reduction gear as a base, press the shaft through the gear and bearing, freeing the bearing, washer and gear.



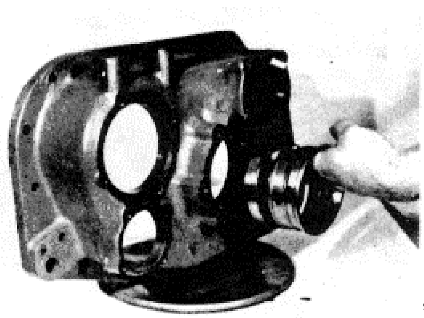
(4) If necessary, remove the snap ring from the ID of the gear.



(5) Turn out the capscrews and remove the rear bearing cover. If necessary, remove the oil seal from the cover.



(6) Remove the bearing rear cone from the rear housing.



(7) Remove the two bearing cups and outer spacer from the housing.

4.32 Inspection

Before reassembling the transmission, the individual parts should be carefully checked to eliminate those damaged from previous service. This inspection procedure should be carefully followed to insure the maximum of wear life from the rebuilt unit. The cost of a new part is generally a small fraction of the total cost of down time and labor should the use of a questionable part cause additional repairs necessary before the next regularly scheduled overhaul. Recommended inspection procedures are set forth in the following check list: (a) Bearings: (Refer to Fig. 1).

**WARNING**

When Using Cleaning Solvents, Use A Low Toxicity, Non-Flammable Solvent In A Ventilated Area.

(1) Wash all bearings in clean solvent. Check balls, rolls and races for pits and spalled areas. Replace bearings which are pitted or spalled.

(2) Lubricate bearings which are not spalled or pitted and check for axial and radial clearances. Replace bearings with excessive clearances.

(3) Check fits of bearings in case bores. If outer races turn freely in the bores, the case should be replaced.

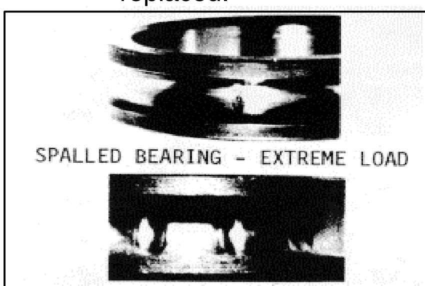



Fig. 1
Bearings

(b) Gears:

(1) Check operating gear teeth for pitting on the tooth faces. Gears with pitted teeth should be replaced.

(2) Check all engaging gear teeth. Gears with teeth worn, tapered or reduced in length from clashing in shifting should be replaced.

(3) Check axial clearances of gears. Where excessive clearance is found, check gear snap ring, washer, spacer and gear hub for excessive wear. Maintain .005"to .012"axial clearance of mainshaft gears.

(c) Splines:

(1) Check splines on all shafts for wear. If sliding clutch gears, companion flange or clutch hub have worn into the sides of the splines, the shafts in this condition should be replaced.

(d) Thrust Washers:

(1) Check surfaces of all thrust washers. Washers scored or reduced in thickness should be replaced.

(e) Reverse Gear and Shaft:

(1) Check bearing sleeye for wear from action of roller bearings.

(f) Gray Iron Parts: (See Fig. 2).

(1) Check all gray iron parts for cracks and breaks. Replace or repair parts found to be damaged. Heavy castings may be welded or brazed providing the cracks do not extend into bearing bores or bolting surfaces.

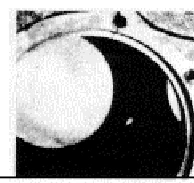


Fig. 2
Gray Iron Parts

(g) Clutch Release Parts: (See Fig. 3)

(1) Check clutch release parts. Replace yokes worn at cam surfaces and bearing carrier worn at contact pads.

(2) Check pedal shafts. Replace those worn at bearing surfaces.

Fig. 3
Clutch Release Parts

(h) Shifting Bar Housing Assembly: (See Fig. 4).

(1) Check yokes and blocks for wear at pads and lever slot. Replace worn parts.

(2) Check yokes for alignment. Straighten those which are sprung.

(3) Check lockscrews in yokes and blocks. Tighten and rewire those found loose.

(4) If housing has been dismantled, check neutral notches of shifting bars for wear from interlock balls. Bars indented at points adjacent to the neutral notch should be replaced.

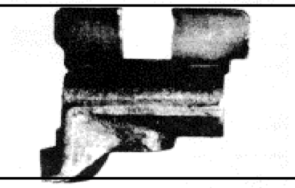


Fig. 4
Shifting Bar Housing Assembly

(i) Gear Shift Lever Housing Assembly:

(1) Check spring tension on shift lever. Replace tension spring and washer if lever moves too freely.

(2) If housing is dismantled, check pivot pin and corresponding slot in lever for wear. Replace both parts if worn.

(j) Bearing Covers:

(1) Check covers for wear from thrust of adjacent bearing. Replace covers worn and grooved from thrust of bearing outer race.

(2) Check bores of covers for wear. Replace those worn oversize.

(k) Oil Return Threads and Seals:

(1) Check oil return threads in front bearing cover. If sealing action of threads has been destroyed by contact with input shaft, replace the cover.

(2) Check oil seal in mainshaft rear bearing cover. If sealing action of lip has been destroyed, replace seal.

(1) Synchronizers:

(1) Check high and low range synchronizers for burrs, uneven and excessive wear at contact surface.

(2) Check blocker pins for excessive wear or looseness.

(3) Check synchronizer contact surfaces on the high and low range gears for excessive wear.

4.33 Location of Gaskets

Seat gaskets with shellac on part to be installed. Use new gaskets throughout when reassembling transmission. Gaskets are located between the following parts:

(1) Gear shift lever housing and shift bar housing.
(2) Shift bar housing and case.
(3) Air valve adaptor plate and case.
(4) Air valve and adaptor plate.
(5) Clutch housing and case.
(6) Front bearing cover and case.
(7) Rear plate and case.
(8) Mainshaft rear bearing cover and rear plate.
(9) Auxiliary range shift cylinder cover and cylinder.
(10) Auxiliary range shift cylinder and rear plate.
(11) Right auxiliary countershaft rear bearing cover and rear plate.
(12) Left auxiliary countershaft rear bearing cover and rear plate.

13) Large PTO cover and case.
(14) Small PTO cover and case.
(15) Hole-gear shift cylinder cover and cylinder.
(16) Hole-gear shift cylinder and case.

4.34 Torque Ratings

Recommended torque ratings, location and thread sizes of capscrews and nuts are listed on next page. Capscrew lengths are given for reference purposes as a guide for installation at proper locations.

Correct torque application is extremely important to assure long transmission life and dependable performance. Over-tightening or under-tightening can result in a loose installation and, in many instances, eventually cause damage to transmission gears, shafts or bearings. Do not torque capscrews dry.

THREAD SIZE TORQUE RATING

| CAPSCREWS | | | |
|---|---|---|---|
| | | **THRAED SIZE** | **TORQUE RATING** |
| **LOCATION** | **QTY.** | **AND LENGTH** | **FOOT-POUNDS** |
| Air Valve | 4 | 1/4-20x1-3/4 | 15-20 |
| Air Valve Adaptor Plate | 2 | 1/4-20x7/8 | 15-20 |
| Filter Bracket | 2 | 3/8-16x3/4 | 20-25 |
| *PTO Cover, small | 6 | 3/8-16x3/4 | (12-15 with oil filter) |
| Hole-Gear Shift Cylinder | 4 | 5/16-18x1-7/8 | 20-25 |
| Aux. Drive Gear Retainer Ring | 6 | 3/8-16x1 | |
| Range Shift Cylinder | 4 | 3/8-16x1 | |
| Range Shift Cylinder Cover | 4 | 3/8-16x1-1/4 | |
| Shift Bar Housing | 16 | 3/8-16xl-1/4 | |
| Gear Shift Lever Housing | 4 | 3/8-16x1-1/4 | |
| Front Bearing Cover | 6 | 3/8-16x1-1/4 | |
| Countershaft Rear Bearing Covers | 8 | 3/8-16xl-1/4 | |
| | 1 | 3/8-16x2 | |
| Rear Plate to Case | 18 | 3/8-16x1-1/2 | |
| Mainshaft Rear Bearing Cover | 6 | 3/8-16x2-3/4 | |
| | | | |
| PTO Cover, large | 8 | 7/16-14xl-1/4 | 50-65 |
| | 2 | 1/2-13x3-1/2 | 70-75 |
| Clutch Housing to Case | 2 | 1/2-13xl-1/2 | 70-75 |
| C/S Front Bearing Retainers | 4 | 1/2-20x1 | 50-65 |
| Aux. C/S Rear Bearing Retainers | 4 | 1/2-20xl | 50-65 |

* **Note**: Installing the capscrews with more than 23 ft-lbs of torque will force the corners of the PTO cover away from the case with resultant oil leakage.

| NUTS | | | |
|---|---|---|---|
| | **QTY.** | **THREAD SIZE** | **FOOT-POUNDS** |
| Reverse Idler Shafts | 2 | 5/8-18 | 75-80 |
| Range Shift Piston | 1 | 5/8-18 | 80-90 |
| Hole-Gear Shift Piston | 1 | 7/16-20 | 45-50 |
| Clutch Housing to Case | 6 | 5/8-18 | 170-185 |
| Drive Gear | 1 | 2-1/8-16 | 250-300 |
| Aux. Drive Gear | 1 | 2-1/8-16 | 250-300 |
| Companion Flange or Yoke | 1 | 2-16 | 450-500 |

4.35 General Precautions for Reassembly

**Note**: Read this section before starting the detailed reassembly procedures.

Make sure that interiors of case and housings are clean. It is important that dirt be kept out of transmission during reassembly. Dirt is abrasive and can damage polished surfaces of sleeves, bushings, bearings and washers. Use certain precautions, as listed below, during reassembly.

(1) Gaskets: Use new gaskets throughout the transmission as it is being rebuilt. Make sure all gaskets are installed, as omission of gasket can result in oil leakage or misalignment of bearing covers. See "Location of Gaskets" paragraph 4.33.

(2) Capscrews: To prevent oil leakage, use shellac on all capscrews. See torque rating chart for recommended torque.

(3) "0" Rings: Lubricate all "0" rings with "Dow Corning 200 Fluid", 50,000cs.

(4) Initial Lubrication: Coat all thrust washers and splines of shafts with Lubriplate during installation to provide initial lubrication, preventing scoring and galling.

(5) Axial Clearances: Maintain original axial clearances of mainshaft forward speed gears of .005" to .012". Mainshaft reverse gear clearance is .005" to .012".

(6) Bearings: (See Fig. 5). Use of flanged-end bearing drivers is recommended for the installation of bearings. These drivers apply equal force to both races of bearing, preventing damage to balls and races and maintaining correct bearing alignment with shaft and bore. If tubular or sleeve type driver is used, apply force only to inner race.

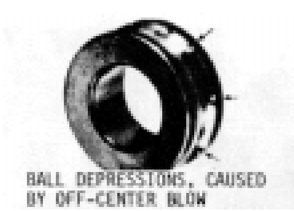



Fig. 5
Bearings

(7) Universal Joint Companion Flange: (See Fig. 6). Pull the companion flange tightly into place with the mainshaft nut, using 450-500 ft-lbs of torque. Make sure the speedometer gear has been 1
installed on yoke. If a speedometer gear is not used, a replacement spacer of the same width must be used. Failure to pull the yoke or flange tightly into _ place will permit the shaft to move axially with resultant damage to rear bearing. Fig. 6 Universal Joint Companion Flange

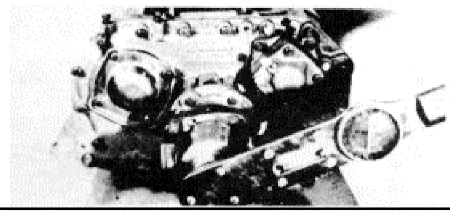
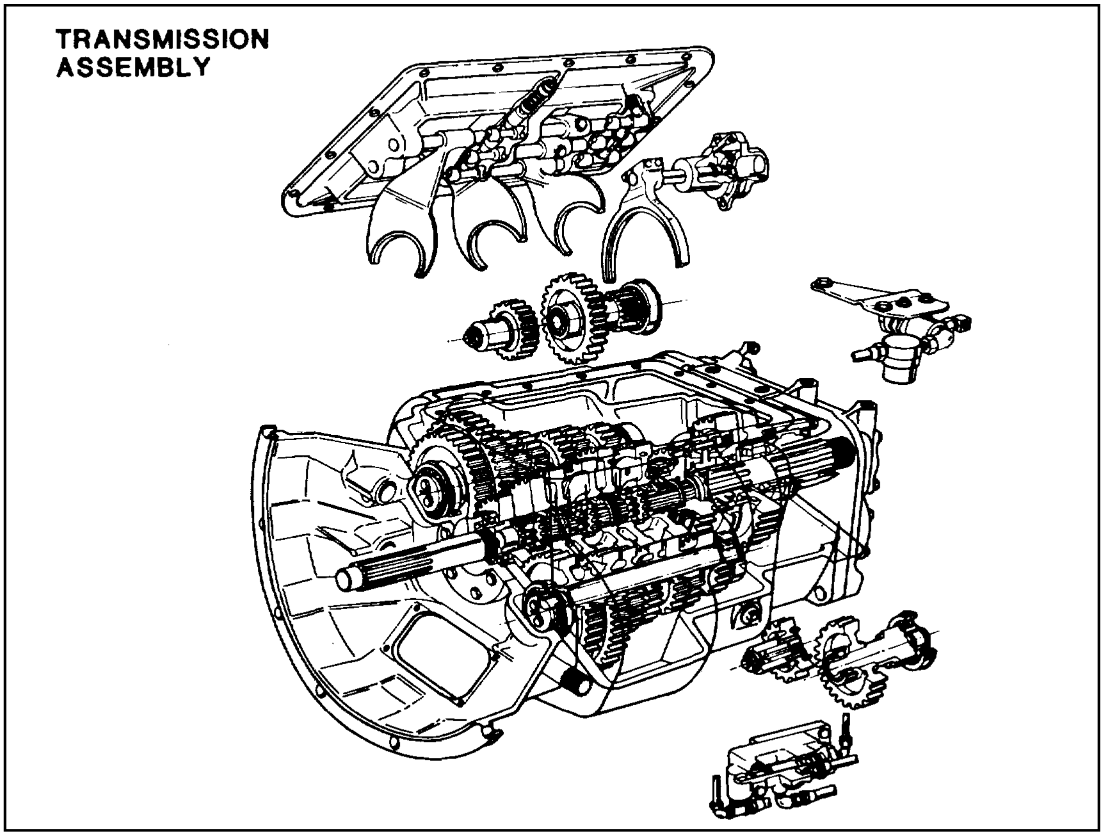


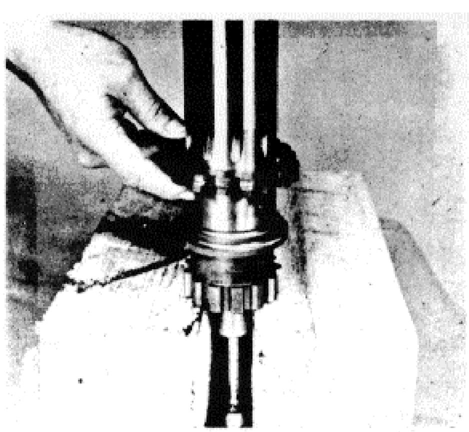
Fig. 6
Universal Joint Companion Flange

4.36 Reassembly Instructions

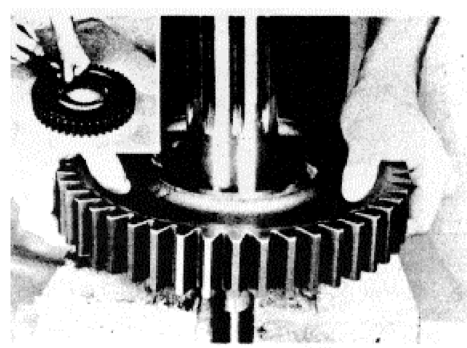



4.37 Auxiliary Section

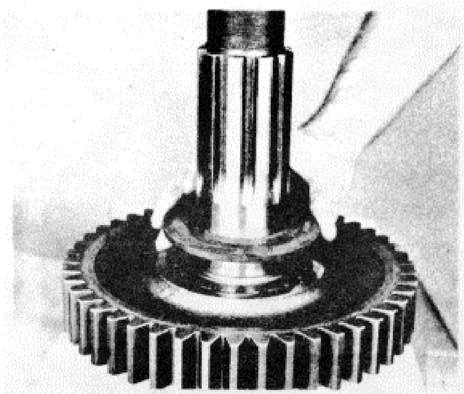
4.38 Reassembly of the Deep Reduction Gear and Output Shaft Assembly



(1) Place the output shaft, threaded end up, on blocks to protect the quill and install the splined spacer on shaft, large diameter down.



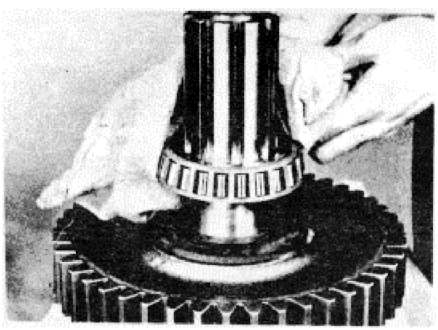
(2) If previously removed, install the snap ring in the groove in deep reduction and install the gear on the shaft, snap ring towards the threaded end.



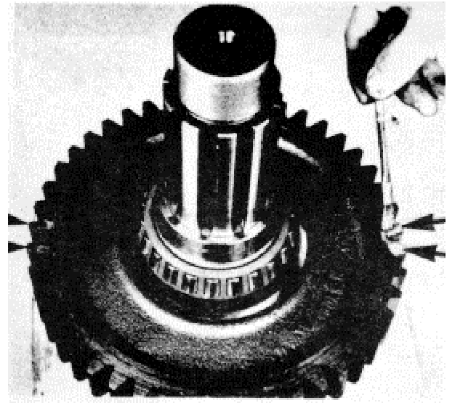
(3) Install the rear washer on the shaft, stepped side towards the gear.

(4) Install the front bearing cone on the shaft and against the rear washer. This is a matched bearing; make sure the correct cone and cup are matched.

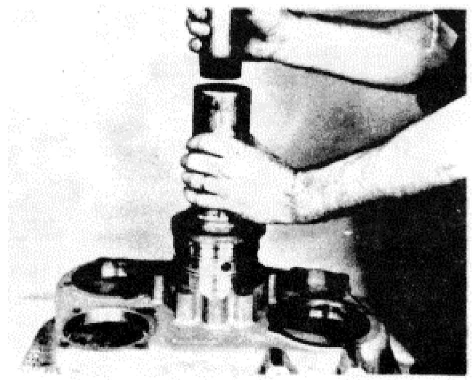
**Note**: Heating of the bearing cones for installation is recommended, provided the bearing is not heated over 275°F.



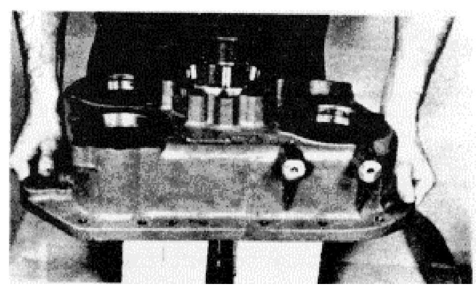
(5) Install the bearing inner spacer on the shaft and against the bearing cone.



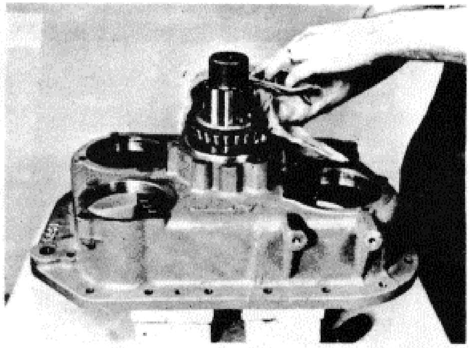
(6) Mark any two adjacent teeth on the deep reduction gear and then mark the two teeth directly opposite.



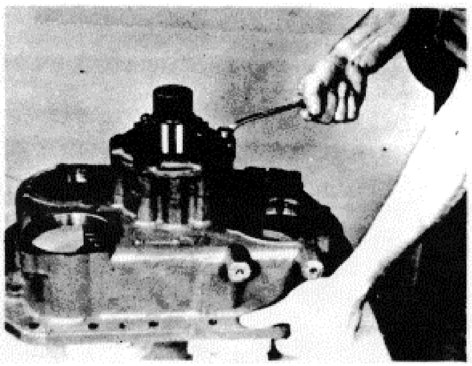
(7) Start the front bearing cup into the bore in the rear housing, taper to the inside, and place the outer spacer and rear cup on the front cup and tap the three evenly into the bore until the lip of the rear cup seats against the housing.



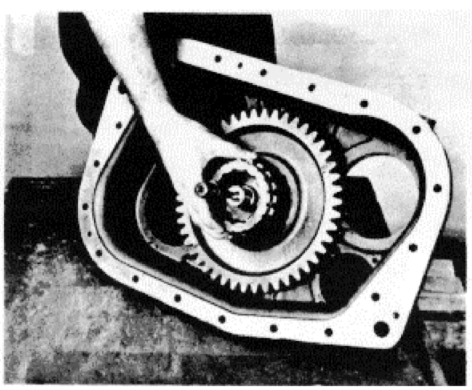
(8) Place the rear housing over the output shaft.



(9) Heat the rear bearing cone and install cone on the shaft and into the rear cup.



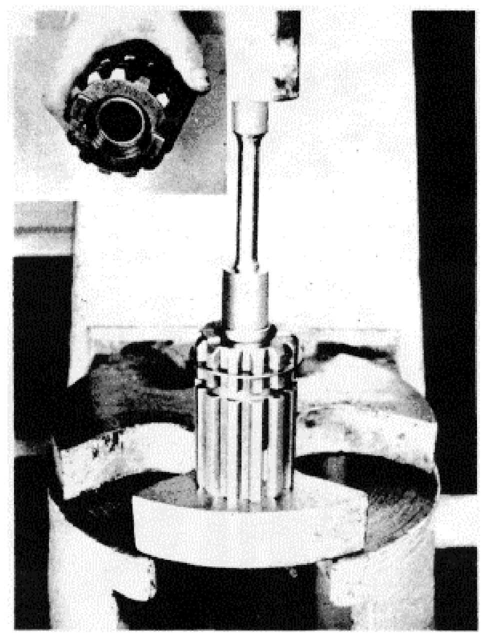
(10) If previously removed, install the oil seal in the rear bearing cover and install the cover on the housing, using a brass washer at the speedometer bore.



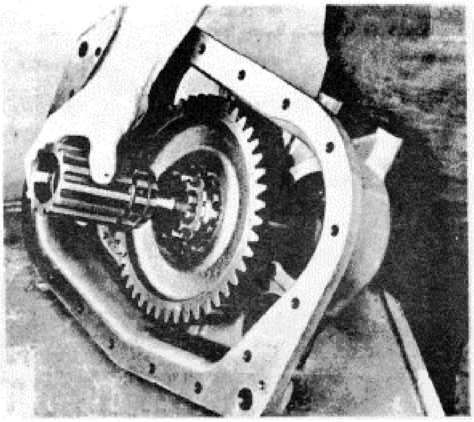
(11) Install the sliding clutch gear on the front of the shaft, yoke slot towards the front.

4.39 Installation of the Range Mainshaft Assembly

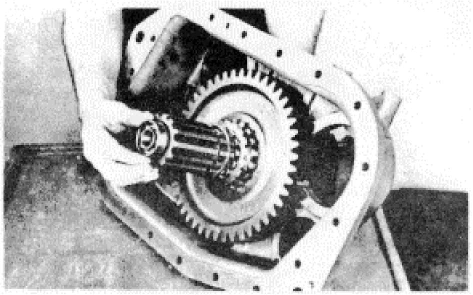
(1) Install the snap ring in the groove in the OD of the mainshaft.



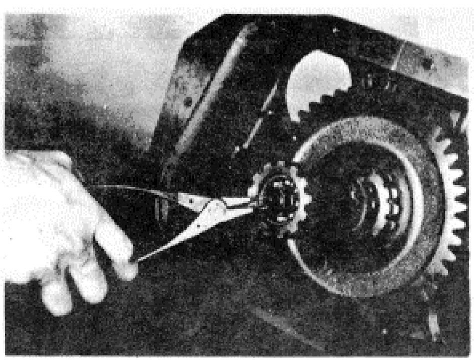
(2) Install the bushing in the shaft, positioning halfway on the rear bearing surface. The distance between top of bushing and lug on rear mainshaft should be 7/16".



(3) Install the mainshaft on the quill of the output shaft, seating the bushing on the bearing surface of the quill.



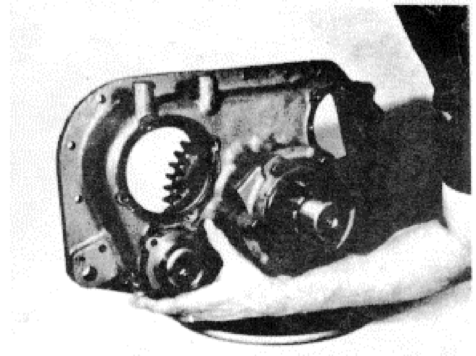
(4) Install the front bearing in the mainshaft and on the quill. Seat with a sleeve driver with a diameter slightly larger than the ID of the bearing inner race.



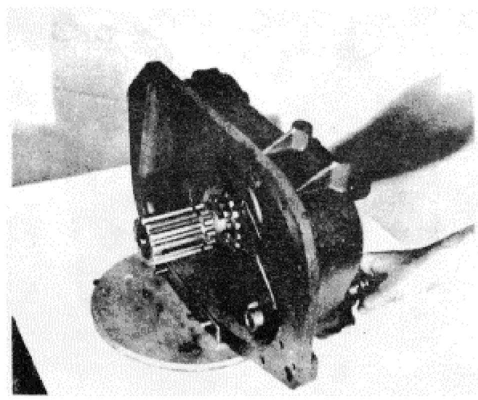
(5) Install the snap ring in the groove in the front of the quill.

## 4.40 Reassembly and Installation of the Deep Reduction Shift Cylinder

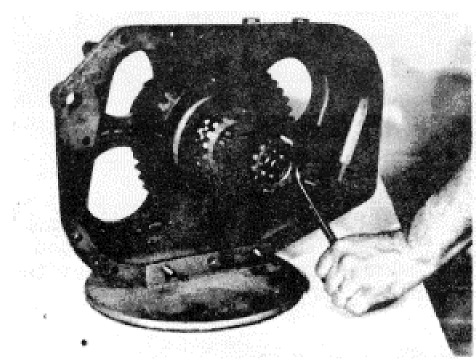




(1) Install the "O" ring in the bore of the shift cylinder and install the cylinder housing into the auxiliary housing with the small air channel to the right.



(2) Install the shift yoke on the sliding clutch with the lockscrew hole to the front and insert the yoke bar from the rear through the shift cylinder and yoke, aligning the indentation in the bar with the lockscrew hole in the yoke.

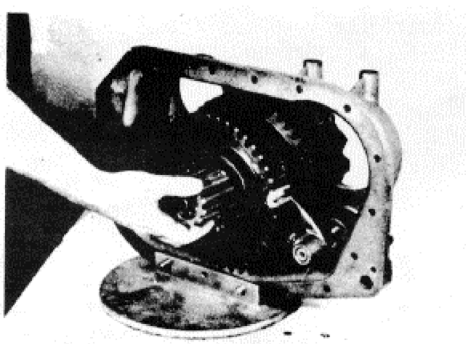


(3) Install the yoke lockscrew; tighten and wire securely.

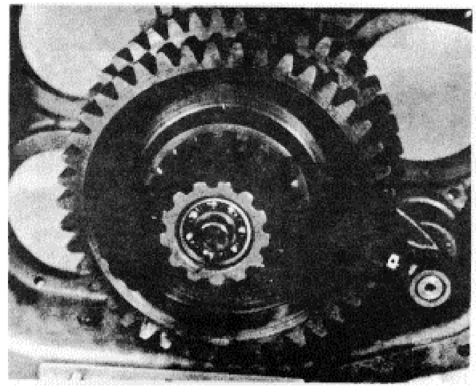
(4) Install the cylinder cover, aligning the air channel with the channel in the cylinder housing.

4.41 Installation of the Low Range Gear

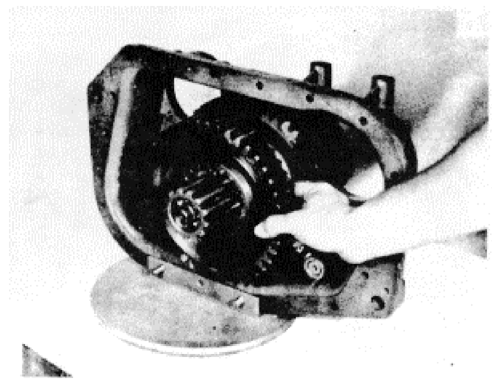
(1) Install the coupler on the shaft, large diameter to the rear.



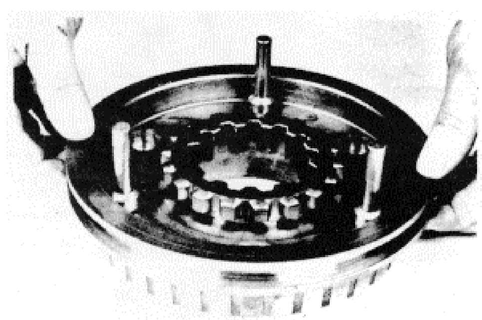
(2) If previously removed, install the snap ring in the ID of the low speed gear and install the gear on the shaft and against the coupler, dished side to the front.



(3) Install the low speed gear splined washer on the shaft and against the snap ring in the hub of the gear. Turn the washer to lock the gear on the shaft.

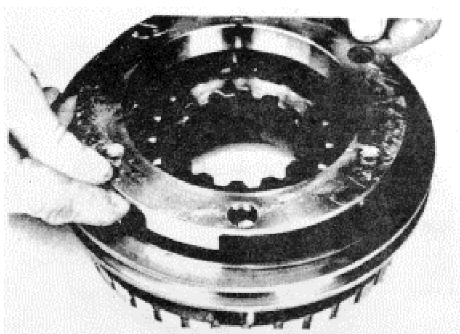


(4) Install the key in the keyway, inserting the thick end between the splines of the washer. 4.42 Reassembly and Installation of the Synchronizer Assembly

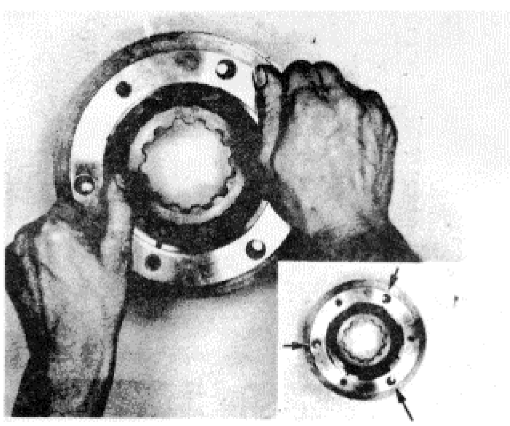


(1) Place the larger low speed ring on a workbench with the pins facing up and install the sliding clutch on the pins with the protruding clutching teeth down.

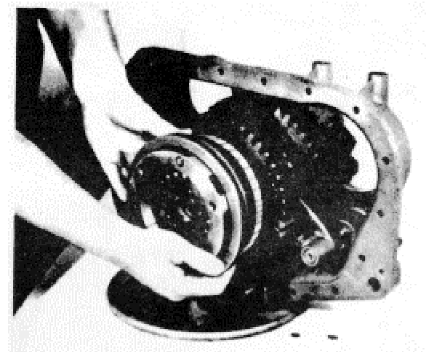
(2) Install the three springs in the bores of the direct ring.



(3) Place the ring, flat side up, over the pins of the low speed ring.

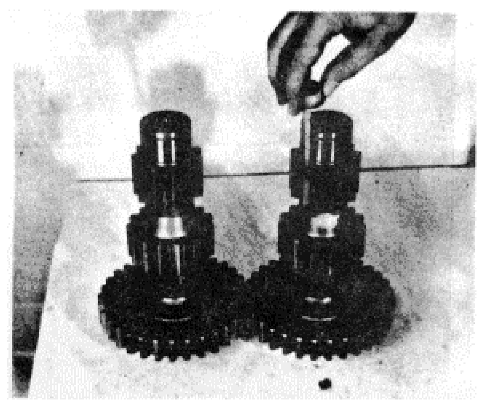


(4) Apply pressure to the direct ring so as to compress the springs and seat the pins of the low speed ring into the bores of the direct ring.

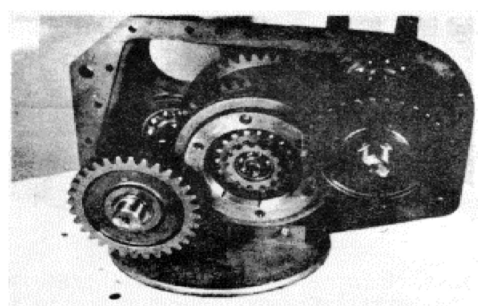


(5) Place the synchronizer on the range mainshaft fitting the low range cone into the mating cone of the low range gear.

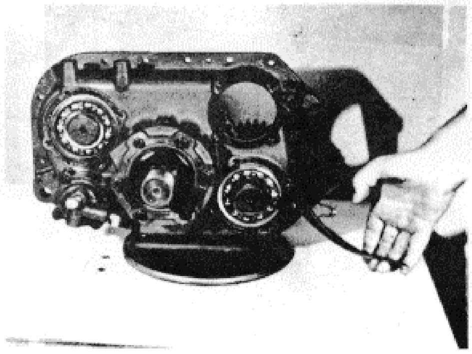
4.43 Timing and Installation of the Auxiliary Countershaft.



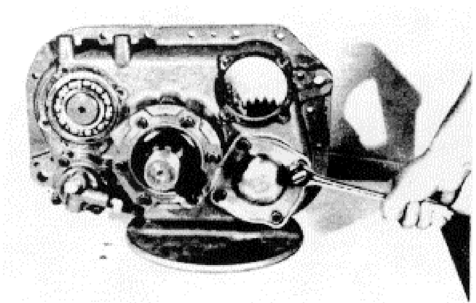
(1) On the smallest diameter gear of each countershaft, mark the tooth which is stamped with an "O".



(2) Place the countershafts into position, meshing the marked tooth on each countershaft between the two of the marked teeth on the deep reduction gear. Block against the front of the countershafts and tap the rear bearings evenly onto the shafts and into the case bores to hold countershafts in position. Use a bearing driver to complete installation of the bearings.

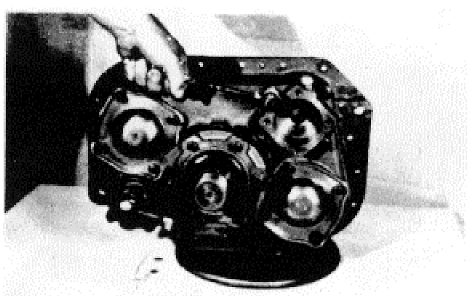


(3) Install the snap ring in the groove on the rear of each countershaft.

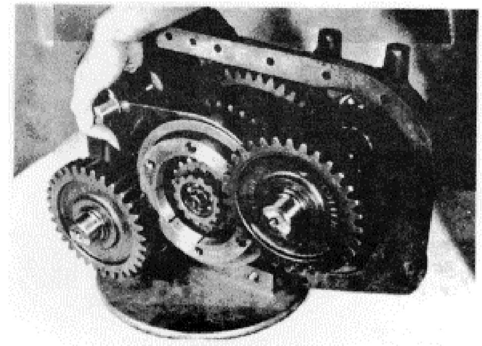


(4) Install the two rear bearing covers.

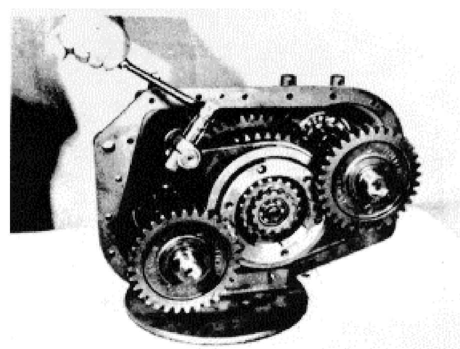
4.44 Reassembly and Installation of the Range Shift Cylinder



(1) Install "O" ring in bore of shift cylinder and install the cylinder housing in the rear housing bore with the air line fitting to the top. Secure with the four capscrews.



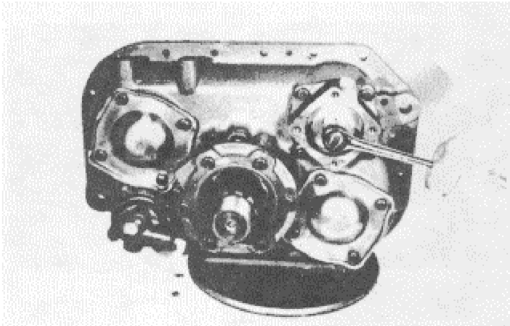
(2) Hold the shift yoke in position on the sliding clutch with the long hub to the rear and insert the shift shaft, threaded end first, through the hub and shift cylinder, aligning the slots in the shaft with the lockscrew bores in the yoke hub.



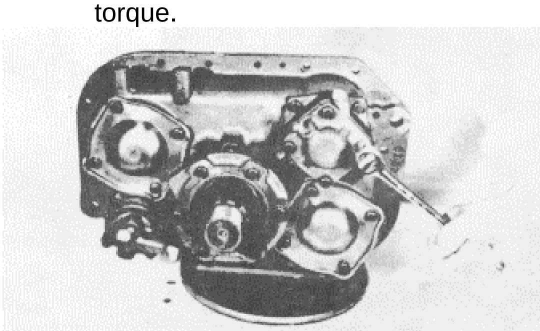
(3) Install the two yoke lockscrews; tighten and wire securely.

(4) Install "O" rings in the OD and ID of the piston and install the piston on the shaft, flat face out.

1



(5) Install the elastic stop nut on the end of the shaft; tighten securely with 80-90 ft- lbs torque.



(6) Install the cover on the shift cylinder with the air line fitting to the top left.

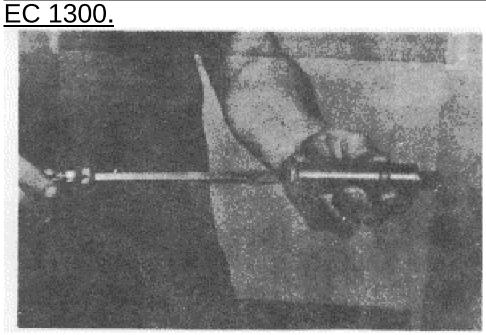
**CAUTION**

If A Gasket Is Used Which Requires Shellac Or Permatex, USE ONLY A VERY SMALL AMOUNT To Prevent Clogging Of Cylinder Air Ports Or Damage To "O" Rings.

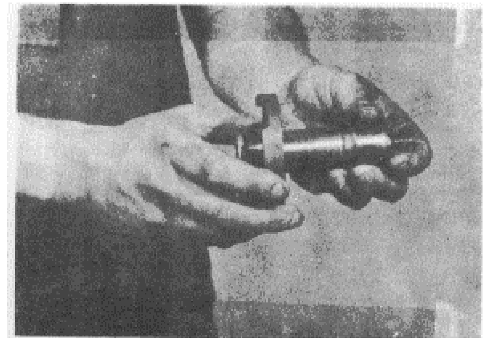
4.45 Front Section

4.46 Reassembly and Installation of the Right Reverse Idler Gear Assembly

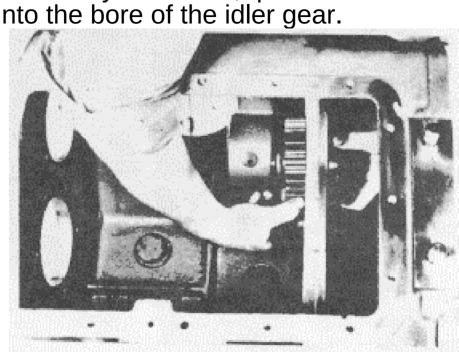
**Note**: Before starting reassembly, check to make sure that all three magnetic discs are solidly in place in the bottom of the case. These can be installed with "3M Brand" adhesive, No. EC 1300.



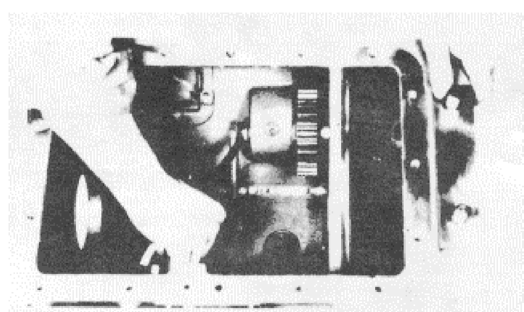
(1) Install the plug in the end of the reverse idler shaft.



(2) Install the idler gear washer on the shaft and if previously removed, press the needle bearing into the bore of the idler gear.



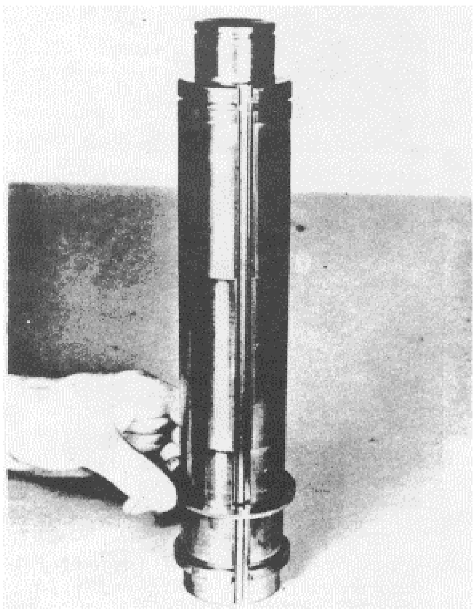
(3) If previously removed, install the bearing inner race on the shaft and insert the shaft, threaded end first, into the lower right wall of the case. As the shaft is moved forward, install the reverse idler gear and thrust washer on the shaft, seating the gear on the bearing inner race. Washer is positioned between the gear and the boss in the case.



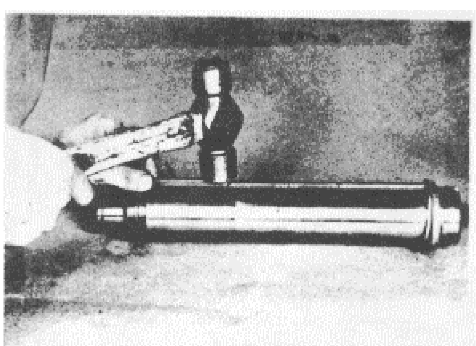
(4) Seat shaft securely in the bore - MAKE SURE NEEDLE BEARINGS ARE LOCATED ON INNER RACE BEFORE MOVING THE SHAFT FORWARD. Secure the shaft with the washer and elastic stop nut.

### 4.47 Reassembly of the Countershaft Assemblies

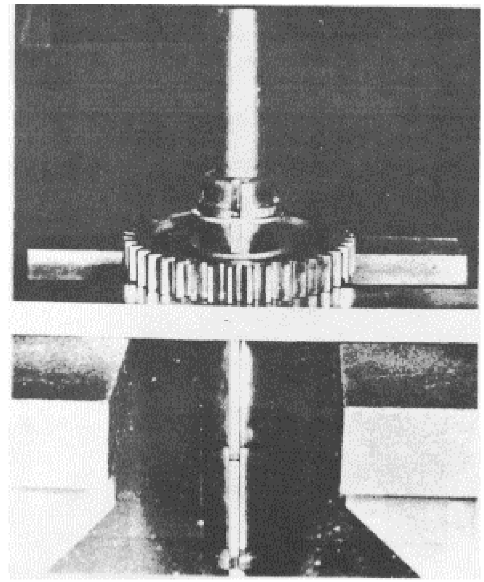
**Note**: Except for the number of teeth on the PTO gears, countershafts are identical and assembled in the same manner.



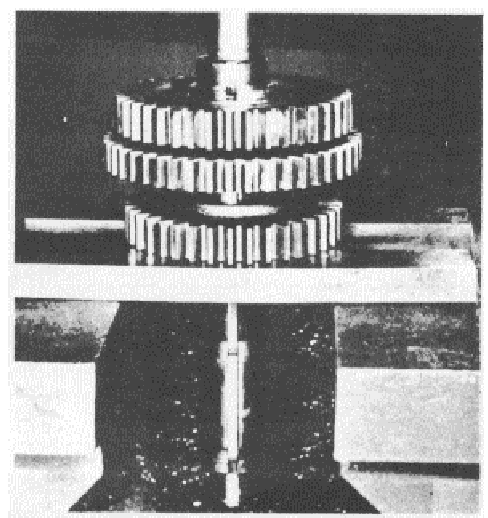
(1) Install the spacer over the rear of the countershaft and move forward against the shoulder at the front of the shaft.



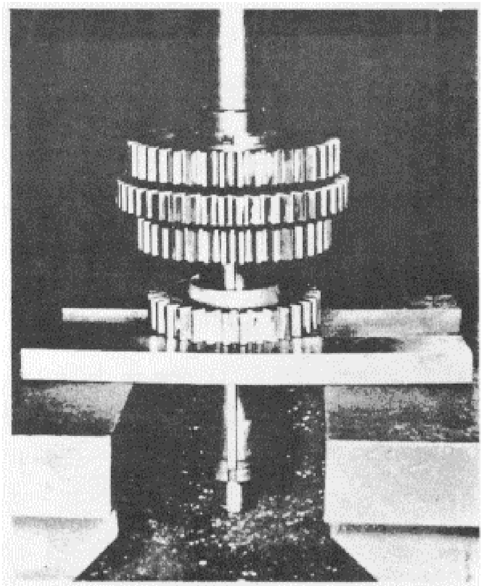
(2) Install the key in the slot in the shaft.



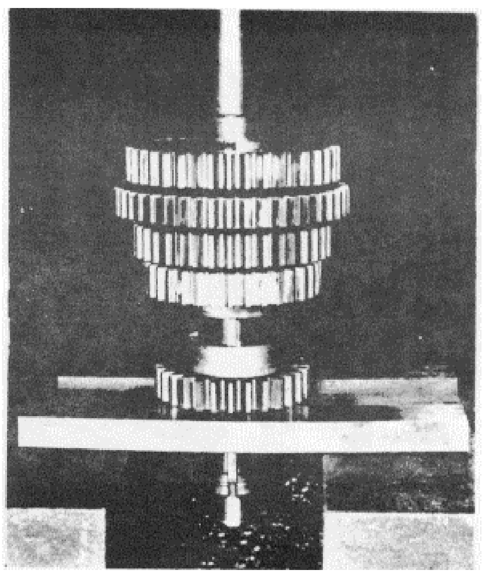
(3) Align the keyway in the gear with the key and press the drive gear on the shaft. Seat against the spacer with the long hub of the gear to the rear.



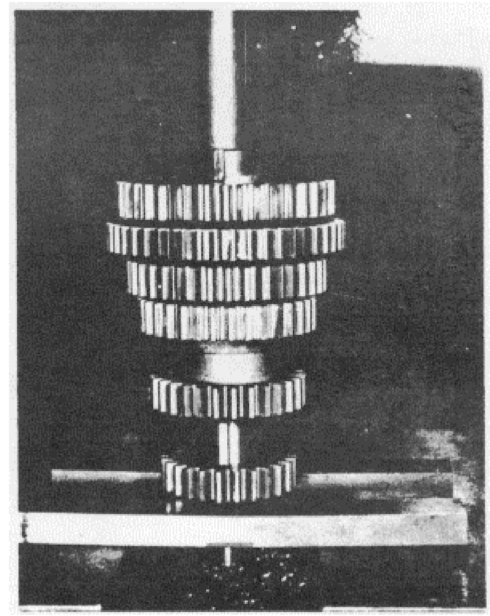
(4) Press the PTO gear on shaft, bullet nose of the teeth to the rear and press the 4th speed gear on the shaft, long hub to the front.



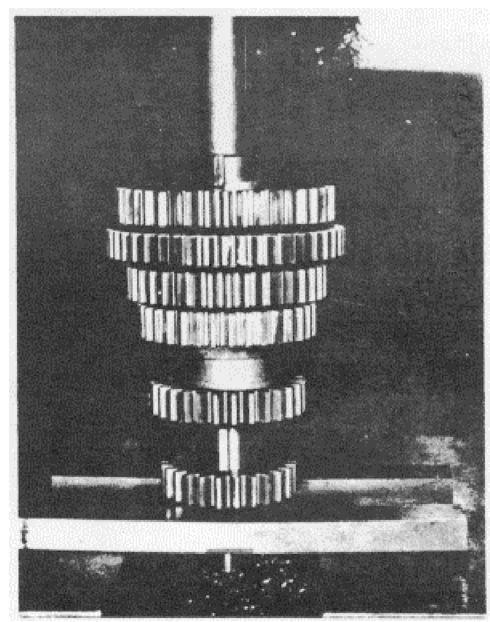
(5) Press the 3rd speed gear on the shaft, long hub to the rear.



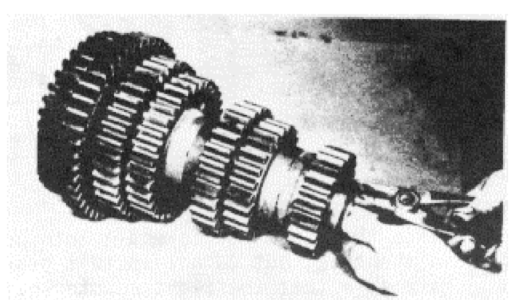
(6) Press the 2nd speed gear on the shaft, long hub to the front.



(7) Press the 1st speed gear on the shaft, long hub to the rear.

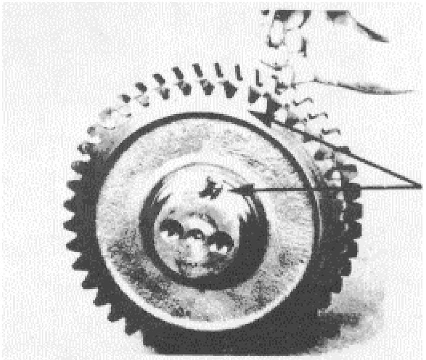


(8) Press the reverse gear on the shaft, long hub to the front.



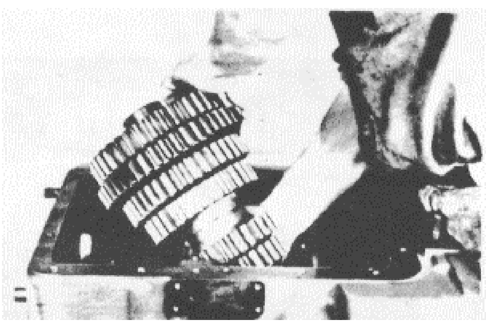
(9) Install the snap ring in the groove at the rear of the countershaft.

### 4.48 Timing and Installation of the Countershaft Assemblies.

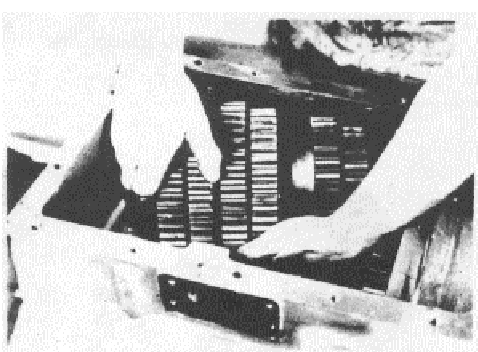


(1) On the drive gear of each countershaft, mark the gear tooth which aligns with the keyway in the shaft. This tooth will-be stamped with an "O".

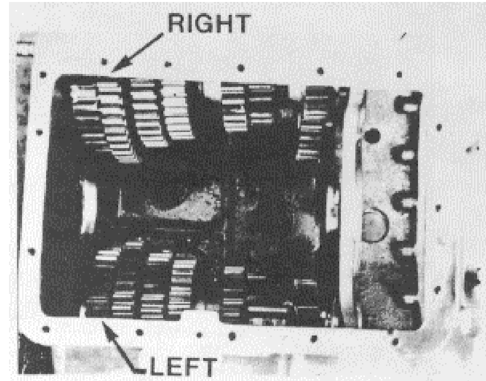
**Note**: The left side countershaft takes a 47-tooth PTO gear; the right side counter-shaft takes a 45-tooth PTO gear.



(2) Place the left countershaft into position in the case, but do not install bearings. Make sure the left countershaft has the large 47-tooth PTO gear.

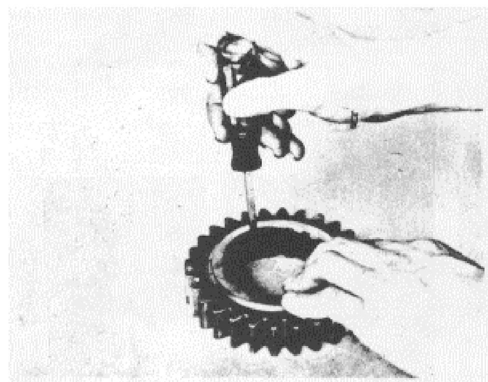


(3) Place the right countershaft into position in the case, but do not install bearings. Make sure that the right countershaft has the smaller 45-tooth PTO gear.

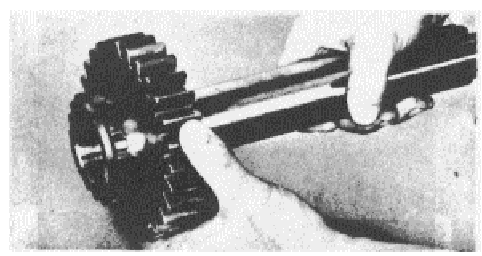



(4) Countershafts will now be in approximate position but without bearings.

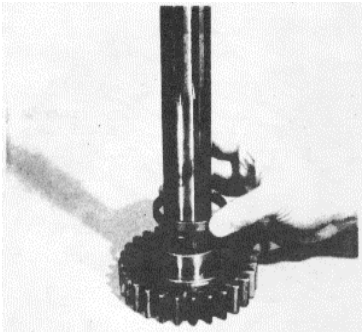
### 4.49 Reassembly of the Drive Gear Assembly



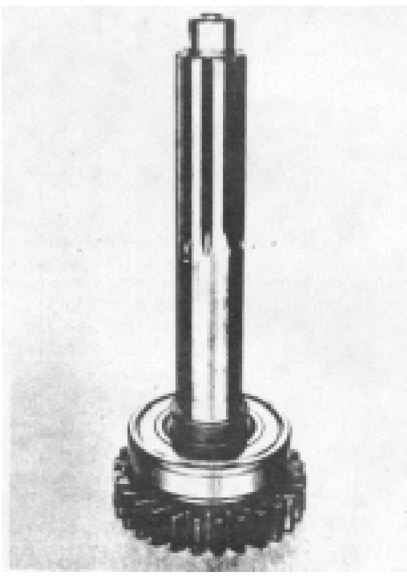
(1) Install the snap ring in the groove in the ID of the drive gear.



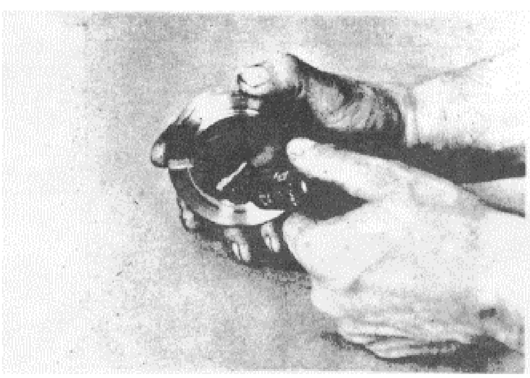
(2) Install the drive gear on the shaft, engaging the internal splines of the gear with the teeth on the shaft, snap ring of gear towards the front.



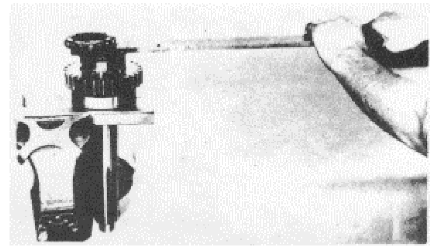
(3) Install the drive gear spacer on the shaft and against the gear.



(4) Press the drive gear bearing on the shaft with the shield to the front.

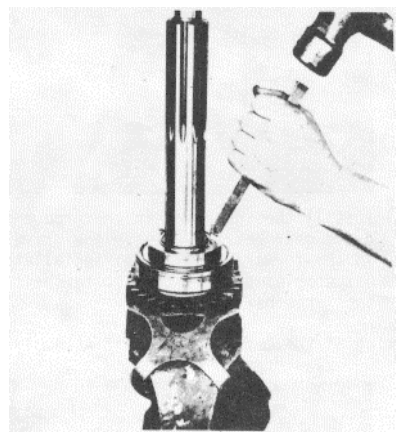


(5) Apply Grade AV Loctite to the threads of the shaft and nut.



(6) Install the bearing nut on the shaft, L.H. thread, with 250-300 ft-lbs of torque. Wipe off excess Loctite.

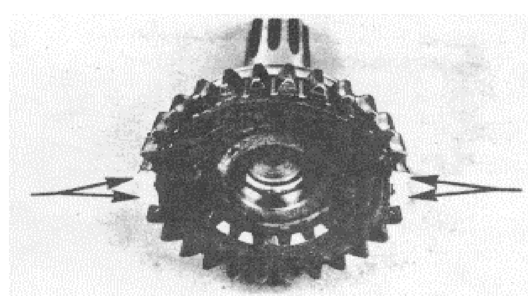
**Note**: If torque wrench is not available, torque can be approximated by multiplying the pounds of pull times the length of the wrench handle. For example: If there are 150 pounds of pull on a wrench with a two foot handle, multiply 150 x 2 which equals 300 ft-lbs of torque. Ordinary pull scales can - be used to measure pounds of pull.



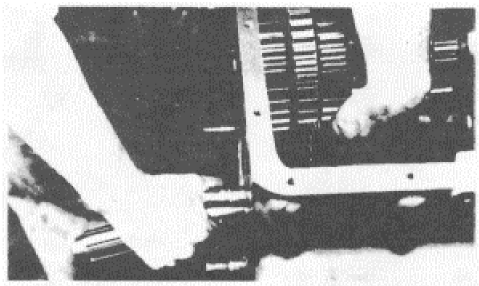
(7) Peen the nut into the two milled slots of the shaft.

Note: To hasten hardening of the Loctite, place the assembly under heat lamps 10 to 15 minutes.

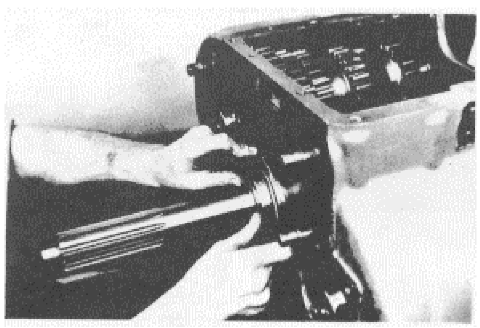
### 4.50 Timing and Installation of the Drive Gear Assembly.



(1) Mark and two adjacent teeth on the drive gear and then mark the two directly opposite.

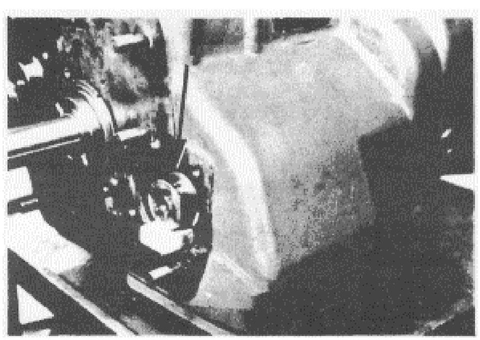


(2) Make sure that the snap ring is removed from the drive gear bearing and insert the drive shaft from inside the case through the front bore and move as far forward as possible to expose the snap ring groove in the bearing. It will be necessary to work the drive gear past the countershaft PTO gears.

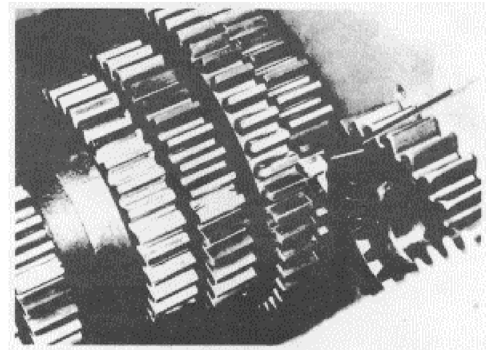


(3) Install the snap ring in the groove in the drive gear bearing. Leave the drive gear in the forward position as installation is not completed until the countershaft bearings are installed.

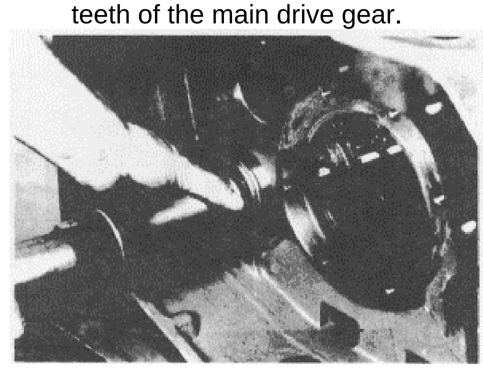
**4.51 Timing of the Left Countershaft Assembly**



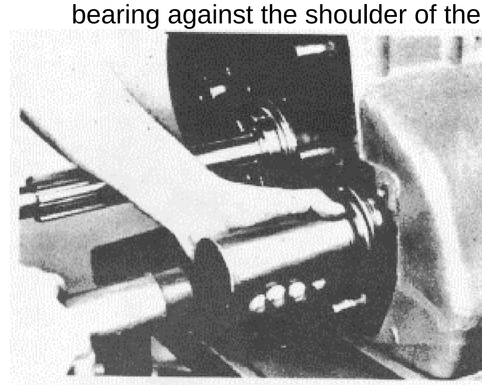
(1) Use blocking to center the front of the left countershaft in the case bore.



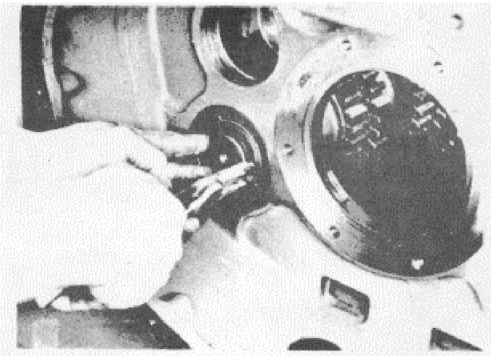
(2) Mesh the marked tooth of the left countershaft drive gear with two of the marked teeth of the main drive gear.



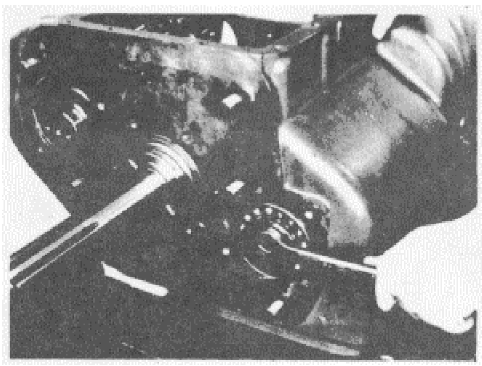
(3) With the countershaft as far to the rear as possible, start the-rear bearing on the shaft. Center and install the rear bearing on the shaft and in the case bore, sealing the bearing against the shoulder of the shaft.



(4) Remove blocking and install the front bearing on the countershaft and in the case bore. Make sure that the timing teeth are still meshed.



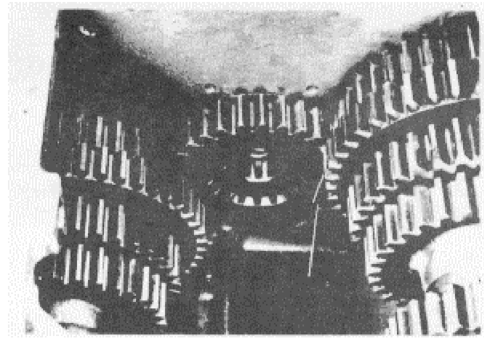
(5) Install the snap ring on the rear of the countershaft.



(6) Install the bearing retainer plate on the front of countershaft. Tighten and wire capscrews securely.

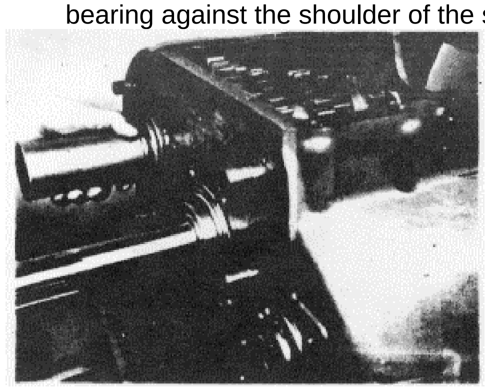
**4.52 Timing and Installation of the Right Countershaft Assembly.**

**Note**: One method of installing the mainshaft assembly is to position it between the two countershafts before installing the right countershaft bearings. With this procedure, the mainshaft assembly is centered in the rear bore and the corresponding gears of the mainshaft and left countershaft are meshed. The right countershaft is then rolled into position meshing with corresponding gears of the mainshaft. The right countershaft is held in place and the bearings installed. The countershaft drive gear must be timed with the main drive gear at the same time. In the following instructions the mainshaft assembly is installed after the countershaft bearings are installed.

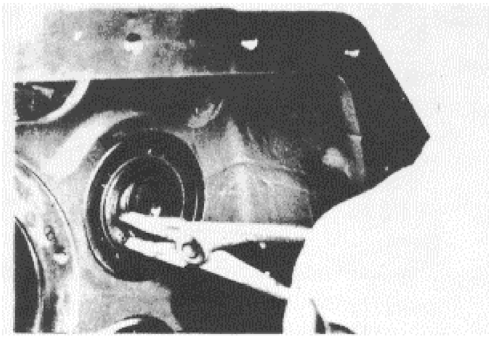


(1) Use blocking to center the front of the right countershaft in the case bore and mesh the marked tooth on the countershaft drive gear between the two remaining marked teeth on the main drive gear.

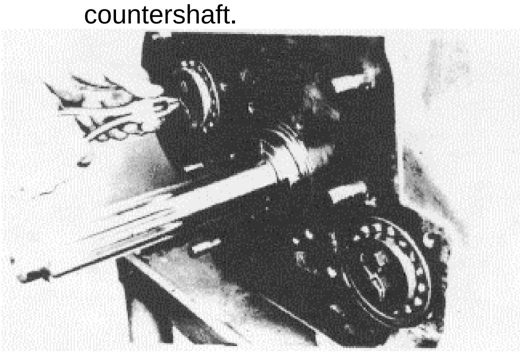
(2) With the countershaft as far as possible to the rear, start the rear bearing on the shaft. Center and install the rear bearing on the shaft and in the case bore, seating the bearing against the shoulder of the shaft.



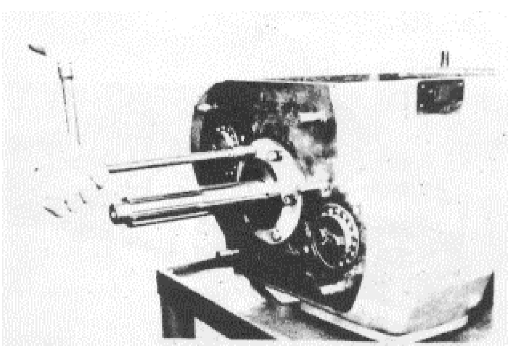
(3) Remove the blocking and install the front bearing on the countershaft and into the case bore. Make sure that the timing teeth are still meshed.



(4) Install the snap ring on the rear of the countershaft.



(5) Install the bearing retainer plate on the front of the countershaft, tighten and wire the capscrews securely.



(6) Complete installation of the drive gear assembly by moving into position and installing the front bearing cover on the drive gear

.

## 4.53 Setting Correct Axial Clearances for Mainshaft Gears

Axial clearance (end play) limits are:

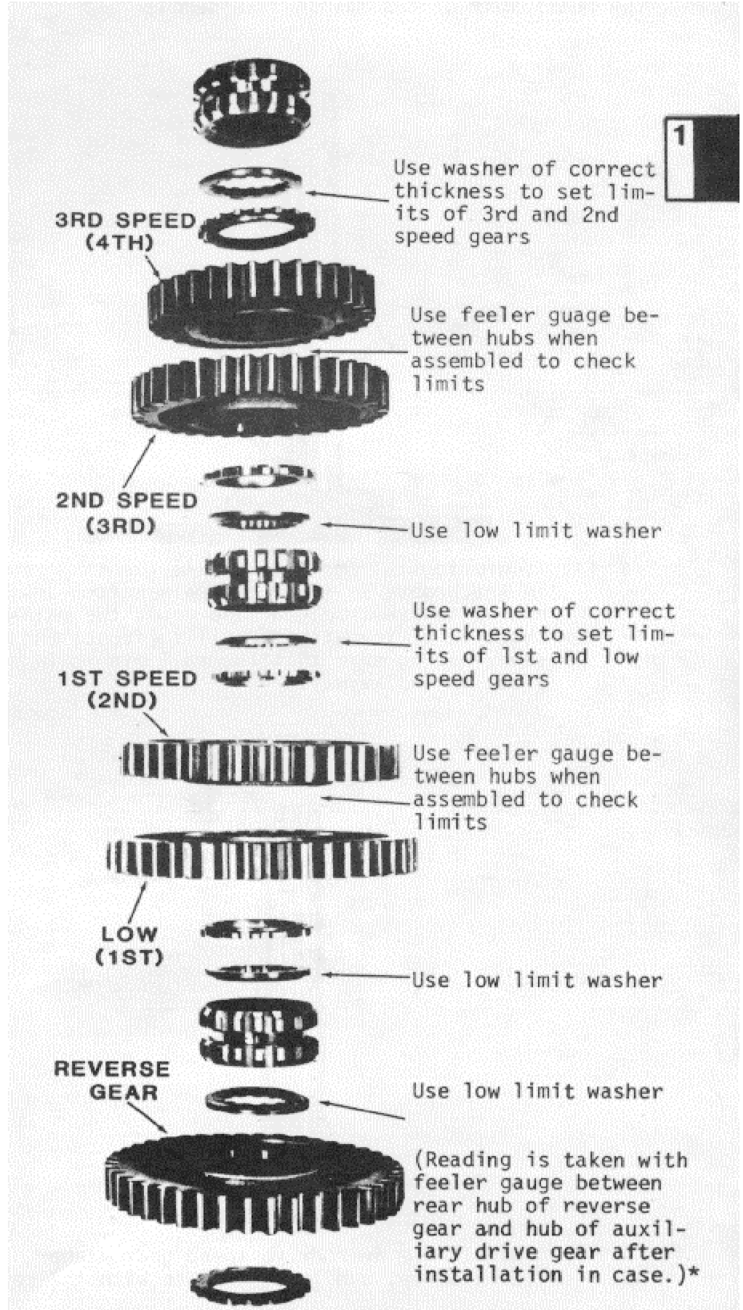
Reverse speed gear --- .005" to .038"
Forward speed gears -- .005" to .012"

Washers are used to obtain the correct limits; six thickness are available as follows:

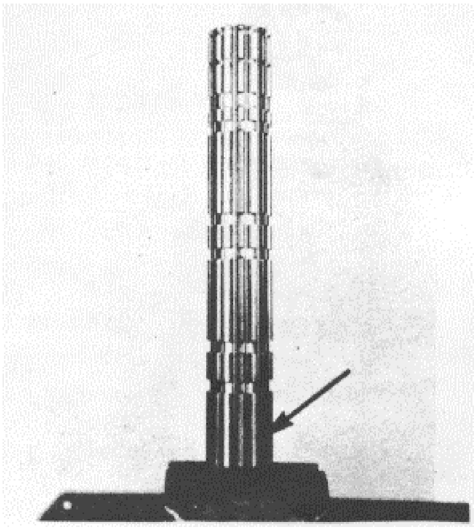
| LIMITS | COLOR CODE |
|---|---|
| .248--.250 | White |
| .253--.255 | Green |
| .258--.260 | Orange |
| .263--.265 | Purple |
| .268--.270 | Yellow |
| .273--.275 | Black |

Always use the low limit washer in the REVERSE, LOW GEAR and 2nd SPEED GEAR positions as shown at right. Refer to the service manual covering mainshaft reassembly for method of assembling parts.

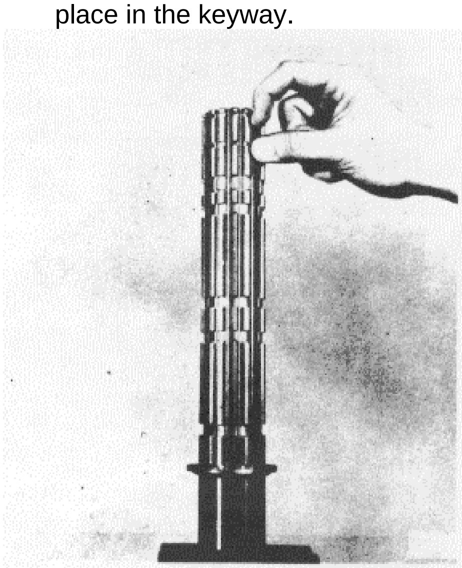
*In most cases, when setting up the reverse gear clearance, the low limit washer will give the correct clearance. However, if desired, this clearance can be measured before the mainshaft assembly is installed in the case. This is done by securing the reverse gear in position on mainshaft with the reverse gear snap ring and the front coupling snap ring; then, secure auxiliary drive gear assembly in position at rear of mainshaft with the rear coupling snap ring.



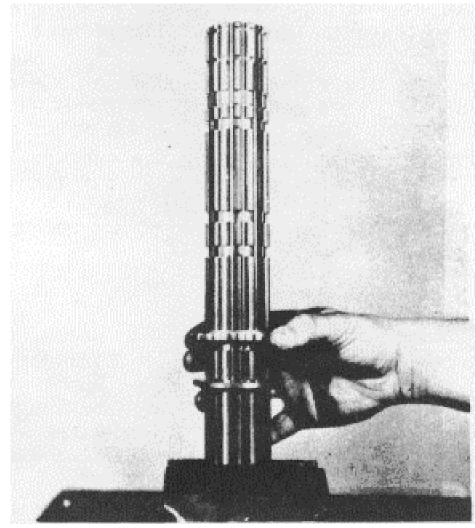
4.54 Reassembly of the Mainshaft Assembly



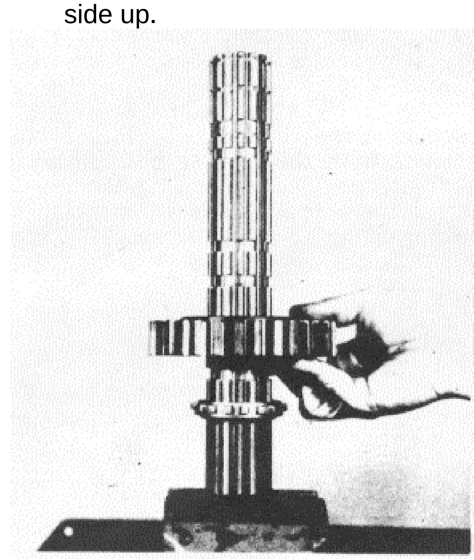
(1) If previously removed, install the snap ring in the groove in ID of all mainshaft gears except the reverse gear and mount the mainshaft in a vise with the pilot (front) end down, making sure that the roll pin is in place in the keyway.



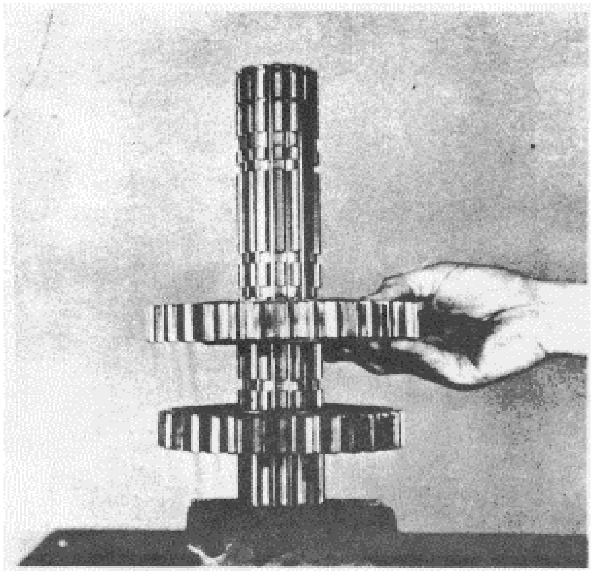
(2) Install the over drive speed gear washer, flat side up, and lock in place with the key.



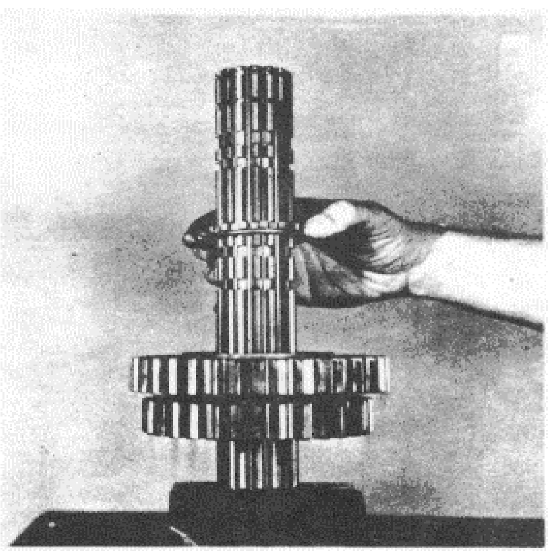
(3) Install the spacer on the washer, stepped side up.



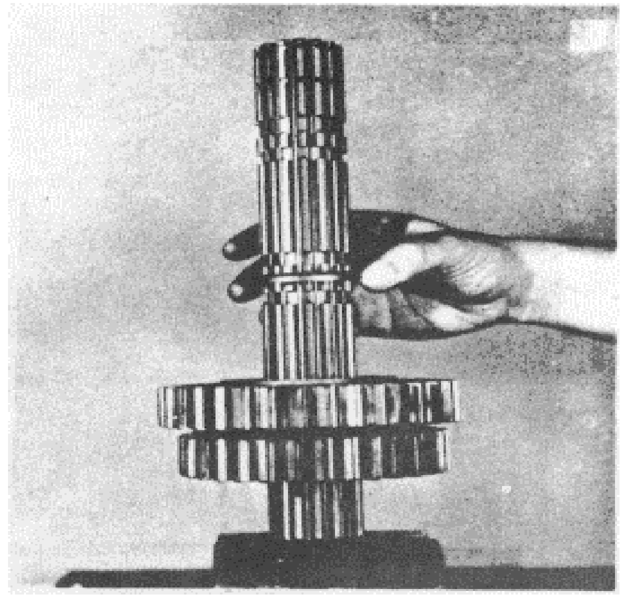
(4) Install the over drive speed gear on the shaft with the clutching teeth down. Turn the gear until it engages the splines of the spacer.



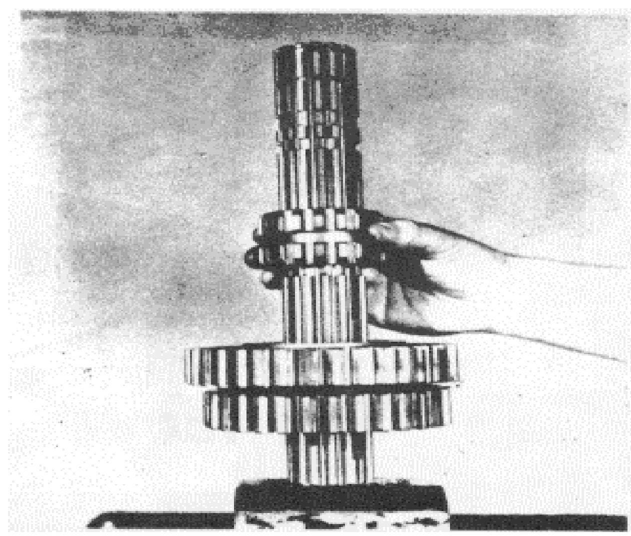
(5) Install the 3rd speed gear on the over drive speed gear, clutching teeth up.



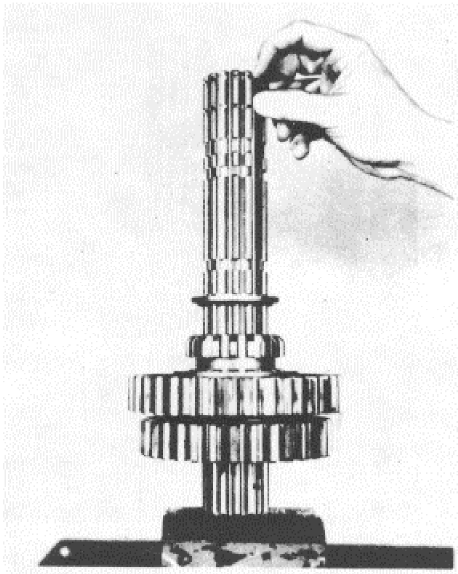
(6) Install the spacer on the shaft and in the 3rd speed gear, stepped side down.



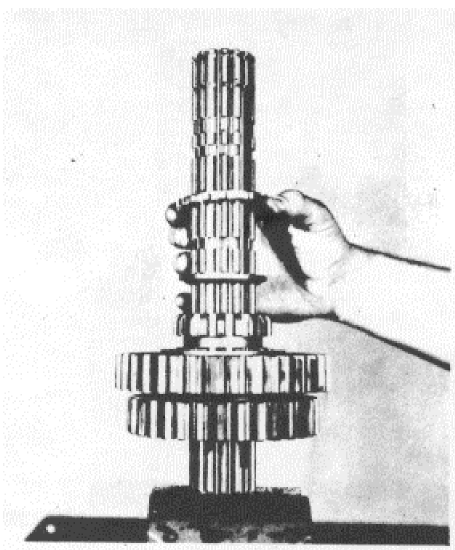
(7) Remove the key and install the 3rd speed gear washer on the shaft and in the gear. Turn the washer to align the large slot with the keyway. Lock the washer in place with the key.



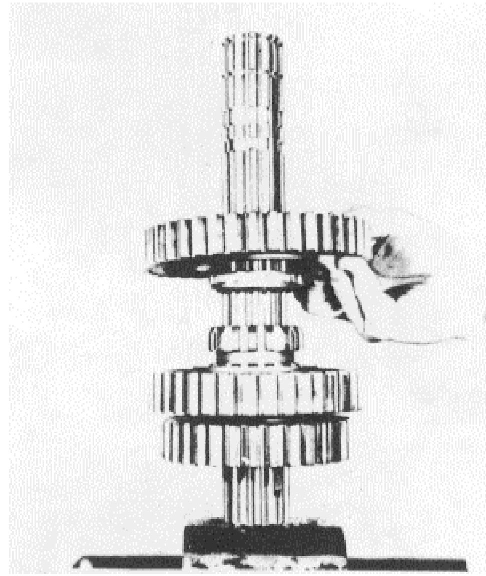
(8) Install the 2nd-3rd speed sliding clutch on the shaft, aligning the large groove in the clutch with the keyway. Remove the key.



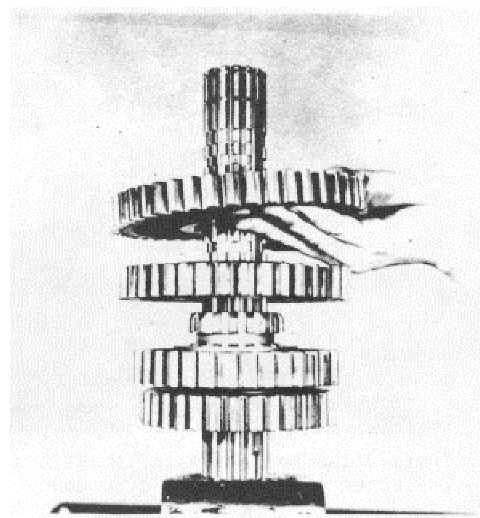
(9) Install the 2nd speed gear washer on the shaft, flat side up, turn to align the large slot with the keyway and lock in position with the key.



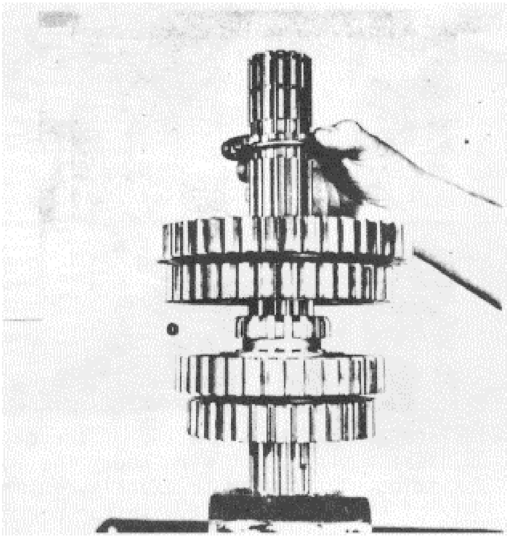
(10) Install the stepped spacer on the washer, flat side down.



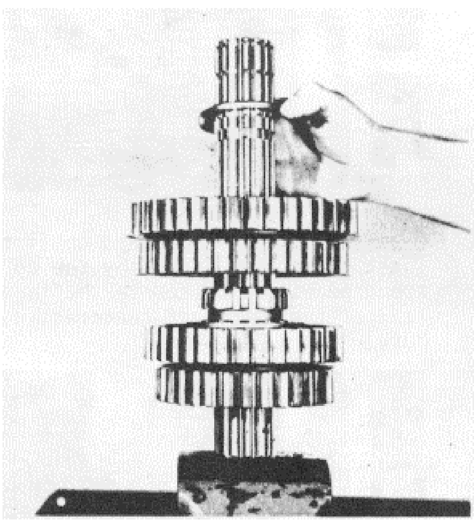
(11) Install the 2nd speed gear on the shaft against the stepped spacer, clutching teeth down-. Turn the gear until its splines engage with the splines of the spacer.



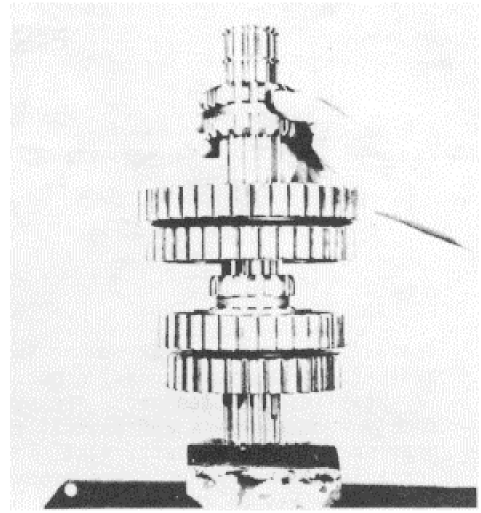
(12) Install the 1st speed gear on the shaft against the 2nd speed gear, clutching teeth up.



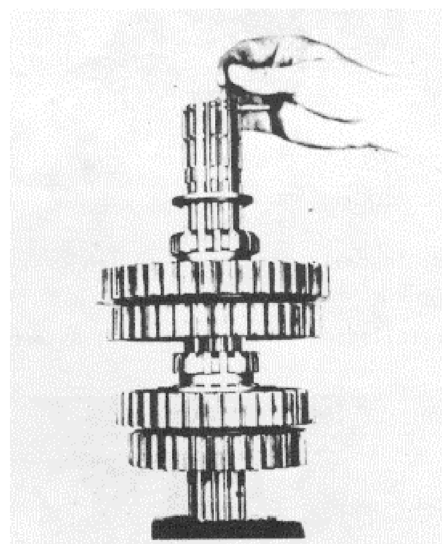
(13) Install the 1st speed gear spacer on the shaft and in the gear, flat side up.



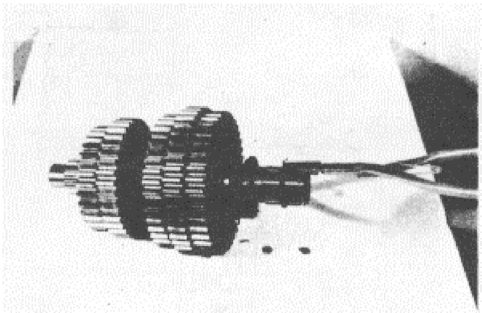
(14) Remove the key and install the 1st speed gear washer on the shaft, flat side down. Align the large slot in the washer with the keyway and lock in position with the key.



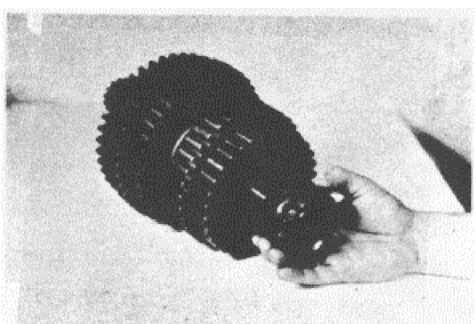
(15) Align the large slot with the keyway and install the 1st reverse speed sliding clutch.



(16) Remove the key and install the reverse gear washer on the shaft. Align the large slot in the washer with the keyway and lock in position with the key.

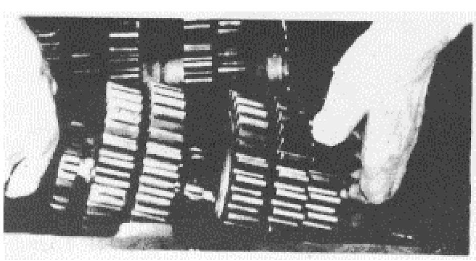


(17) Install the reverse gear on the shaft and against the 1st speed gear, engaging splines of the sliding clutch gear. Remove the assembly from the vise and install the reverse gear spacer on the shaft, flat side forward. Install the snap ring in the groove at the end of the key on the shaft.

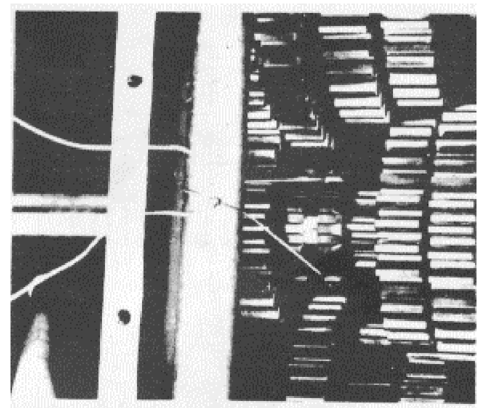


(18) Install the sliding clutch gear on the front of the mainshaft.

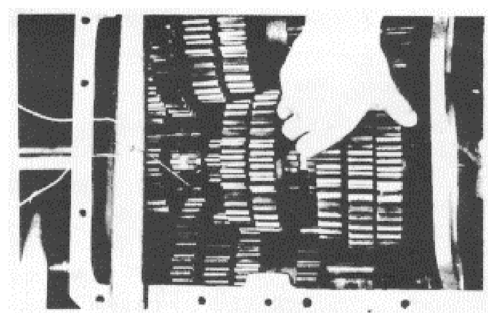
4.55 Installation of the Mainshaft Assembly



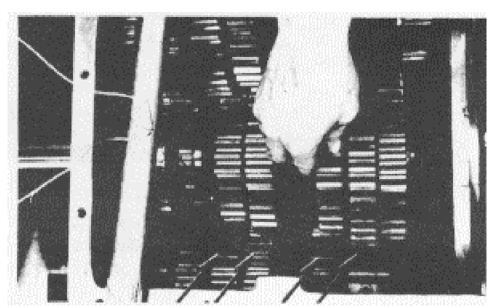
(1) With the reverse gear as far forward as possible, insert the rear of the mainshaft into the case and through the rear bearing bore. Keep mainshaft as far to the rear as possible in the case.



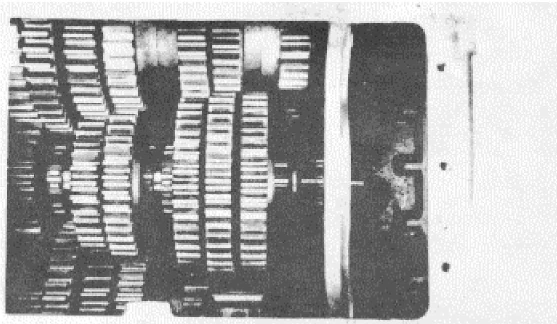
(2) Place a bar across the top of the case and insert a supporting wire under the forward sliding clutch gear to exactly center the front of the mainshaft with the pocket of the drive gear.



(3) Move the mainshaft forward until the mainshaft gears are stopped by the corresponding speed' gears on the countershafts. Keep the rear of the mainshaft centered in the rear bore.



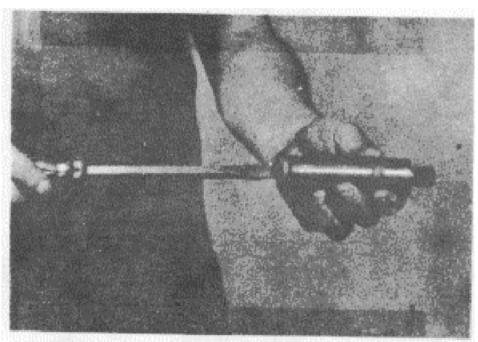
(4) Align the gear teeth on the mainshaft gears with the corresponding gears of the countershafts so that all gears will properly mesh.



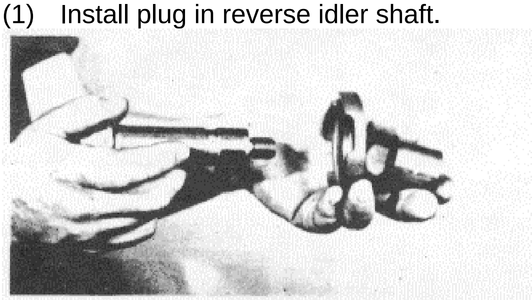
(5) Move the mainshaft forward into proper position, seating the front of the mainshaft in the drive shaft bushing and meshing all gears. Remove the wire and bar.

Note: Keep the mainshaft in the forward position during reassembly of the left reverse idler gear so that the gears will not slip out of mesh.

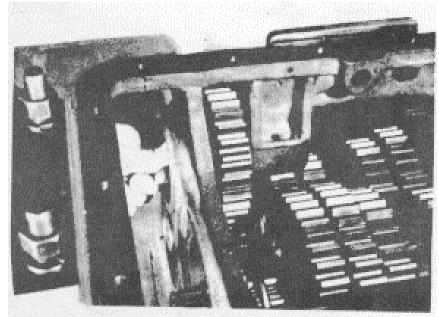
4.56 Reassembly and Installation of the Left Reverse Idler Gear.



(1) Install plug in reverse idler shaft.

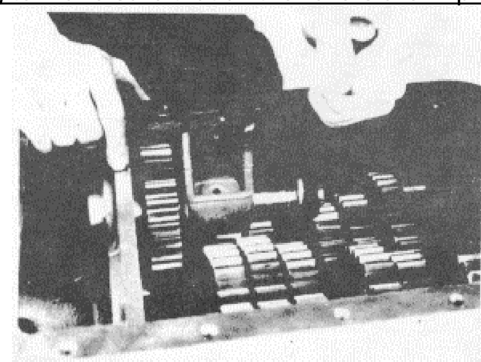


(2) Install the rear washer and bearing inner race on the shaft. If previously removed, press the needle bearing in the bore of the gear.



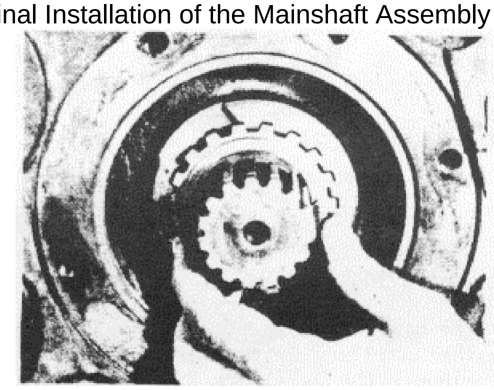
(3) Hold the gear and thrust washer in place in the case with the thrust washer between the gear and housing boss and the idler gear meshed with the teeth of the countershaft reverse gear. Insert the idler shaft through the bore in the rear case wall, the gear and washer and the housing boss.

Note: Do not force the shaft into the gear, as this will result in damage to the bearing. Check the needle bearing to make sure that all the rollers are in place.

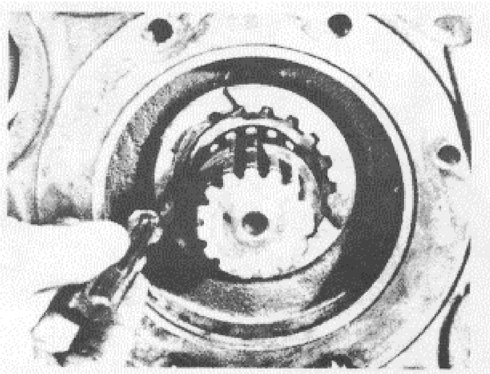


(4) Secure the shaft with the washer and elastic stop nut.

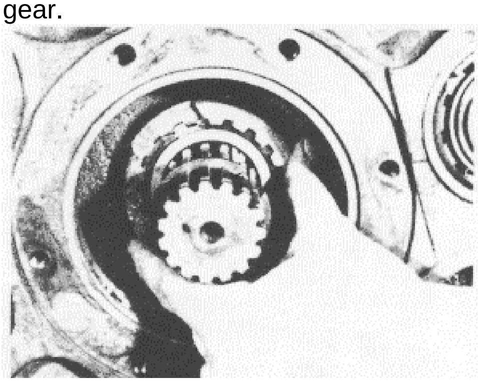
4.57 Final Installation of the Mainshaft Assembly



(1) Move; the reverse gear as far as possible to the rear, against the wall of the case and mesh teeth with those of the reverse idler gears. Slide the reverse gear spacer forward and into the reverse gear.

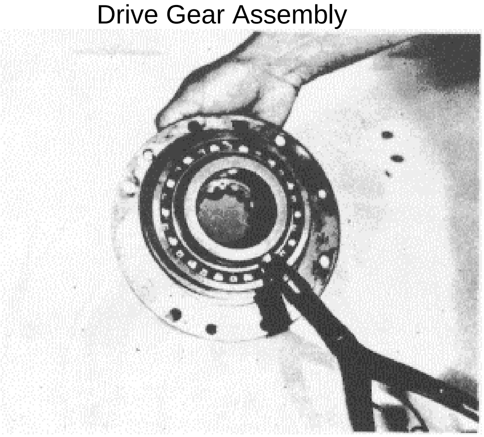


(2) Install the snap ring in the hub of the reverse gear.

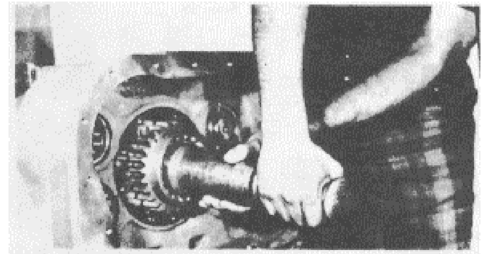


(3) Move the reverse gear forward on the shaft and into correct position.

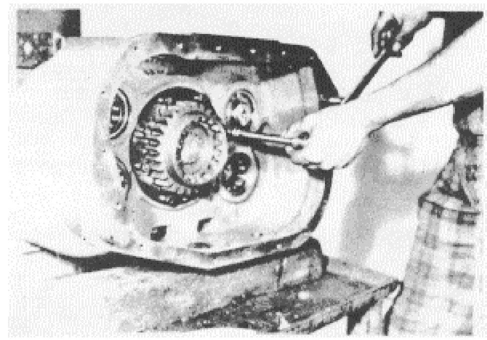
4.58 Reassembly and Installation of the Auxiliary Drive Gear Assembly



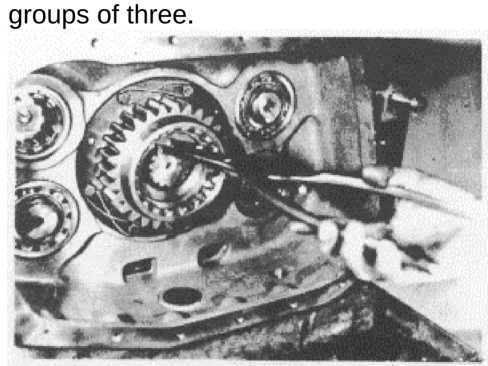
(1) If previously removed, install the retainer ring on the auxiliary drive gear and press the bearing, snap ring towards retainer, on the auxiliary drive gear. Install the snap ring in the auxiliary drive gear.



(2) Install the auxiliary drive gear assembly into the rear case bore, fitting over the rear of the mainshaft and seating the bearing in the case bore.



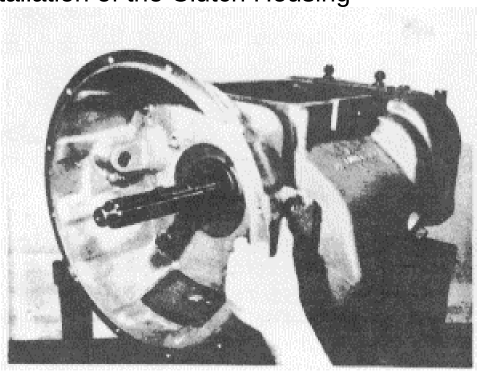
(3) Install the six capscrews which attach the retainer ring to the case. Wire the capscrews in groups of three.



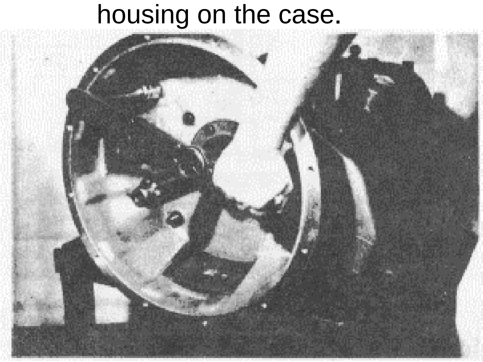
(4) Install the mainshaft rear coupling snap ring on the rear of the mainshaft.

4.59 Companion Flange, Clutch Housing and Auxiliary Section

4.60 Installation of the Clutch Housing

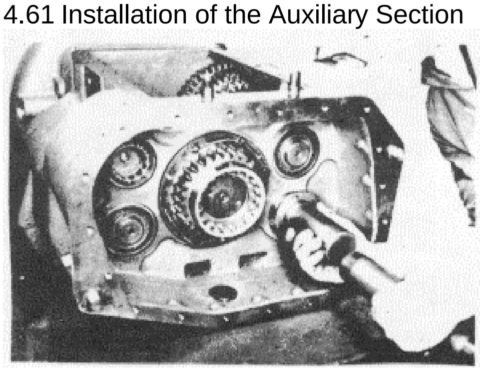


(1) Install the clutch housing on the six studs on the front of the case. Move evenly against the case as the drive gear bearing cover pilots the clutch housing on the case.

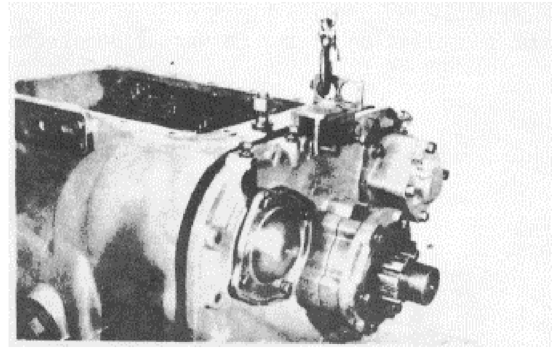


(2) Install lockwashers and nuts on the studs, and install the four bolts in the housing. Secure the nuts with 180-190 ft-lbs of torque, and secure the bolts with 90-100 ft-lbs of torque.

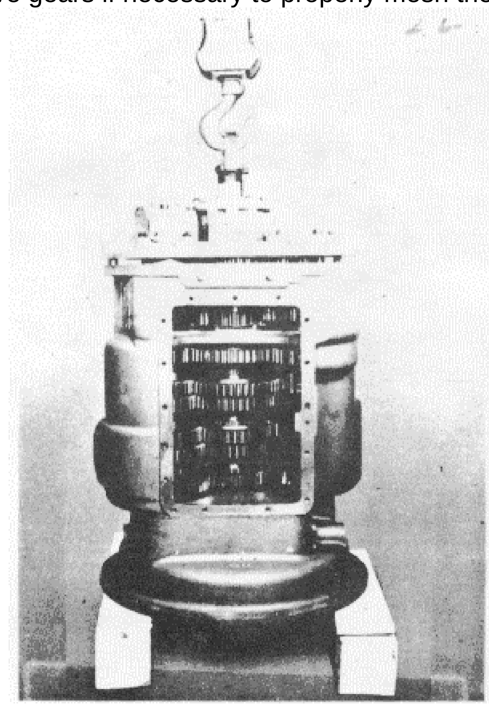
4.61 Installation of the Auxiliary Section



(1) If not previously done, install the auxiliary countershaft front bearings into the bores in the rear wall of the front case which contain the reverse idler gear shafts.

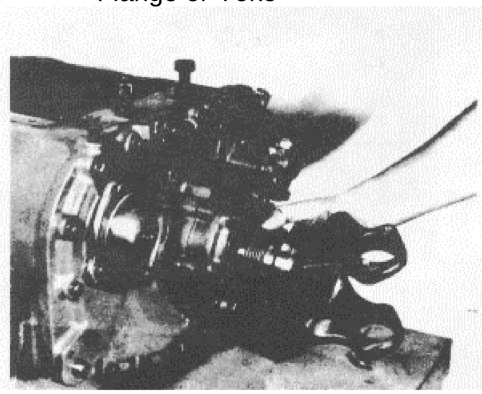


(2) Place a chain hoist on the auxiliary section to properly balance and hold its weight. Move the auxiliary section evenly onto the rear of the front case. The two counter shaft drive gears will mesh with the auxiliary drive gear and the front of both countershafts will seat in the two bearings installed in the front section. Move assembly evenly, rotating drive gears if necessary to properly mesh the gears.

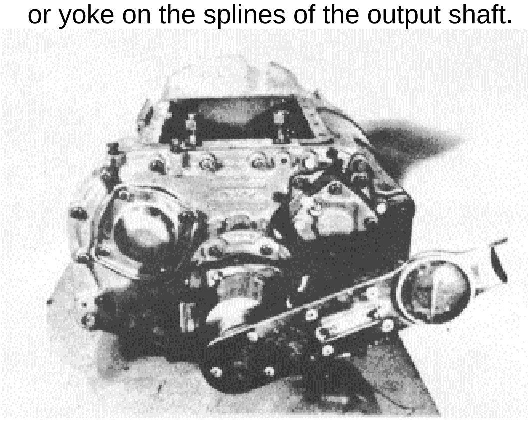


(3) Auxiliary section can also be installed by setting the front section vertically on wood blocks and by lowering the auxiliary evenly on transmission. Install the attach ing capscrews and tighten securely.

4.62 Installation of the Universal Joint Companion Flange or Yoke



(1) Lock the mainshaft in two speeds and install the speedometer drive gear or the replacement spacer on the flange or yoke. Install the flange or yoke on the splines of the output shaft.

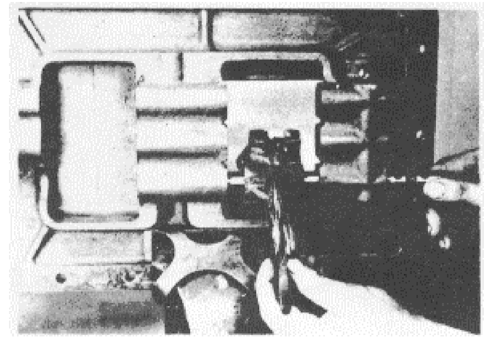


(2) Secure the flange or yoke with the elastic stop nut, tightening with a torque wrench to 450-500 ft-lbs of torque.

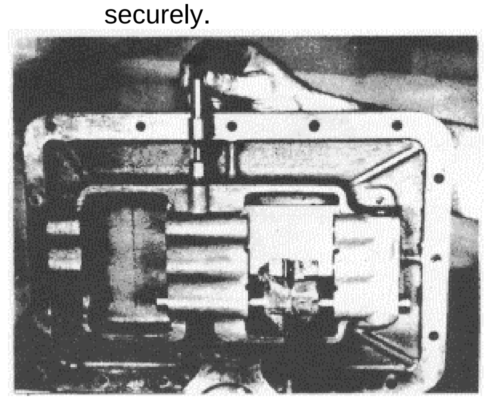
4.63 Shift Bar Housing Assembly

4.64 Reassembly of the Shift Bar Housing Assembly

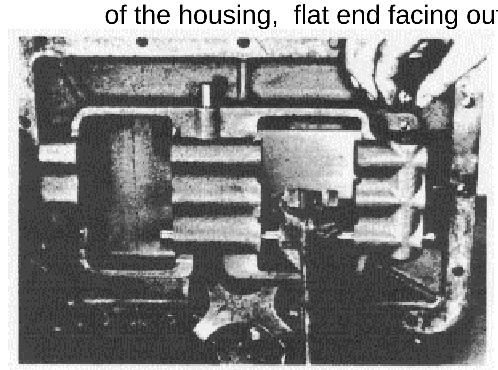
Note: If previously disassembled, install the reverse stop plunger, spring and plug in the bore until l-1-7to 2 threads protrude. Make sure that the plunger can fully depress into the bore at the yoke slot. Stake the plug through the small hole in the yoke.



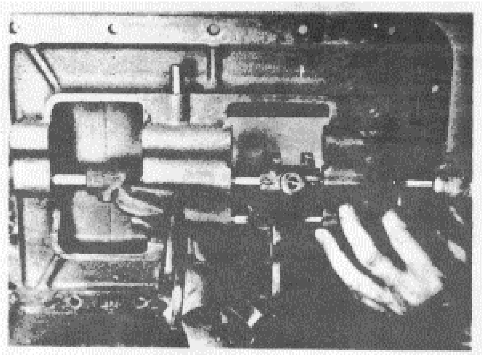
(1) Install the housing in a vise with the hole for the actuating plunger facing up. Install the short 1st reverse shifting bar into the housing in the lowest bore, installing the shifting yoke on the bar. Install the yoke lock screw; tighten and wire securely.



(2) Install the actuating plunger in the bore at the top of the housing, flat end facing out.

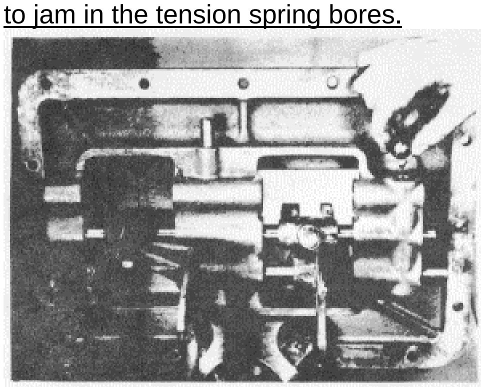


(3) Install one 3/4" interlock ball in the bore in the rear boss. This ball rides between the 1st reverse shift bar and the 2nd-3rd speed bar.

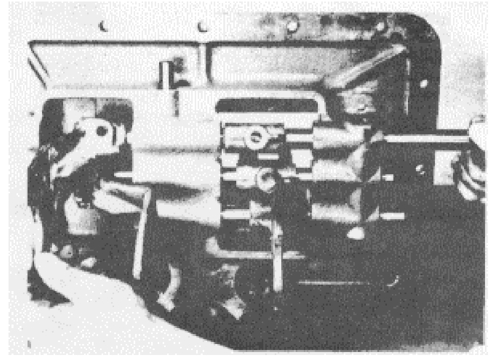


(4) Install the 2nd-3rd shift bar through the center bore in the housing, through the shift block, center boss and the 2nd-3rd speed shift yoke. At the same time install the interlock pin in the bore in the neutral notch of the bar as the notch enters the housing. Install the block and yoke lockscrews; tighten and wire securely.

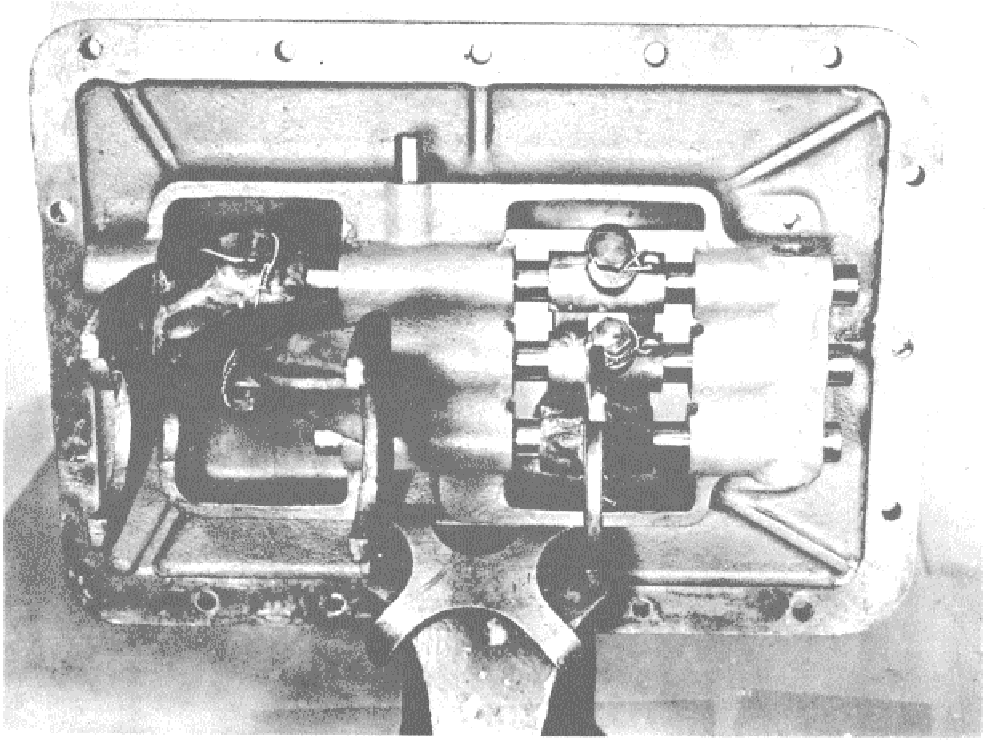
Note: Keep the bar so that the interlock pin remains in a vertical position during the remainder of the assembly. Rotation of the bar will allow the interlock pin to jam in the tension spring bores.



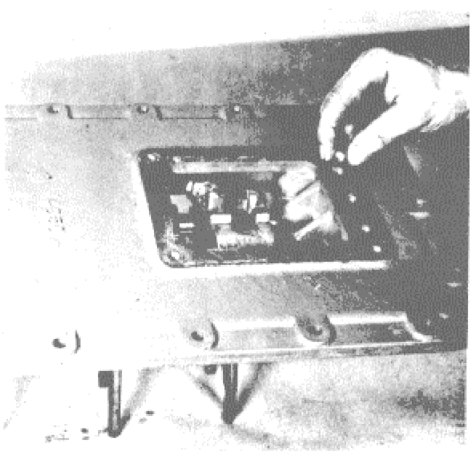
(5) Install the 3/4" interlock ball in the bore in the rear boss. This ball rides between the 2nd-3rd speed shift bar and the 4th-5th speed bar.



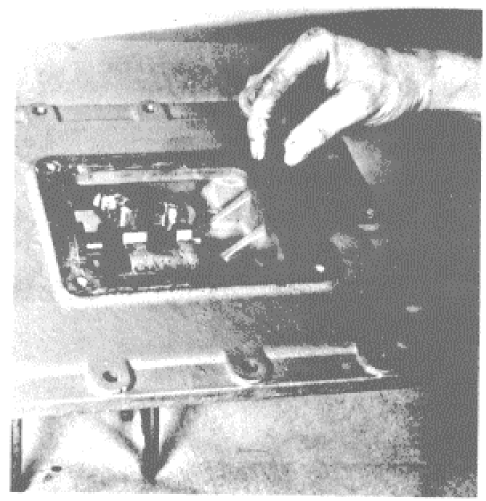
(6) Install the 4th-5th speed shift bar in the top bore of the housing, the shifting block, center boss and the shift yoke. Install the yoke and block lockscrews; tighten and wire securely.



(7) All shift bars, block and yokes installed correctly.

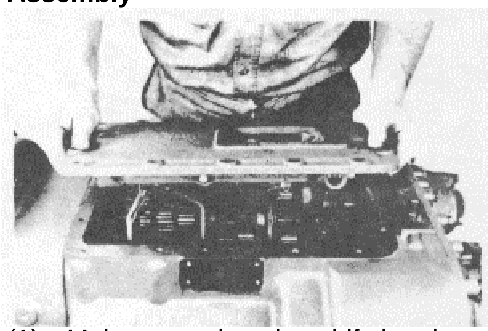


(8) Place the assembly upright on a bench and install the three tension balls in the bores in the top of the housing.



(9) Install the three tension springs on top of the balls.

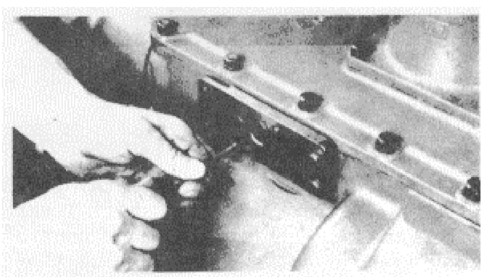
## 4.65 Installation of the Shift Bar Housing Assembly



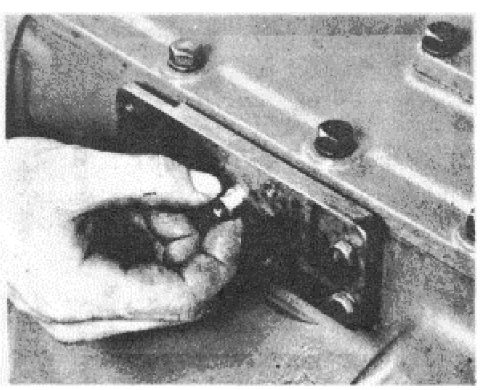
(1) Make sure that the shift bar housing and sliding clutch gears in the transmission are in the neutral position and install the housing on the transmission, fitting yokes into the yoke slots of the corresponding clutch gears. Install the retaining capscrews.

## 4.66 Range Shift Air System

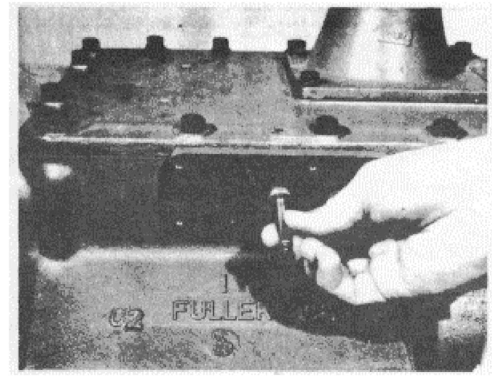
## 4.67 Installation of the Air Valve



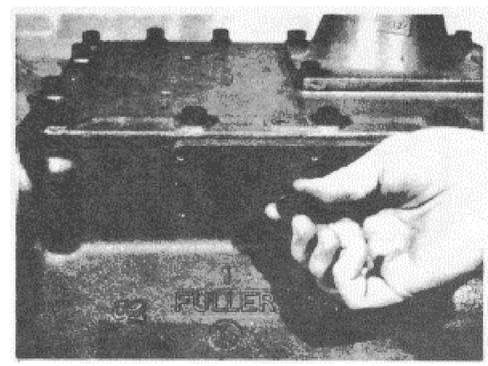
(1) If previously removed, install the fittings of the air valve and install the adapter plate on the transmission, aligning the large bore in the plate with the bore in the transmission. Secure with two capscrews at the rear and two Allen-head screws at the front.



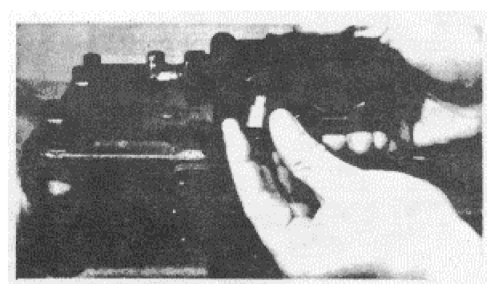
(2) Use the small alignment sleeve to check the plate bore alignment with the case bore. If not properly aligned, loosen the capscrews and Allen-head screws and reposition the adapter plate.



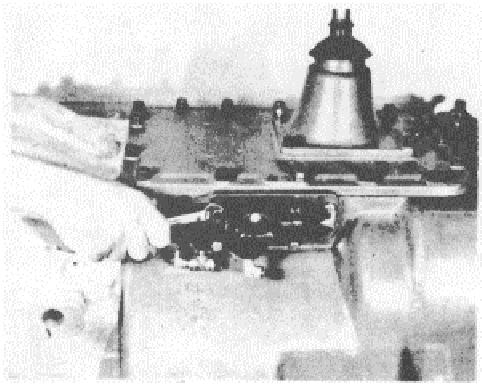

(3) Install the actuating pin in the bore in the adapter plate.



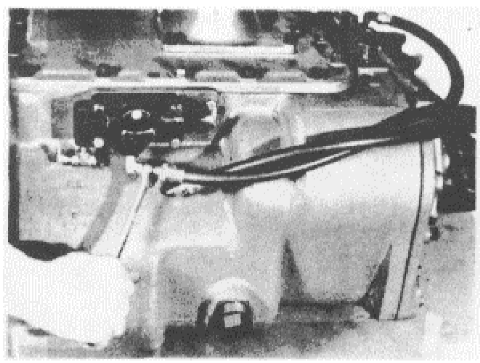

(4) Install the spring on the pin in the bore.



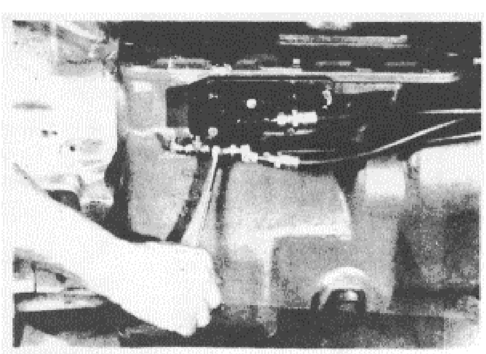
(5) Check to make sure that the piston in the air valve is either all the way forward or to the rear and install the alignment sleeve in the bore.



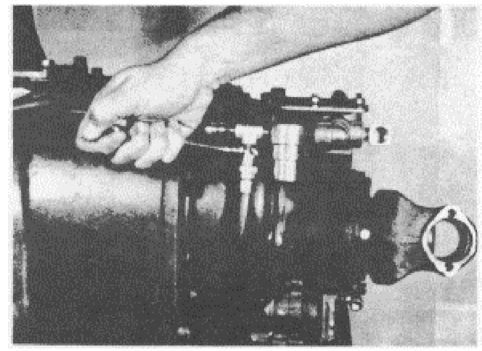
(6) Install the air valve on the adapter plate, tightening the four capscrews evenly.



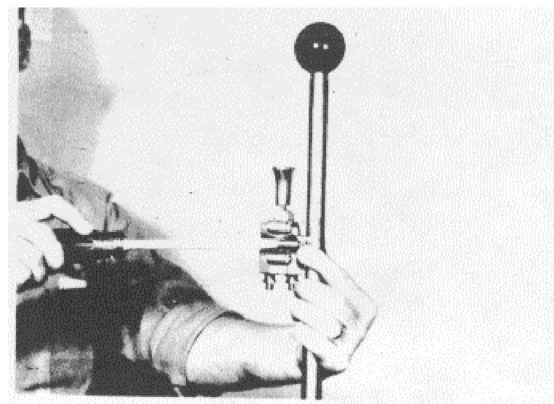
(7) If previously removed, install the fittings in the range shift cylinder and install the two 1/4" ID air lines between the shift cylinder and the air valve. The air line from the forward fitting of the shift cylinder is connected to the bottom fitting of the air valve side cap, and the air line-from the rear fitting of the shift cylinder is connected to the rear bore of the side cap on the air valve.



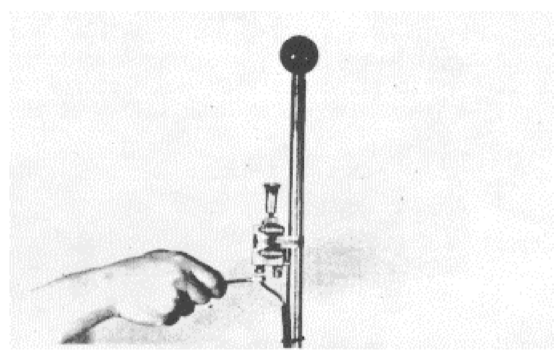
(8) Secure the air filter/regulator assembly to the rear housing with the two capscrews and connect the 1/4" ID air line between the regulator and the tee fitting on the air valve.



(9) (RT-915 Models) Connect the 1/4" ID air line between the filter/regulator assembly and the deep reduction shift cylinder.

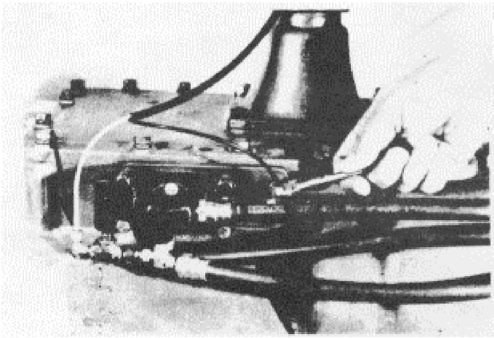


(10) Install the air lines, sheathing, "0" rings, range control valve and shift lever ball on the gear shift lever. Range control is secured in desired position by tightening the screw on the clamp.



(11) Connect the two 1/8" OD air lines to the range control valve; Black line to the front and white line to the rear.

1



(12) Connect the two 1/8" OD air lines at the air valve; White air line at the front fitting and the black air line at the rear of the air valve.

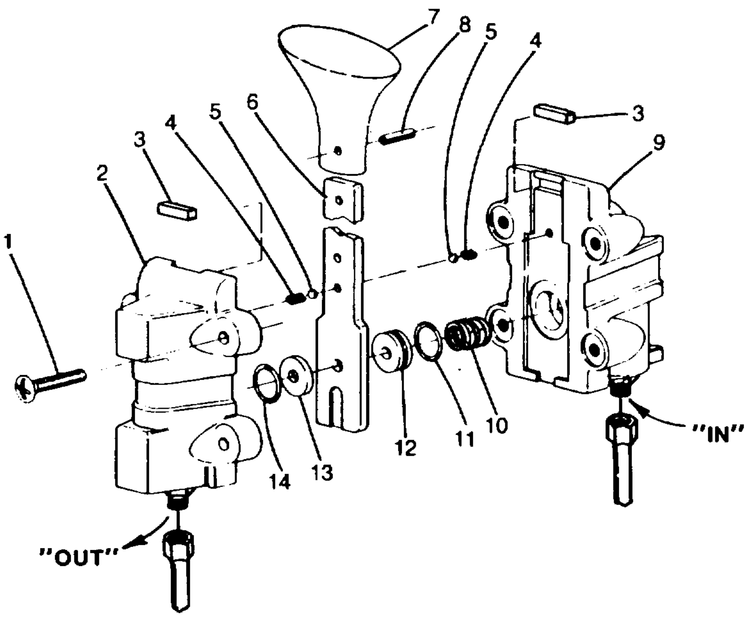



Fig. 1 L680-B
Control Valve

| | | |
|---|---|---|
| (1) Screw | (6) Slide | (11) "O" Ring |
| (2) Outlet Housing | (7) Control Knob | (12) Valve Insert |
| (3) Seal | (8) Rollpin | (13) Seal |
| (4) Position Spring | (9) Inlet Housing | (14) "O" Ring |
| (5) Position Ball | (10) Spring | |

The "IN" port is constant supply. The "OUT" port is connected by /8" O.D. air line to end cap of air valve.

If the "0" rings or parts in the control valve are defective there will be a constant air leak out the exhaust located on bottom of control valve.

A defective insert valve "0" ring (11) will result in a constant leak through exhaust in both ranges and valve will not make range shifts.

A defective housing "O" ring (14) will result in a constant, low volume leak through exhaust in low range only.

If the slide (6) is assembled back-wards, there will be a constant leak through exhaust in high range.

When installing slide (6) in control valve make sure that slot in slide faces the outlet housing (2).

**5.1 Control Valve Disassembly**

(1) Remove the four screws (1) to separate outlet and inlet housings (2 and 9).

(2) Remove the slide (6) and the two position balls (5) and springs (4).

(3) Remove the flat metal seal (13) from outlet housing (2) and remove the "0" ring (14) from housing.

(4) Remove the valve insert (12) from inlet housing (9) and remove "O" ring (11) from valve insert (12).

(5) Remove the spring (10) installed under valve insert(12).

(6) Remove the two seals (3) from housings (2 and 9).

(7) Punch out rollpin (8) and remove control knob (7) from slide (6).

## 6.1 Air Filter and Regulator Assembly

1

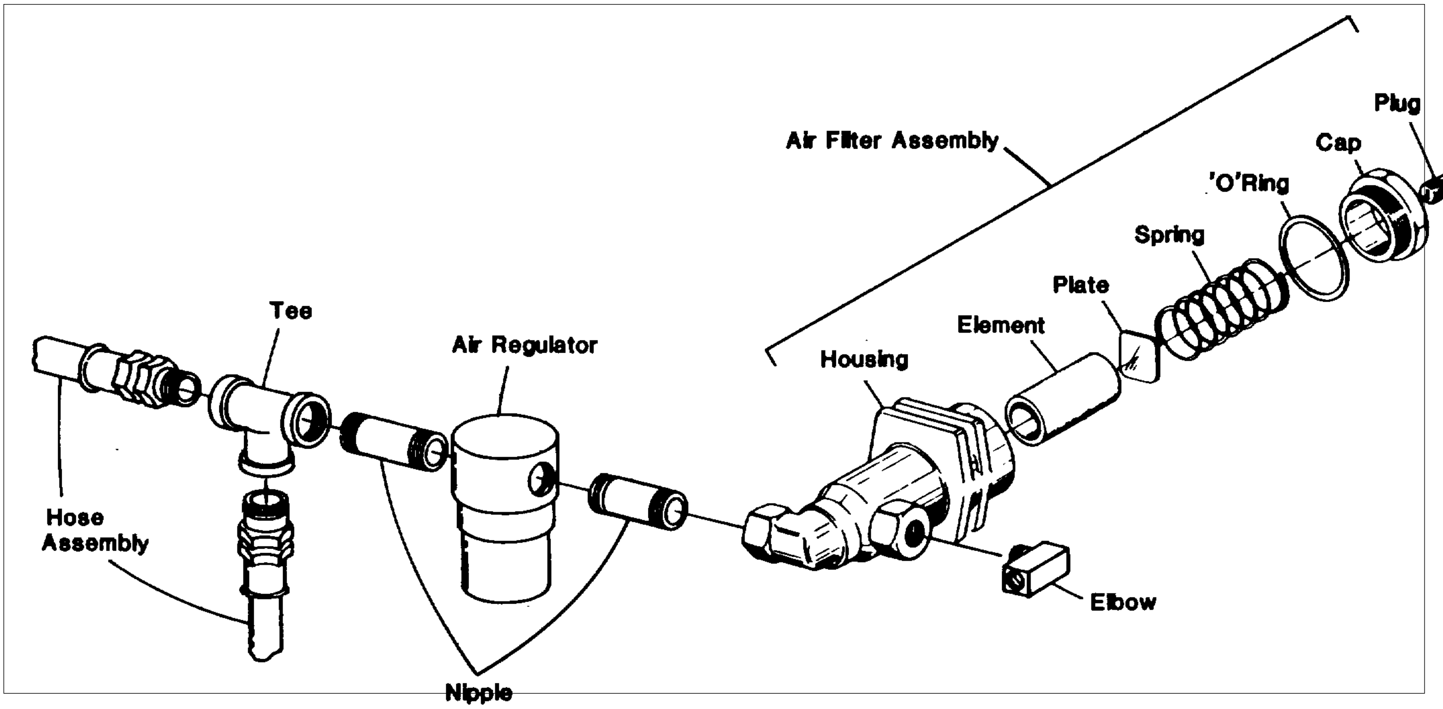



Fig. 1
Air Filter And Regulator Assembly

## 6.2 Air Regulator

The air regulator is not serviceable. If defective replace the air regulator unit. Reading at output of air regulator should be 57 to 62 psi.

## 6.3 Air Filter

Remove element, clean and reinstall at each oil change.

## 7.1 Air Valve Operation

With the range control button up the control valve shuts off the air supply to the end cap. Thus, the constant air entering at the constant supply port forces the piston to the rear. The constant air also flows through a channel in the center of the piston and to an external port which is aligned with the high range port of the air valve.

With the control button down the control valve opens and supplies air to the end cap. Since the piston area is larger on this end of the piston, it is forced in the opposite direction. The external air port in the piston is now aligned with the low range port of the air valve. 1

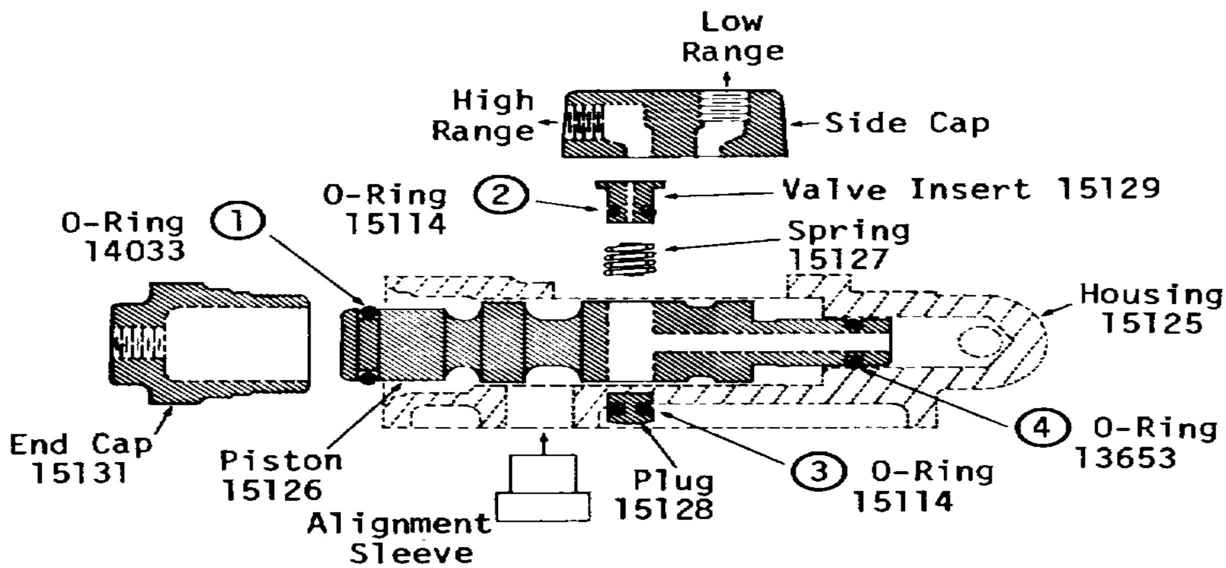



Fig. 1
Exploded view of air valve. The alignment sleeve is not part of the assembly, but must be installed in housing for proper pre-select operation.

The four "O" rings are indicated by circled numbers. If any of these are defective, there will be a constant air leak out of the exhaust on the air valve. In normal operation, exhaust will occur only for an instant as the range shift is made. The following chart is to be used as a guide to determine defective "0" rings.

| Defective "O" Rings | RESULT |
|---|---|
| 1 | Constant leak through exhaust in low range only. |
| 2 or 3 | Constant leak through exhaust in both ranges. |
| 4 | Constant leak through exhaust in high range; steady but low volume leak through exhaust in low range. |

## 7.2 To Disassemble Air Valve

(1) Turn out the two capscrews and remove the side cap from valve body.
(2) Remove the valve insert from piston and remove "O" ring from the valve insert.
(3) Remove the spring from piston.
(4) Turn end cap from valve body and withdraw piston from bore.
(5) Remove the two "O" rings from piston.
(6) Remove the nylon plug from piston and remove "O" ring from plug.

## SM1-18-8.0 Special Procedure For Changing Clutch (Input) Shaft

1

In some cases in field repair it may be necessary to replace only the input shaft due to clutch wear on the splines.

In these instances, the input shaft can be removed without disassembling the transmission other than removing the shifting bar housing. Removal of the clutch housing is optional. Following is the detailed procedure:

### 8.1 Disassembly

(1) Remove gear shift lever housing and shift bar housing from transmission.
(2) Remove the front bearing cover.
(3) Engage the mainshaft sliding clutches in two gears and remove the drive gear bearing nut.
(4) Move the drive gear assembly as far forward as possible and remove the drive gear bearing.
(5) Remove the washer from the input shaft.
(6) From the front, remove the snap ring from I.D. of drive gear.
(7) Pull the input shaft forward and from splines of drive gear.

### 8.2 Reassembly

(1) Install new input shaft into splines of drive gear just far enough to expose snap ring groove in I.D. of drive gear.
(2) Install snap ring in I.D. of drive gear.
(3) Install washer on shaft.
(4) Move the fourth-fifth speed sliding clutch gear forward to contact end of input shaft in hub of drive gear. Block between rear of sliding clutch and front of the fourth speed gear. When installing bearing, this will hold input shaft in position to seat the bearing properly.
(5) Install drive gear bearing on shaft and into case bore, making sure blocking remains in place.
(6) Remove blocking from mainshaft and install the drive gear bearing nut, left-hand thread. Use Loctite sealant on threads of nut and shaft.
(7) Peen nut into milled slots in shaft.
(8) Re-install front bearing cover, shifting bar housing and gear shift lever housing.

Note: The above instructions are for changing the input shaft only. To change the drive gear, complete dis-assembly of the front section must be made.

1

The transmission is attached to the engine flywheel housing. Power (torque) from the engine flywheel is transferred to transmission input shaft through the clutch assembly. A clutch release mechanism is located in the transmission clutch housing. Removal, installation of transmission and inspection of the clutch release mechanism is discussed in this SM.

**10.1 Transmission Removal (Refer to Fig. 1)**

(a) Park machine on a firm level surface. Apply emergency brake. Securely block carrier wheels so the carrier cannot move.
(b) Swing upper over the side of the carrier and lower attachment to the ground.
(c) Remove the floor plate from top of carrier frame.
(d) Disconnect shift linkage (3), clutch linkage, driveshaft and etc. from transmission.
(e) Drain lubricant from transmission.

Note: <u>Drain transmission while lubricant is warm.</u>

(f) Hook onto transmission with a hoist. Take slight strain against transmission with the hoist so it will not fall when removed.
(g) Remove support bracket assembly (1). Remove all transmission mounting capscrews (5).
(h) Pull transmission to rear until its input shaft disengages from clutch plates. Lower transmission to the ground and slide it out from under the carrier.

Note: <u>Do not damage clutch discs when removing transmission.</u>

Note: <u>Whenever transmission is removed, check condition of release bearing, bearing carrier, flywheel pilot bearing, clutch, release yoke, and pedal shafts. Repair or replace any worn components.</u>

**10.2 Transmission Repair**

See SM1-18-4.0

**10.3 Carrier Clutch**

See SM1-17-2.0

**10.4 Inspect Transmission Clutch Release Mechanism (Refer to Fig. 2)**

(a) Check release bearing carrier (17) wear pads.
(b) Check release yoke (15) contact with release bearing carrier (17).
(c) Check pedal shafts (3) and housing bushing (10), replace if worn.
(d) Check release bearing (18) travel, should be a total forward travel of 5/8". Keep tension on release yoke (15) while turning adjusting screw (6). Tighten jam nut (5).
(e) Check release bearing carrier (17) lubrication fitting and tube.
(f) Check release bearing (18), if worn replace and lubricate.

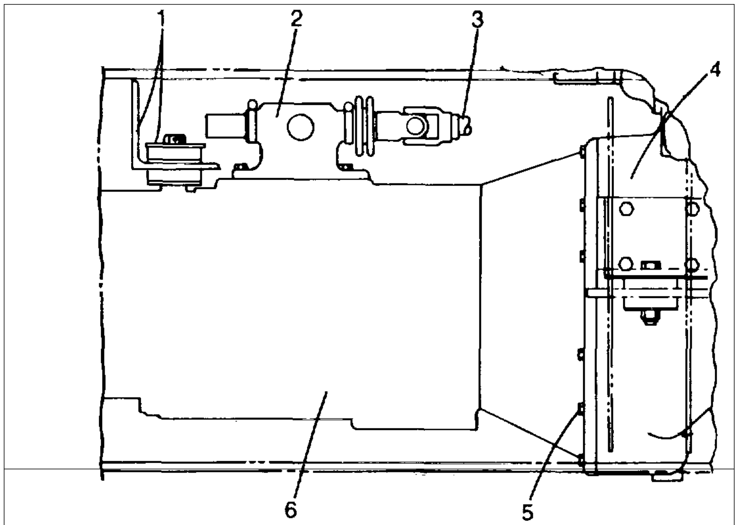



Fig. 1 LA719-D
Transmission Assembly
(1) Support Bracket Assembly
(2) Slave Control Assembly
(3) Shift Linkage
(4) Engine
(5) Mounting Capscrews
(6) Transmission

**10.5 Transmission Installation**

(a) Slide transmission under carrier. Hook onto it with a hoist so transmission will hang level.
(b) Raise transmission until it is in line with splines in clutch discs and flywheel pilot bearing.

Note: <u>If transmission does not hang level lower it and readjust sling.</u>

(c) CAREFULLY push transmission into place. Install and tighten mounting capscrews (5), which connects transmission to engine housing, to 30 ft./lbs. (40 N-m) torque.

Note: <u>Do not damage clutch discs when positioning transmission. Disc assemblies are not sprung in service but rather during installation or removal.</u>

(d) Install support bracket assembly (1). Release hoist.
(e) Connect driveshaft, shift linkage (3). Clutch linkage, and etc.
(f) Adjust release bearing clearance (distance between the clutch release levers and release bearing) to 1/8" when clutch is in engaged position. The release bearing must move forward 1/8" to take up this clearance before it contacts the release levers and then move 1/2 " to disengage the clutch.

Note: <u>Check clearance after 5,000 miles and before 10,000 miles.</u>

(g) Install cover plate.
(h) Fill transmission with proper lubricant, refer to Section 2 of Operators Manual for proper type and amount.

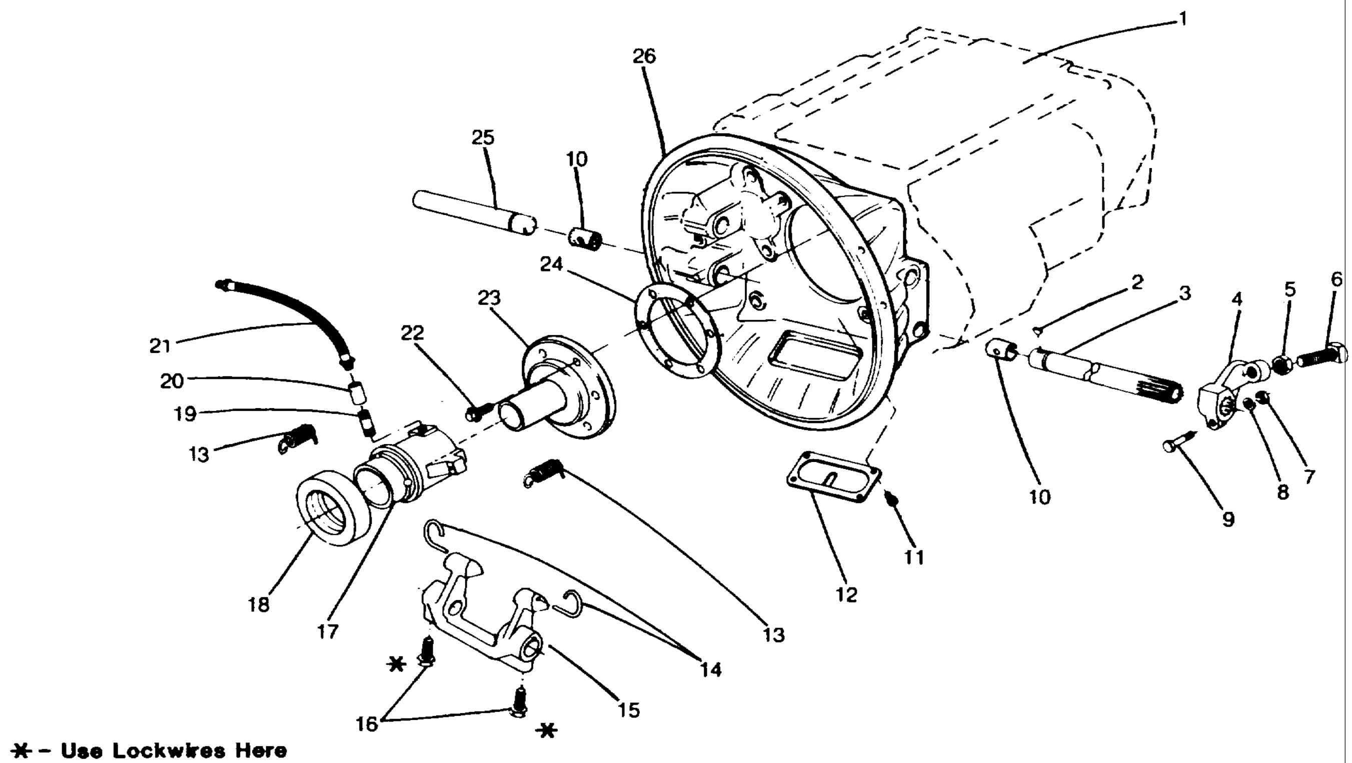



Fig. 2 L672-B
Clutch Release Mechanism

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) | Transmission | (8) | Lockwasher | (15) | Release Yoke | (22) | Capscrews & Lockwashers |
| (2) | Key | (9) | Capscrew | (16) | Capscrews | (23) | Front Bearing Cover |
| (3) | Pedal Shaft | (10) | Bushing | (17) | Bearing Carrier | (24) | Gasket |
| (4) | Adjusting Arm | (11) | Capscrews | (18) | Release Bearing | (25) | Pedal Shaft |
| (5) | Jam Nut | (12) | Hand Hole Cover | (19) | Nipple | (26) | Clutch Housing |
| (6) | Adjusting Screw | (13) | Springs | (20) | Coupling | | |
| (7) | Nut | (14) | Springs | (21) | Hose Assembly | | |

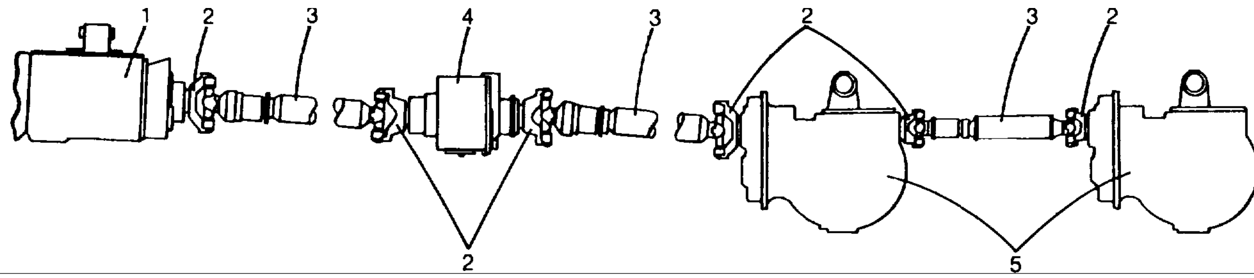



Fig. 1 NA265-D
Drive Train Assembly
(1) Main Transmission (2) Companion Flange (4) Creeper Transmission (5) Rear Axles

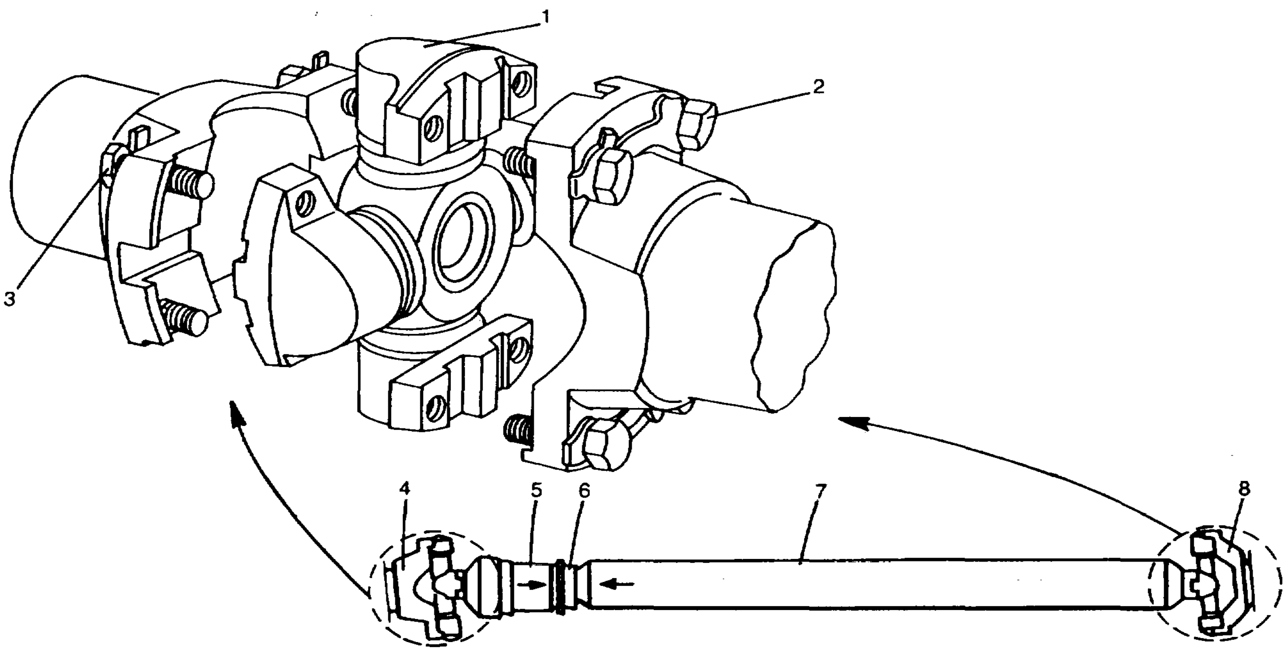



Fig. 2 NA225-D, A112-D
Drive Shaft Assembly
(1) "U" Joint (3) Capscrews (5) Slip Yoke (7) Drive Tube
(2) Capscrews (4) Companion Flange (6) Stuffing Cap (8) Companion Flange

The companion flanges and driveshaft assemblies are used to transmit power from main transmission through creeper transmission to and between the rear axles. The SM will discuss the removal, inspection, and installation of the drive shaft assemblies.

**2.1 Disassembly (Refer to Fig. 2)**

(a) Park machine on level ground. Apply park brakes. Shift transmission to neutral.

Note: The Drive shaft assembly is removed as a complete assembly.

(b) Loosen and remove the companion flange capscrews (3). Slide the slip yoke (5) toward the drive tube (7) to free the "U" joints (1) from their seats between the companion flanges (4 & 8).

Note: The companion flanges remain on the vehicle.

(c) Remove the "U" joints by removing slip yoke and tube capscrews (2).

(d) Unscrew the stuffing cap (6) from the slip yoke (5), then slide slip yoke and drive tube apart.

Note: Make sure the arrow marks are stamped on the drive tube and slip yoke before separating. If arrows are not readily seen, mark both members such that when reassembly they will be in exactly the same relative position, since the slip yoke lugs MUST be in the same plane as the drive tube lugs to prevent vibration during operation.

## 2.2 Inspection

(a) Check for damage or dents on the tube which could cause unbalance. If dents are severe enough they can weaken the drive tube (7) and a failure might occur under torque load.
(b) Splines should slide freely with a slight drag.
(c) "U" joint bearings should flex and be free of excessive bind. A "slight drag" is desirable on a new "U" joint. When rotating, yoke lug deflections will cause additional clearances. Excessive looseness is not desirable due to resulting unbalance.
(d) Companion flanges and pilots should be free of burrs, paint and foreign material which will not allow proper seating when assembling.

## 2.3 Assembly (Refer to Fig. 2)

(a) Thoroughly lubricate spline on slip yoke (5), with Molybdenum Disulfide grease, and slide drive tube (7) and slip yoke (5) together. BE SURE the arrows on the slip yoke and drive tube are in line, because the lugs must be in the same plane to prevent excessive vibration.
(b) Screw the stuffing cap (6) onto the slip yoke.
(c) Position the "U" joints (1) on either end. Install and tighten capscrews (2) to 110-120 ft/lbs (146-160 N-m) torque. Make sure the grease fittings on both "U" joints are in line.
(d) Make sure both companion flanges (4 & 8) are in the same plane.
(e) Bring one end of the "U" joint and drive shaft up against one of the companion flanges. Make sure the "U" joint properly seats in companion flange. Install the four capscrews (3) to 110-120 ft/lbs (146-160 N-m) torque.
(f) After one end of the drive shaft has been put into place, the drive tube can be compressed into the slip yoke to permit raising other end of drive shaft and then, coming forward against the companion flange, proceed as stated above.
(g) Lubricate drive shaft as explained in Section 2 of Operators Manual.

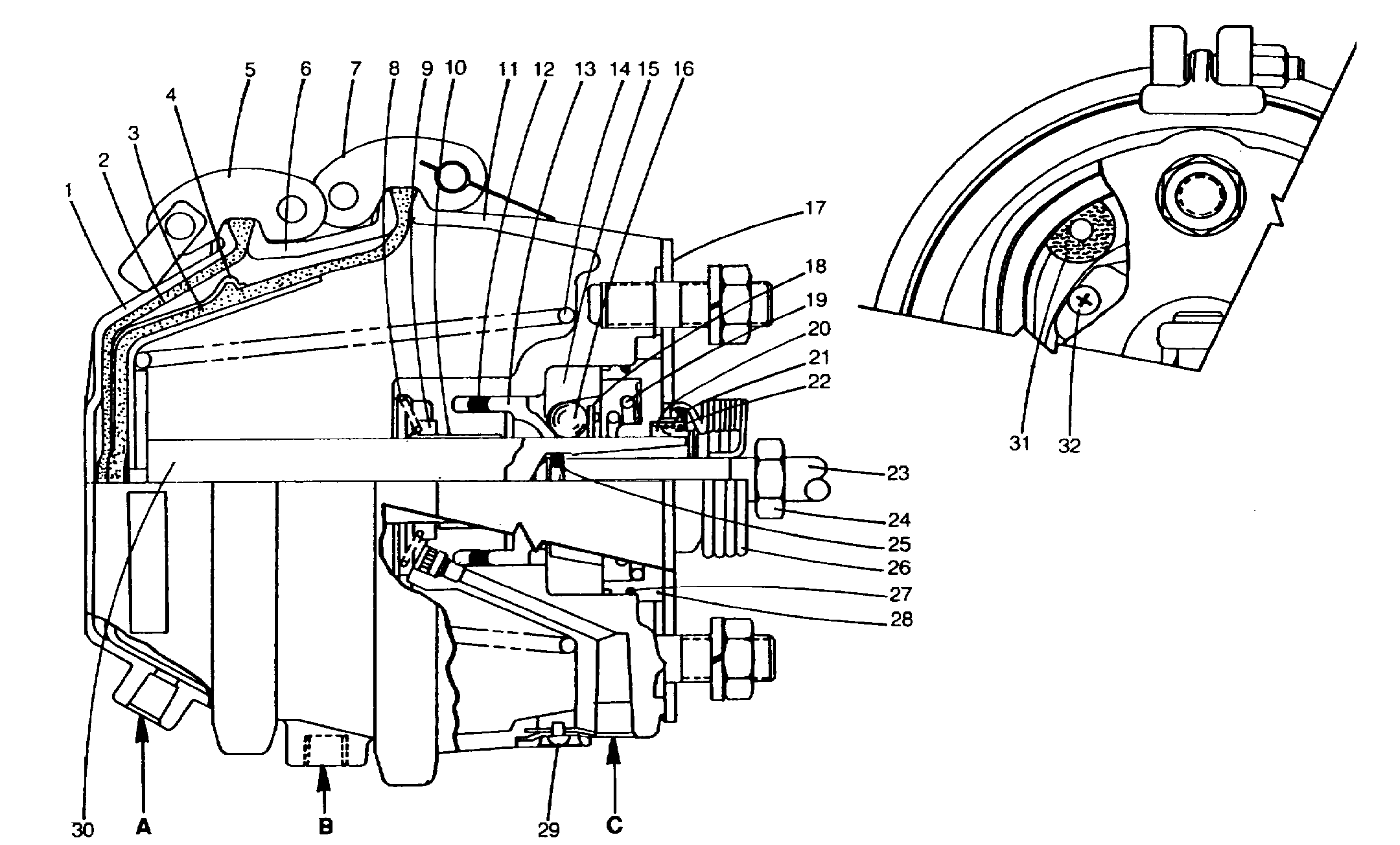



Fig. 1 NA238-B
Rear Brake Chamber

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (A) | Park Or Emergency Port | (6) | Service Pressure Plate | (15) | Collar | (24) | Nut |
| (B) | Service Port | (7) | Service Clamp Ring | (16) | Rollers | (25) | Retaining Ring |
| (C) | Lock Port | (8) | Retaining Spring | (17) | Splash Guard & Gasket | (26) | Boot |
| | | (9) | Rod Wiper | (18) | Washer | (27) | “O” Ring |
| (1) | Aux. Pressure Plate | (10) | Bearing | (19) | Roller Spring | (28) | Cap |
| (2) | Aux. Diaphragm | (11) | Non-pressure Plate | (20) | Seal | (29) | Check Valve |
| (3) | Service Diaphragm | (12) | "O" Ring | (21) | Retainer Spring | (30) | Shaft Assembly |
| (4) | Diaphragm Separator | (13) | Piston | (22) | Retainer | (31) | Breather |
| (5) | Aux. Clamp Ring | (14) | Return Spring | (23) | Push Rod | (32) | Screws |

4.1 Rear Brake Actuator Maintenance

The rear brake actuators should be serviced at the same interval as the front brake actuator. Service consists of disassembling, cleaning, replacing all rubber parts if necessary and lubricating. The following steps should be followed:

(a) Block carrier by some means other than brakes.

(b) With actuators released, remove lines leading to the park and service ports. After disconnecting, actuate park valve (in cab) to exhaust air supply, and locking port.

(c) Remove line from locking port. Remove yoke pin, cotter pin and knock out yoke pin. Remove mounting nuts, then actuator.

(e) Thoroughly clean exterior of actuator to prevent entry of foreign material when disassembling.

(f) Remove yoke, yoke locknuts, boot (26), splash guard with gasket (17) and felt breather (31).

(g) Remove auxiliary and service clamp rings 15 & 7) nuts and bolts. Spread clamp rings just enough to slip them off the plates.

(h) Remove auxiliary pressure plate (1), auxiliary diaphragm (2), service pressure plate (6), service diaphragm (3) and separator (4).

(i) Place non-pressure plate assembly on a smooth surface with push plate down. Connect an air supply line to the locking port (C). By hand, push down on the non-pressure plate (11), and apply air to the lock port. As the shaft unlocks, ease the non-pressure plate back and remove push plate and shaft assembly (30) with push rod (23) and return spring (14).

(j) Hold lock cap (28) down against roller spring tension and completely remove all four screws (32) before removing cap (28).

(k) Remove roller spring (19), spring seat washer (18), and all eight rollers (16).

(l) Cautiously apply air at the locking port to assist in removal of collar (15), piston (13) and "0" Ring (12).

(m) Remove rear retaining spring (8) by dislodging it from groove of plate and remove rod wiper (9).

(n) Inspect bearing (10) in shaft bore of non-pressure plate and remove ONLY if worn.

(o) The push rod (23) should not be removed from the shaft unless it is damaged. If rod is removed it must be replaced. To remove the rod, place a washer over the rod, against the shaft, then position a spacer and second washer over the rod and under the yoke lock-nuts. Turn locknuts down with a long handled wrench, pulling the push rod from the shaft.

(p) Remove exhaust check valve (29) from non-pressure plate (11).

### 4.2 Cleaning And Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(a) Wash all metal parts in solvent and dry. Wipe reuseable rubber parts clean.

(b) Discard felt breather.

(c) Inspect all parts for excessive wear or deterioration.

(d) Particular attention should be given to the piston and collar bores in the non-pressure plate (11). The air passage from the lock port to piston bore should be clean and not restricted.

(e) Rollers (16) should be inspected, if one or more needs to be replaced then all have to be replaced.

(f) Check springs for cracks, distortion, or corrosion.

### 4.3 Reassembly

Note: <u>Actuator must be installed with the exhaust check valve down.</u>

(a) Lubricate piston and collar bores, shaft, "0" Ring (12), piston, and roller cavity with Bendix Westinghouse (BW 404-M) "Never Seez".

(b) Position "O" Ring (12) in piston bore, then piston (13) with smooth end down against "O" Ring.

(c) Place collar (15) in its bore, chamfer side down. Coat rollers with "Never Seez" (BW 404-M). Position all eight rollers (16) in groove formed by top of piston and collar ramp. Pack roller cavity with "Never Seez" (BW 404-M).

(d) Place spring seat washer (18) on top of rollers.

(e) Place roller spring (19) on washer with mall end to washer.

(f) Install "O" Rings in cap: small "O" Ring in inner bore, large "O" Ring on outside of cap; insure "O" Rings are seated in grooves.

(g) Place seal (20) in bore of cap (28) with lip of seal facing front of cap. Place retainer spring (21) on seal, position retainer (22) on spring, compress spring, line up tabs on retainer to slots on cap, and lock retainer on cap by turning 1/4 turn counterclock-wise.

(h) Position cap assembly (28) on roller spring (19). Push cap down while installing and tighten the four screws (32) evenly. Install new felt breather (31).

(i) Turn over non-pressure plate and install rod wiper (9) with lip facing cavity. Install retaining spring (8) in grove of non-pressure plate.

(j) Install push plate return spring (14) with larger end down.

(k) Position push plate and shaft (30) over return spring and push shaft assembly through lock. Lock should hold shaft in place against return spring. If not, recheck assembly to this point.

(j) Install service diaphragm (3), separator (4), pressure plate (6), and clamp ring (7). (m) Install auxiliary diaphragm (2), pressure plate (1),and clamp ring (5).

(n) Install capscrews in both clamp rings and tighten down.

(o) Install exhaust check valve (29).

(p) Install boot (26) and splash guard with new gasket (17).

(q) Install actuator on machine. Check for leakage with soapy water. No air leaks are permissible.

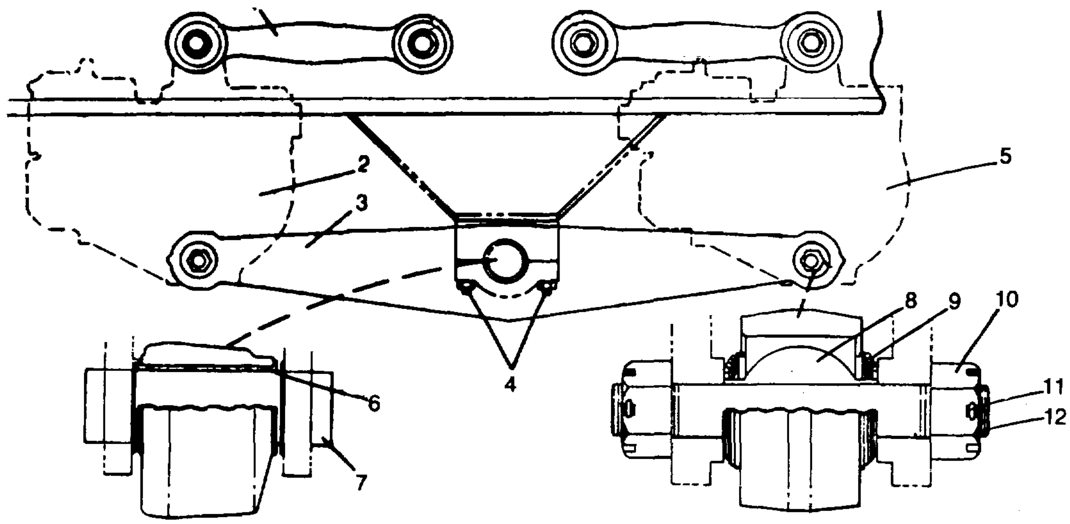



Fig. 1 LA744-C
Rear Axle and Equalizer Beams

| | | | | | |
|---|---|---|---|---|---|
| (1) | Torque Rod | (5) | Rear Rear Axle | (9) | Seal And Retainer Spring |
| (2) | Front Rear Axle | (6) | Bushings | (10) | Castle Nut |
| (3) | Equalizer Beam | (7) | Center Pin | (11) | Cotter Pin |
| (4) | Studs and Nuts | (8) | Bushing Assembly | (12) | Stud |

6.1 Axle Disassembly

(a) Jack machine up until the tires clear the ground. The hydraulic outriggers can be used for this purpose. Block securely under the frame so the machine cannot fall.

(b) Remove tire and wheel assemblies.

(c) Cleanliness is of extreme importance and an absolute must in the repair and overhaul of this axle. Before attempting any repairs, the exterior of the unit must be thoroughly cleaned to prevent dirt and foreign material from entering the mechanism.

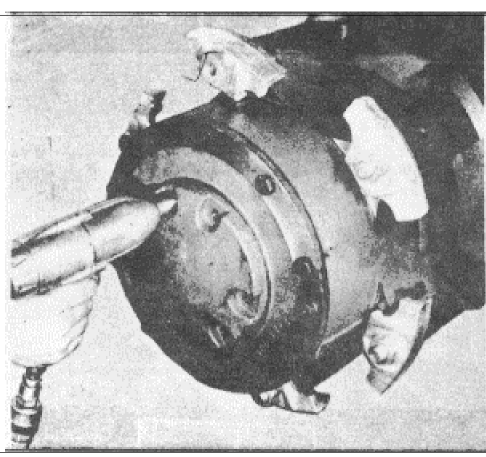


Fig. 2
Removing Thrust Cap

(d) Remove thrust cap from planetary carrier

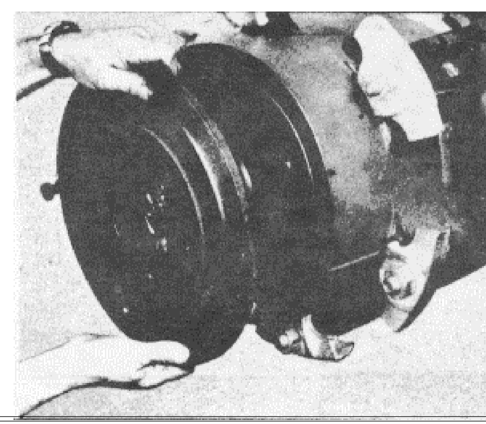


Fig. 3
Removing Planetary Carrier

(e) Remove planetary carrier assembly

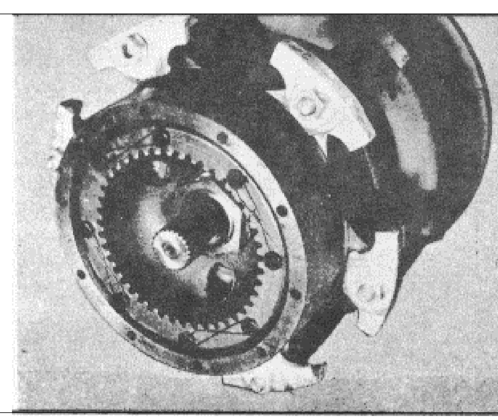


Fig. 4
Removing Axle Shaft

(f) Remove snap ring and sun-gear from axle shaft. Pull axle shaft from housing tube.

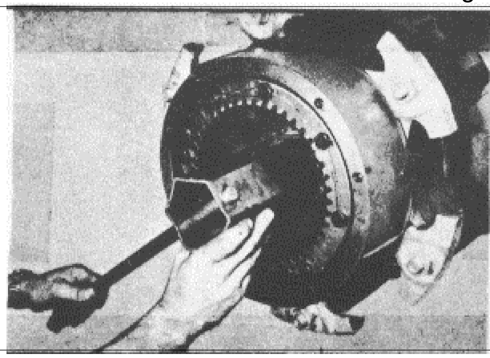


Fig. 5
Removing Tube Nuts

(g) Unclinch axle tube nut lock. Remove locknut, nut lock, and adjusting nut.

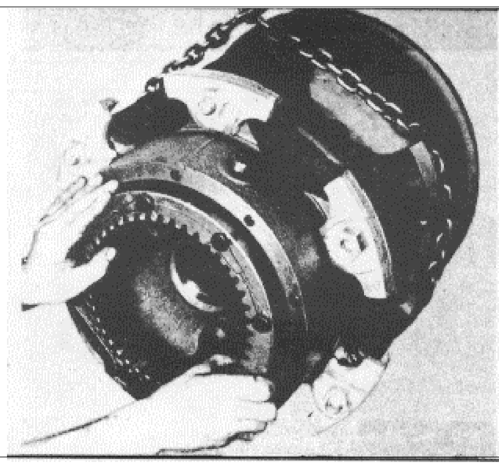


Fig. 6
Removing Internal Gear and Hub

(h) Remove internal gear and hub assembly.

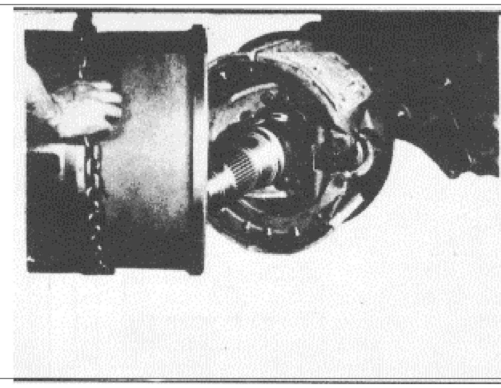


Fig. 7
Removing Wheel Hub and Drum

(i) Remove wheel hub and drum assembly. Inner and outer hub bearing cone will come out with hub and drum.

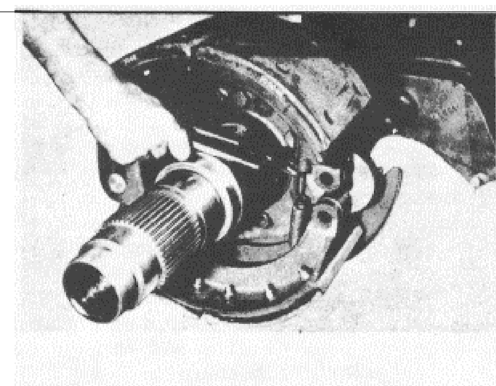


Fig. 8
Removing Brake Shoe Springs

(j) If brakes are being relined, axle disassembly need not go further. After removing release spring, brake shoes can be separated. Relining can now be done, but shoes should be removed first. When installing new brake lining, tighten lining bolt nuts to 190 inch-lbs. torque (dry threads).

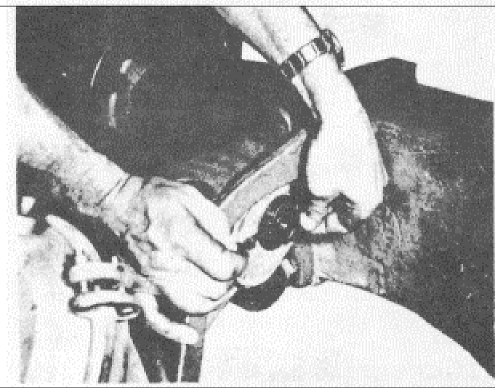


Fig. 9
Removing retainer Ring and Washers (Rear)

(k) Remove rear camshaft to slack adjuster retainer ring and washer.

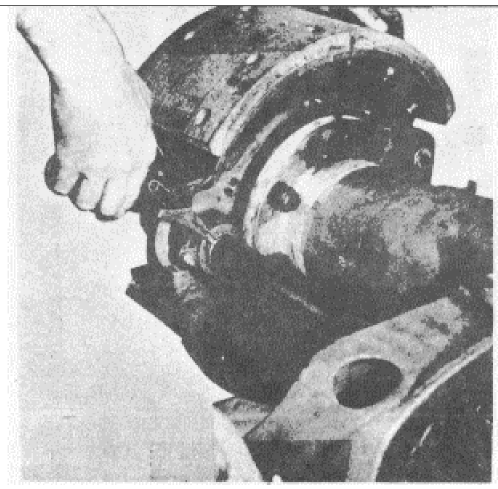


Fig. 10
Removing Retainer Ring and Washers (Front)

(l) Remove front camshaft retainer ring and washer. Remove camshaft from axle housing and brake assembly.

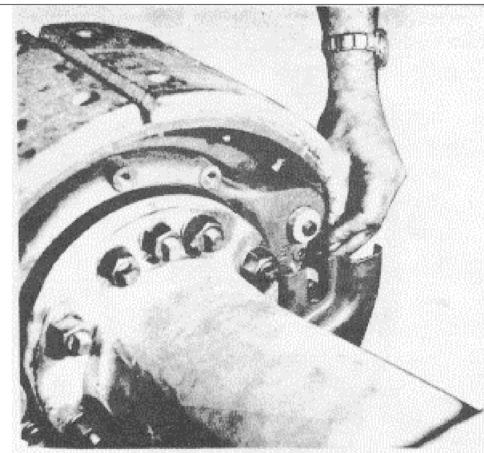


Fig. 1
Removing Brake Dust Cover

(m) Remove brake dust cover and brake anchor pin lock.

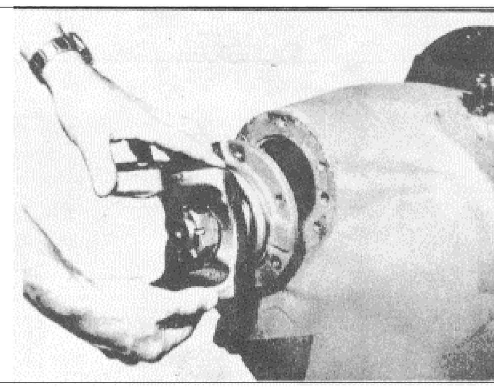


Fig. 12
Removing Output Yoke

(n) Remove rear output shaft and yoke assembly. (Front rear drive axle only).

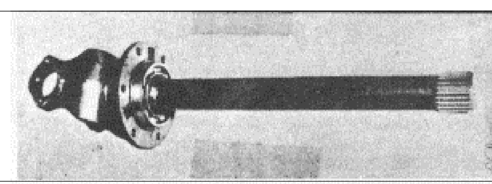


Fig. 13
Sequence of Output Shaft and Yoke Parts

(o) The sequence of parts for the output shaft and yoke assembly is shown in Fig. 13. (Front rear drive axle only).

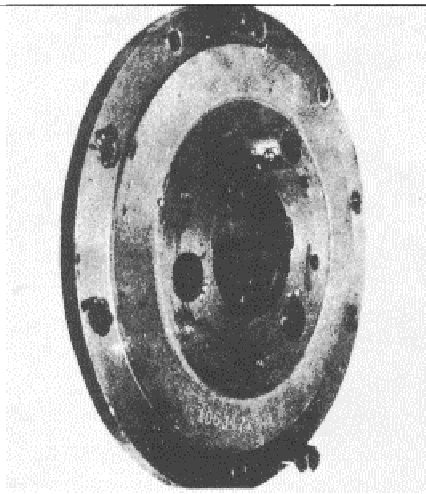


Fig. 14
Planetary Carrier

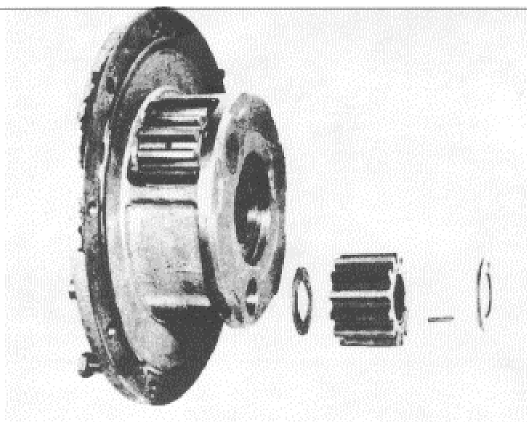


Fig. 15
Sequence of Parts for Planetary Carrier Assembly

(p) Sequence of parts for planetary carrier assembly is shown in Figs. 14 and 15.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Cleanliness of the respective parts is absolutely necessary when reassembling. Dirt in its many forms can and will cause trouble. Before reassembling the axle or differential or any of its parts, be sure the parts have been thoroughly cleaned with a suitable cleaning fluid. After cleaning, dry all parts with moisture free compressed air.

Examine all parts before reassembly. Any part that is worn excessively or damaged must be replaced. Remove small nicks or burrs with a hone, or crocus cloth. Replace all gaskets, oil seals, "0" rings, and internal lockwashers.

## 6.2 Axle Reassembly

(a) If differential was removed, coat axle housing with Permatex #2 and install differential in axle housing. Secure with taper dowels, nuts, bolts, and lockwashers. Tighten to specified torque. (See torque chart, page 19 of 20).

If axle spindle end and/or brake spider have been removed, reassemble to axle housing. Tighten nuts to specified torque.

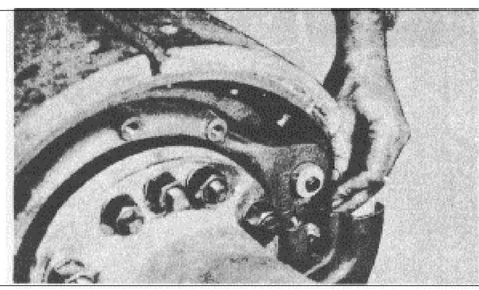


Fig. 16
Installing Anchor Pin Lock

(b) Install shoe and lining assembly. Secure with brake anchor pins.

Note: When installing anchor pins make sure slots are lined up with lock screw holes to allow lock to be installed. Install anchor pin, lock, and screw.

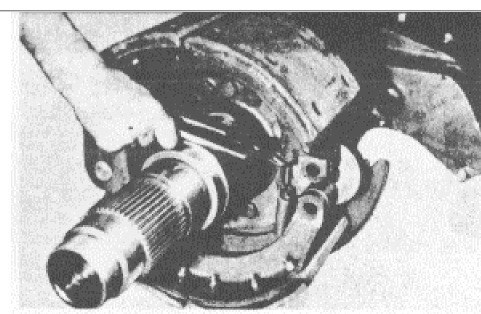


Fig. 17
Installing Brake Return Springs

(c) Install brake shoe return spring.

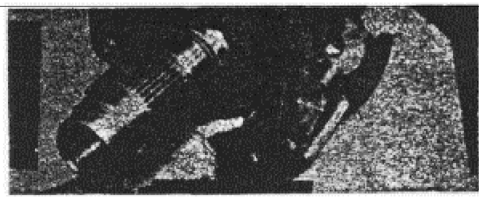


Fig. 18
Blocking Brake Shoes

(d) Block the brake shoes as shown in Fig. 18. This makes camshaft installation easier. Be careful not to over stretch return spring.

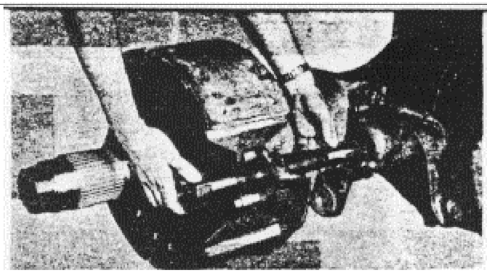


Fig. 19
Installing Camshaft

(e) Install "O" ring and camshaft thrust washer into position between brake spider, and roller ends of brake shoe. Camshaft may now be installed through the brake spider camshaft support boss.

Slide grease retainer, retainer washer and retainer ring on the camshaft. Push the camshaft through air chamber and slack adjuster.

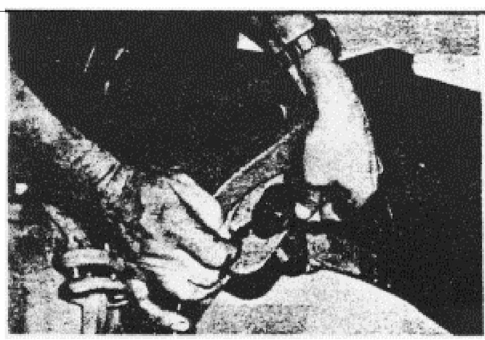


Fig. 20
Installing Washer and Retainer Ring (Rear)

(f) Install the rear slack adjuster and retainer ring.

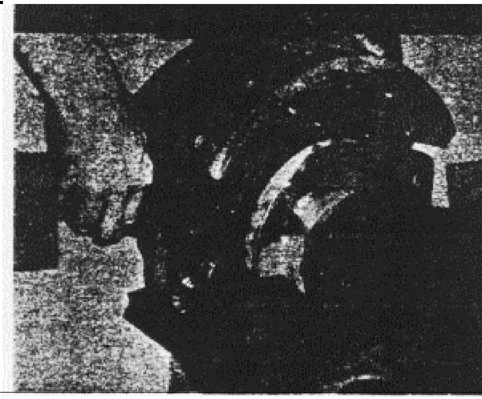


Fig. 21
Installing Washer and Retainer Ring (Front)

(g) Install the front camshaft retainer ring Fig. 22

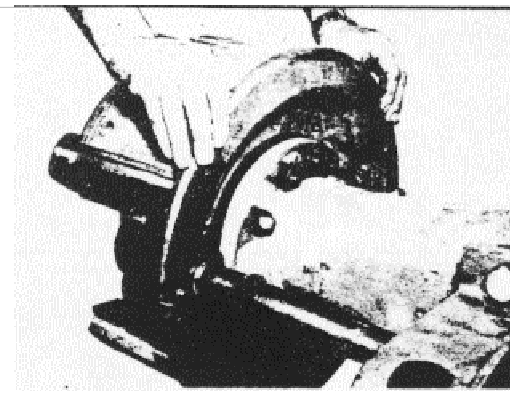


Fig. 22
Installing Dust Cover

(h) Install brake dust cover. (See note, on page 7 of 20).

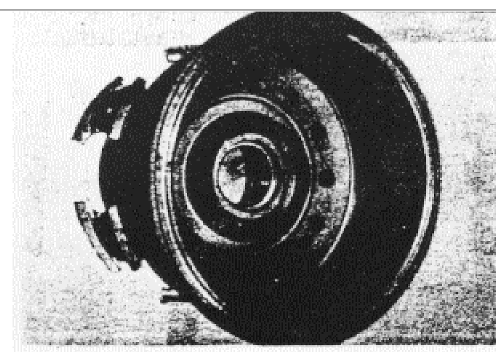


Fig. 23
Hub and Drum Assembly

(i) If wheel hub and brake drum have been disassembled, reassemble same and tighten bolts to specified torque. (See torque chart, page 19 of 20). Lock wire in pairs to prevent loosening.

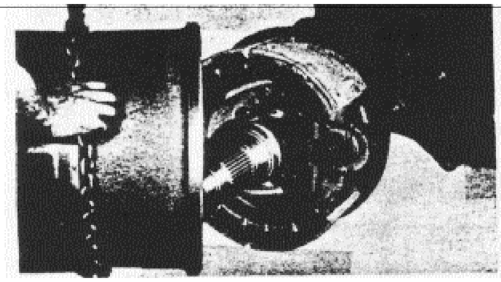


Fig. 24
Installing Hub and Drum

(j) Install wheel hub and brake drum assembly on axle housing. See brake adjustment, later in this section.

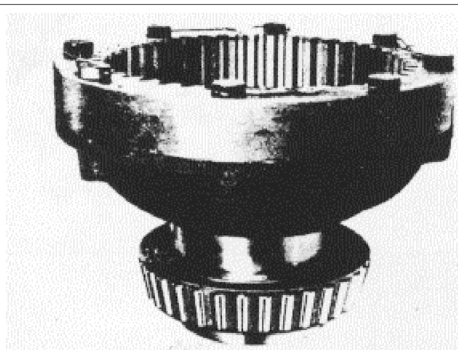


Fig. 25
Gear and Hub Assembly

(k) Internal gear and hub assembly showing sequence of parts. Tighten bolts to specified torque. (See torque chart, page 19 of 20). Lock wire bolts in pairs to prevent loosening.

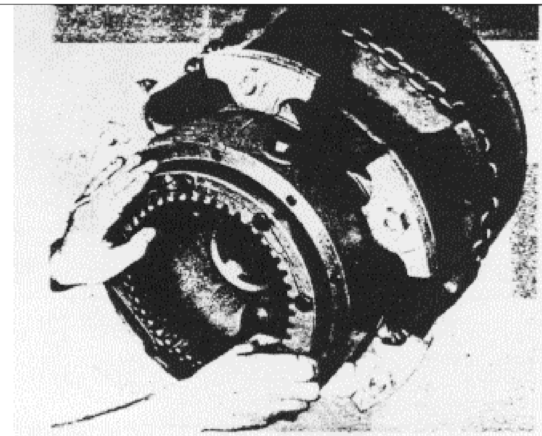


Fig. 26
Installing Gear and Hub

(1) Install internal gear, hub and bearing assembly on splines of spindle end.

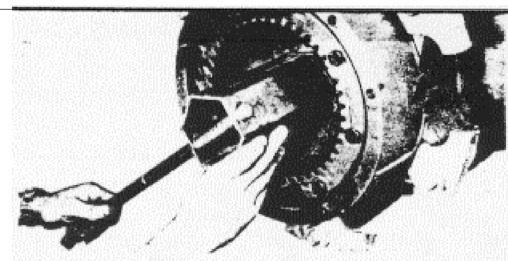


Fig. 27
Wheel Bearing Adjustment

(m) See wheel bearing adjustment, later in this section.

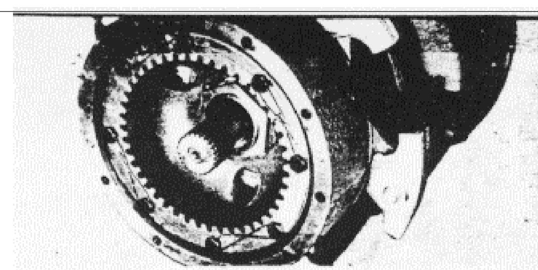


Fig. 28
Install Nuts

(n) When proper pre-load is achieved install adjusting nut lock and jam nut. Tighten jam nut to a higher wrench torque than the adjusting nut. Recheck rolling torque. Pre-load must not be greater than highest value shown on page 8 of 20. Bend two tangs of nut lock on flats of inner nut and two tangs on flat of jam nut.

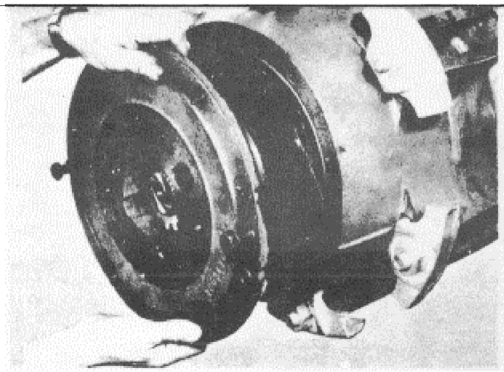


Fig. 29
Install Planetary

(o) Use Permatex No. 2 on Planetary assembly. Assemble planetary assembly to wheel hub.

Install axle shaft sun gear and retaining ring.

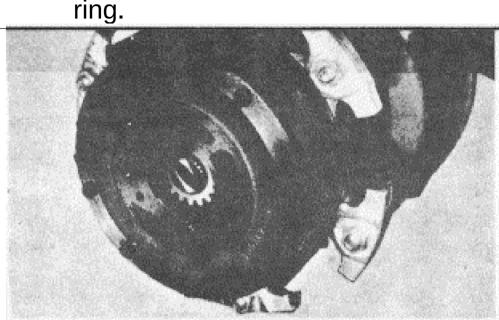


Fig. 30
Tighten Planetary Carrier Bolts

(p) Tighten planetary carrier to hub bolts to specified torque. (See torque chart, page 19 of 20).

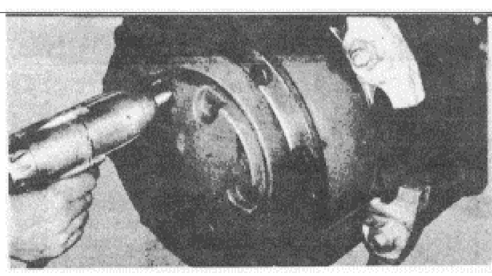


Fig. 31
Install End Cap

(q) Use Permatex No. 2 on thrust cap and install cap to planetary assembly. Tighten bolts to specified torque. (See torque chart, page 19 of 20).

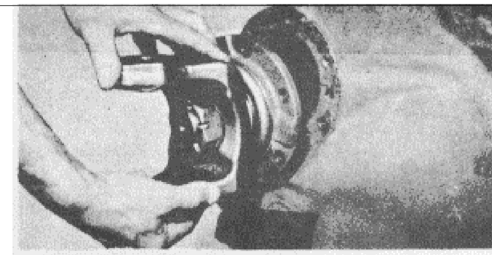


Fig. 32
Install Output Shaft

(r) Install output shaft assembly (front rear drive axle only) in axle housing, aligning splines of output shaft with internal splines of differential input shaft. Tighten cap-screws to specified torque. (See torque chart, page 19 of 20).

**6.3 Air Brake Adjustment**

After assembly of axle, adjust brake as follows:

(1) Use a torque wrench and socket to adjust slack adjusters to attain correct brake lining-to-brake drum clearance.
(2) Position socket on adjusting screw and press far enough to cause locking collar to disengage locking mechanism.
(3) While depressing collar, rotate adjusting screw clockwise until snug, approximately 20 ft-lbs torque.
(4) Back off adjusting screw one-half turn. Locking collar will automatically return to locking position to lock adjustment when socket is removed. This provides proper brake lining-to-drum clearance.

**6.4 Lubrication**

Camshaft at slack adjuster: At each grease job with chassis grease.

Camshaft at brake spider: Grease every 300 to 500 hours or 15,000 miles. Use E.P. Lithium Soap Base Grease No. 2. DO NOT OVER GREASE.

Note: <u>It is recommended brake dust cover be removed before greasing to be certain no grease enters the brake drum and lining area.</u>

**6.5 Drive Axle Wheel Bearing Adjustment Procedure**

Before wheel bearing adjustment is made, all tapered bearings and bearing cups must be pressed to full position in their respective locations. Do not depend on the wheel bearing adjusting nut to "shoulder" tapered bearings and cups.

(1) The wheel bearing adjusting nut should be tightened to its limit while rolling the wheel. Strike the rim and surrounding parts with a mallet to shock the wheel end and better seat the parts (cups and cones) that

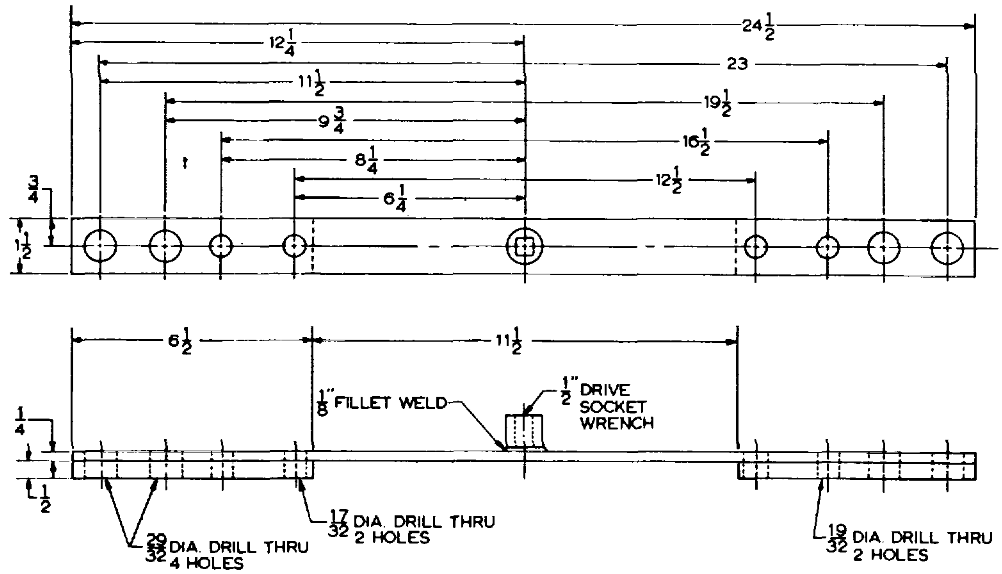



Fig. 33
Torque Wrench Adapter Bar

may not already be seated. Reverse the adjusting nut and again strike the rim with a mallet. Loosen adjusting nut until a slight bearing end play is detected.

(2) Using the torque wrench adapter bar shown in Fig. 33, determine the rolling torque of the wheel end with the bearings in a no-load end play condition. Due to unbalance of parts, etc., there will be a variation of rolling torque as the wheel hub is rotated. Record the maximum value of rolling torque throughout a revolution. This figure is the "no-load rolling torque" value.

(3) Using the following chart, tighten the adjusting nut to achieve a bearing pre-load in foot pounds above the "no-load rolling torque" value recorded. It is best to use the lowest pre-load value as the pre-load may increase when the Jam nut is installed and tightened. Also record wrench torque when tightening adjusting nut.

Example: 10 ft-lbs "No-load rolling torque"
7 ft-lbs "A" Series Axle (New Bearings)
17 ft-lbs Pre-loaded rolling torque 6.6 Adjusting NEW Tapered Bearings

(a) Drive Axles: All models thru FD and RD-37,500.

7 to 12 ft-lbs torque greater than "no-load rolling torque" value.

### 6.7 Readjusting USED Tapered Bearings

(a) Axle models same as "A" above.

3 to 5 ft-lbs torque plus no-load value.

### 6.8 Differential Removal

(a) Jack machine up until tires clear the ground. The hydraulic outriggers can be used for this purpose. Block securely under the frame so the machine cannot fall.
(b) Drain lubricant from differential.
(c) Refer to procedure on page 1 of 20. Remove' both axles from rear axle assembly.
(d) Disconnect the universal joint from the input shaft of the differential. Remove the capscrews which hold the differential to the axle housing.
(e) Remove the differential from the axle housing.

### 6.9 Differential Disassembly

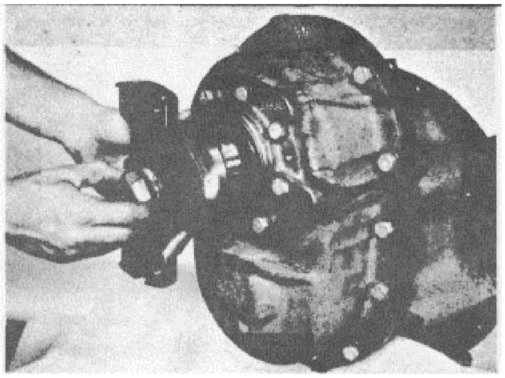


*Fig. 34*
*Removing Input Flange*

(a) Remove input flange bolt, washer, and input flange.

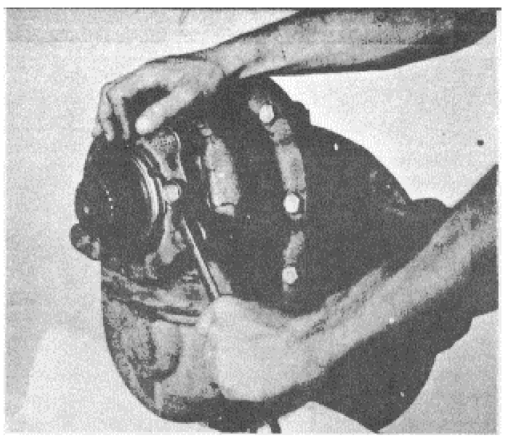


*Fig. 35*
*Removing Oil Seal Retainer*

(b) Remove oil seal retainer bolts. Install two bolts in threaded holes and use as jack screws to remove retainer.

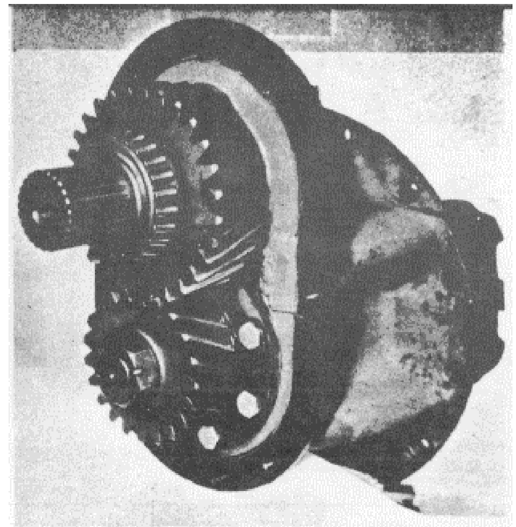


*Fig. 36*
*Removing Drop Gear Cover*

(c) Remove drop gear cover bolts. Remove drop gear cover.

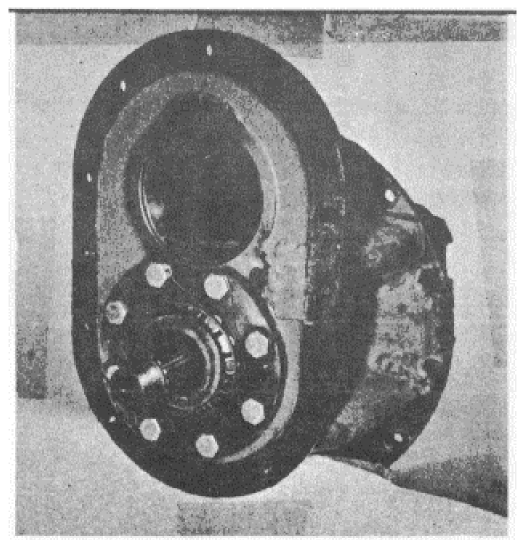


*Fig. 37*
*Removing Input Shaft*

(d) Remove the input shaft and taper bearings as an assembly. Remove nut cotter, nut and pinion gear.

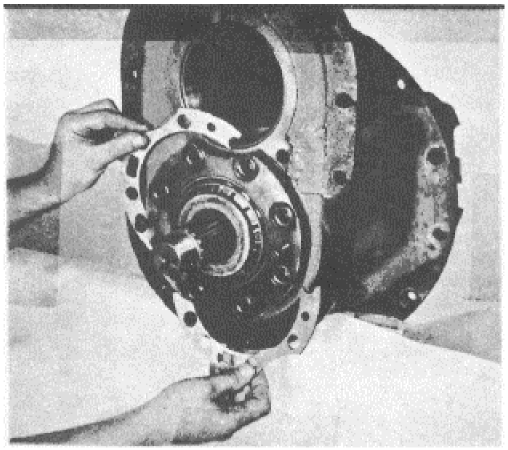


*Fig. 38*
*Removing Pinion Shaft*

(e) Remove pinion shaft and bearing cage assembly from housing.

Note: Jack screw holes are provided in bearing cage to facilitate disassembly. Use caution not to damage shims located between bearing cage and differential housing.

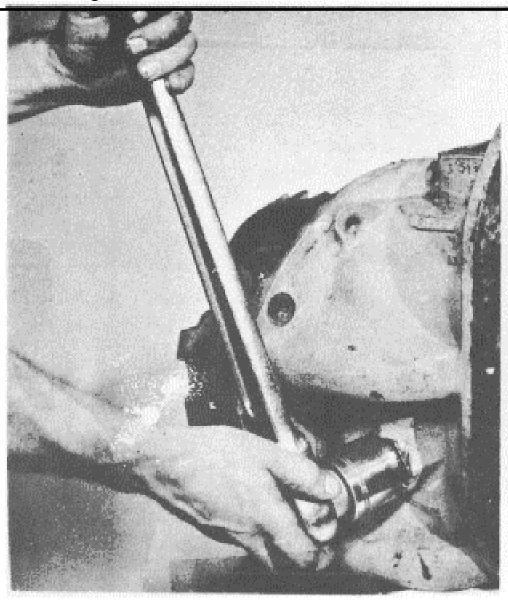


*Fig. 39*
*Removing Thrust Screw*

(f) Straighten tangs on thrust screw nut lock. Remove locknut and thrust screw.

*Fig. 40*
*Removing Bearing Lock*

(g) Remove differential bearing adjusting nut lock, screw and lock.

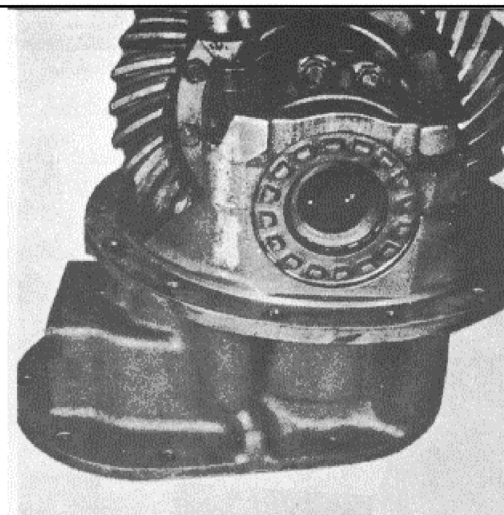


*Fig. 41*
*Removing Carrier Caps*

(h) Remove differential carrier caps.

Note: Each cap must be marked, as they must be reassembled on the same side as they were removed.

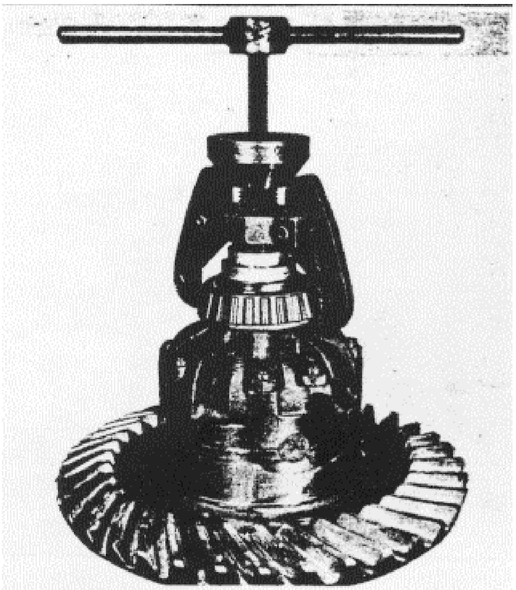


*Fig. 42*
*Removing Bearing*

(i) Remove ring gear and differential case assembly from carrier housing. Differential bearing may be removed, should either the bearing or differential case need replacing.

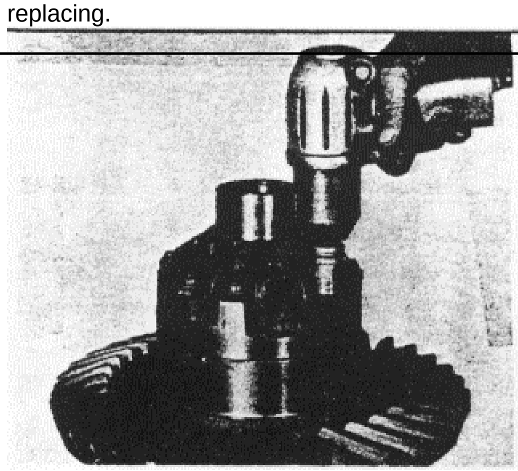


*Fig. 43*
*Removing Case*

(j) Differential plain case half and flange case half must be marked so they can be reassembled at the same place they were removed. Remove differential case bolts and nuts.

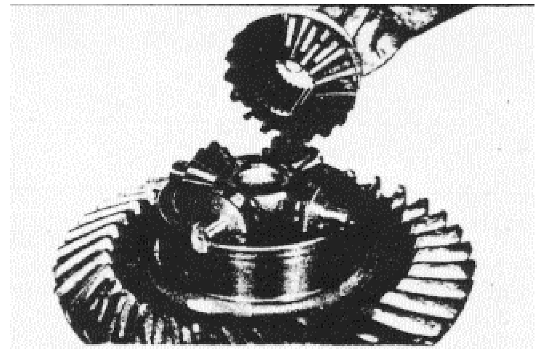


*Fig. 44*
*Removing Plain Half Case*

(k) Lift plain half case from flange half case.

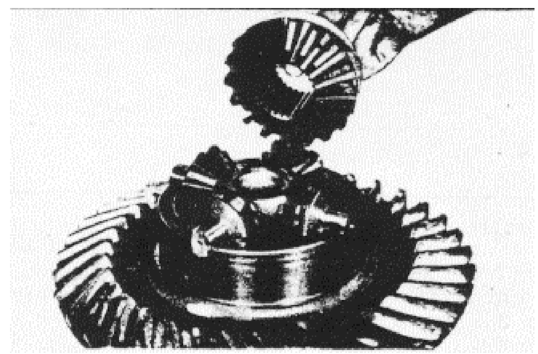


*Fig. 45*
*Removing Side Gear*

(1) Lift side gear and thrust washer from flange half.

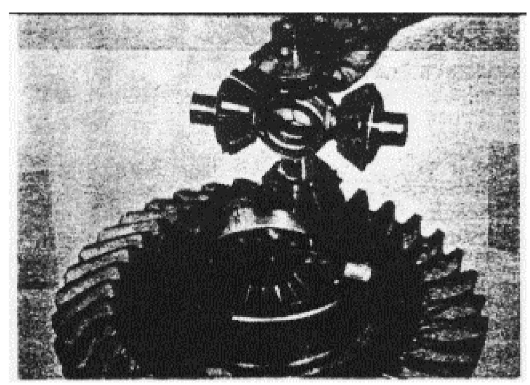


*Fig. 46*
*Removing Spider*

(m) Lift spider, differential pinions, thrust washers, inner side gear and thrust washer from flange half.

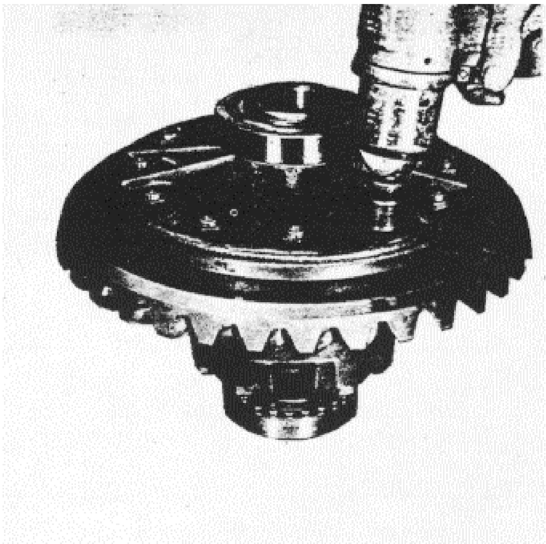


*Fig. 47*
*Removing Ring Gear*

(n) Procedure used to remove ring gear, when only ring gear and pinion are to be replaced. Pinion bearing cage may be pressed from pinion. Outer bearing will be removed with bearing cage. Center bearing and bearing spacer will remain on pinion .Pull center bearing from pinion. Press inner pinion bearing from pinion shaft.

**6.10 Inspection of Parts**

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames. Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Cleanliness of the respective parts is absolutely necessary in reassembling.Dirt in its many forms can and will cause trouble. Therefore, before reassembling the axle or differential or any of its parts be sure all parts have been thoroughly cleaned with a suitable cleaning fluid. After cleaning, all parts should be dried with moisture-free compressed air. A thorough visual examination of all parts should be made before reassembly. Any parts that show excessive wear or damage should be replaced. Small nicks or burrs may be removed with a hone or crocus cloth. It is recommended that all gaskets, oil seals, "0" rings and internal lockwashers be replaced.

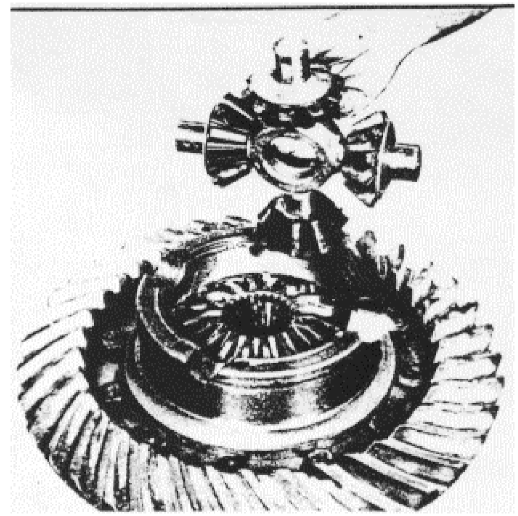


*Fig. 48*
*Installing Spider*

(a) Place side gear thrust washer and side gear in flange half of the differential. Assemble pinions and thrust washers on spider and place in position in flange half case.

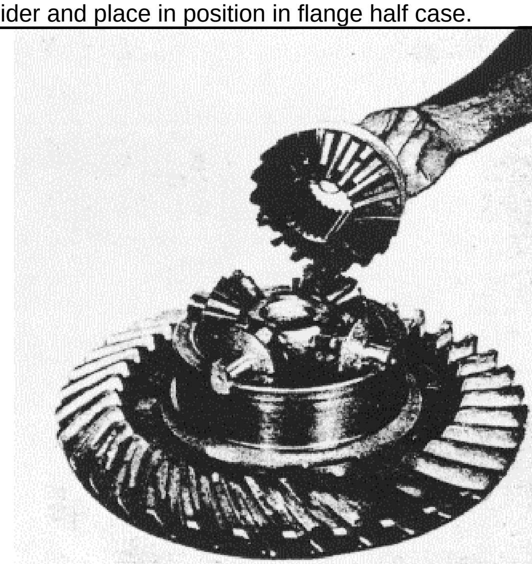


*Fig. 49*
*Installing Side Gear*

(b) Place side gear and thrust washer in position on pinions.

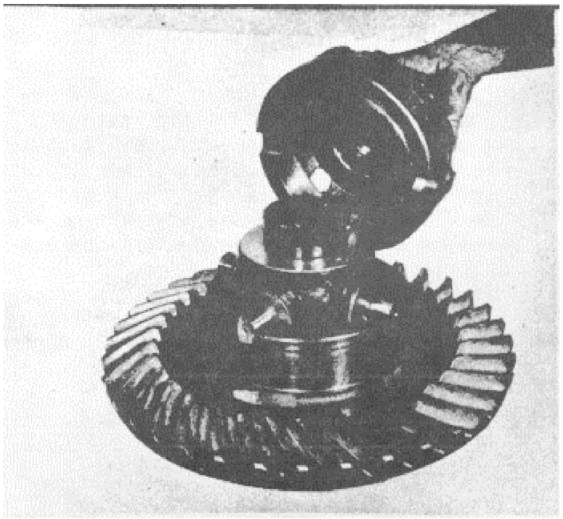


*Fig. 50*
*Installing Differential Case*

(c) Place plain half of differential case in position on flange half.

Note: Make certain matching marks of both halves are in alignment.

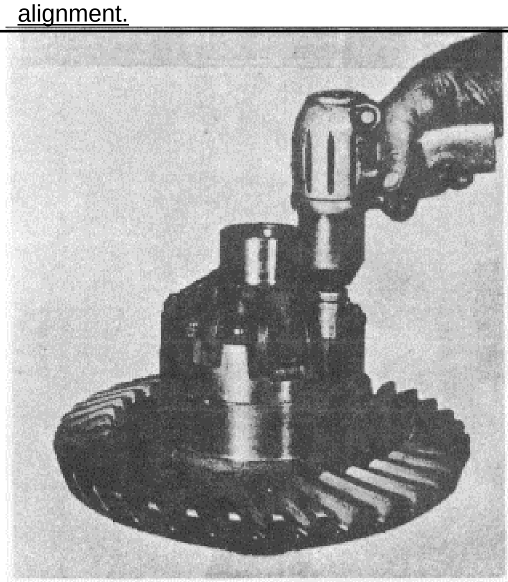


*Fig. 51*
*Installing Case Bolts*

(d) Install differential case bolts and self locking nuts. Tighten to specified torque. (See torque chart, page 19 of 20).

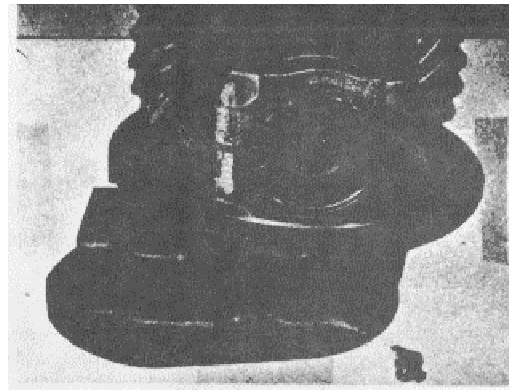


*Fig. 52*
*Installing Differential in Carrier*

(e) Press bearing cones and install differential and bearing assembly in differential carrier. Place adjusting nuts in position. Install differential carrier caps, do not tighten.

Note: Make certain carrier caps are reassembled on the same side they were removed.

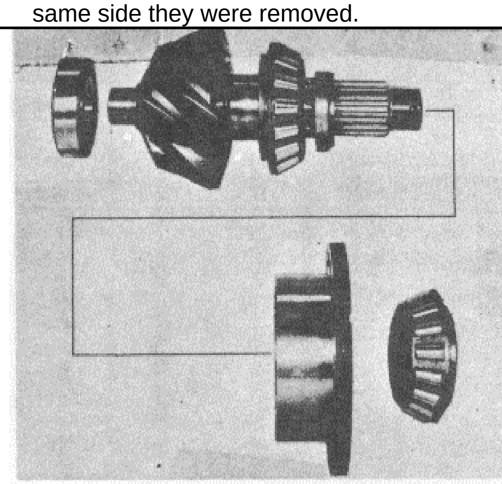


*Fig. 53*
*Pinion Shaft Parts* Sequence

(f) Assemble pinion and bearings as follows:

(1) Press center bearing cone onto pinion shaft, with rollers upward; then slide bearing spacer into place, making certain the inside chamfer is toward the cone. If the bearing cage does not require replacement, the spacer furnished as original equipment may be reinstalled. This spacer as provided in the original assembly is ground to proper length to obtain the specified bearing preload of 13 to 23 inch lbs. rolling pinion bearing resistance. Should a new pinion bearing cage or pinion bearings be used in reassembly, a service spacer and shim kit must be used.

(2) Press pinion bearing cups into bearing cage, then set cage and cup assembly in place over shaft and press outer cone onto pinion shaft and into position in cup. Maintain full pressure on the cone and check for proper bearing preload. To increase preload, shims may be removed; to decrease preload, shims may be added.

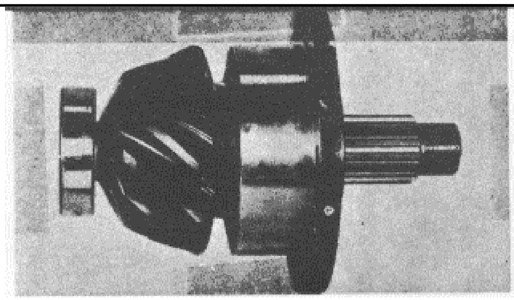


*Fig. 54*
*Pinion Shaft Assembly*

(g) Press pinion and bearing assembly into carrier until outer pinion bearing cage is approximately 1/4" from face of carrier. During this operation, be certain the oil return holes are in line.

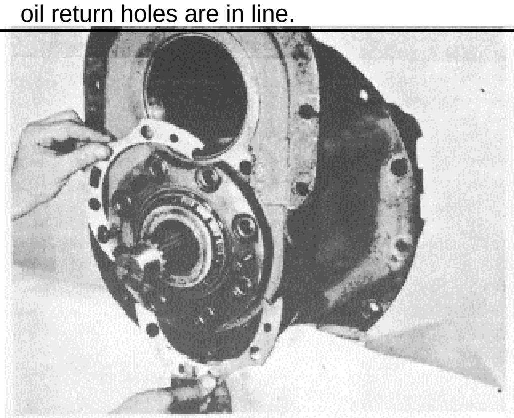


*Fig. 55*
*Installing Shims*

(h) Split shims are used to adjust pinion to ring gear contact. Remove jack screws from pinion bearing cage. Use the same thickness shims for reassembly as were removed at disassembly. Shims may be added or removed as required to move pinion inward or outward. Shims are installed between bearing cage and face of carrier. Draw pinion assembly into position by tightening bolts evenly.

(i) Adjust backlash to specification on backlash chart:

(1) If backlash is too great, back off adjusting nut on plain half of case and tighten opposite side until all lash is removed. Tighten nut on plain half case solidly to seat bearings. Back off nuts in flange side, one notch at a time and follow with opposite nut until correct backlash is obtained.

(2) If backlash is under minimum specifications, back off nut on flange half and tighten nut on opposite side. Operation should be done in one notch steps until correct backlash is obtained.

(3) Tighten carrier caps and recheck backlash. If backlash has changed, repeat above procedure to correct.

Note: Carrier cap bolts should be tightened to specified torque. (See torque chart, page 19 of 20).

Install pinion drop gear on pinion shaft (long hub outward). Place washer on shaft and install pinion nut. Tighten to specified torque (See torque chart; page 19 of 20).

Paint 3 or 4 teeth of the ring gear with red lead and rotate pinion by turning piston gear. Check tooth contact with tooth contact chart and correct by adding or omitting shims from the pinion bearing cage. After proper tooth contact and backlash is achieved, remove pinion gear and lockwire bearing cage bolts, reinstall pinion gear, nut and washer. Tighten to specified torque. (See torque chart, page 19 of 20).

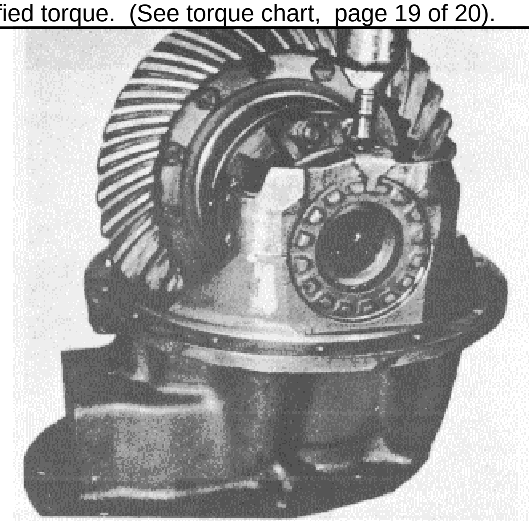


*Fig. 56*
*Installing Nut Locks*

(k) Install differential bearing adjusting nut locks and secure with screw and lockwasher. Tighten to specified torque. (See torque chart, page 19 of 20). Lockwire to prevent loosening.

(1) Thrust screw adjustment:

(1) Turn thrust screw (item No. 3) IN to contact ring gear (item No. 4).

(2) Install a dial indicator on end of thrust screw.

(3) Turn thrust screw AWAY from ring gear until a .012 reading is taken on the dial indicator. The specification is .010 to .015 distance from end of thrust screw to side of ring gear. .012 was used as an in-between reading.

(4) Hold thrust screw and tighten locknut.

Note: Dial indicator reading must not move during this operating. Bend one tang of nut lock over flat side of housing and one tanq over flat side of the locknut.

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*Fig. 57*
*Thrust Screw Adjustment*

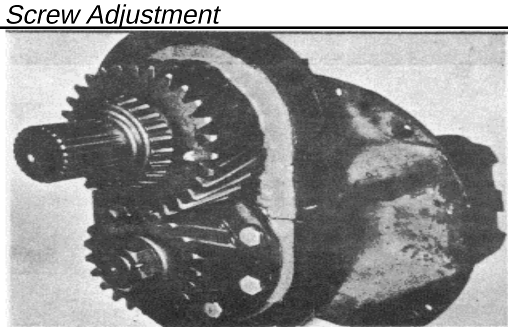


*Fig. 58*
*Installing Drop Gear*

(m) Press inner taper bearing (small diameter out) on rear of input shaft.
Install drop gear on input shaft.

Note: Drop gear is counterbored to prevent spline interferences. This counterbore must face rear input bearing.

Press outer taper bearing (small diameter out) on front of input shaft.

Install input shaft outer bearing cup in cup and seal retainer.

Install input shaft assembly in differential housing. Install drop gear cover.
Installing Seal Retainer

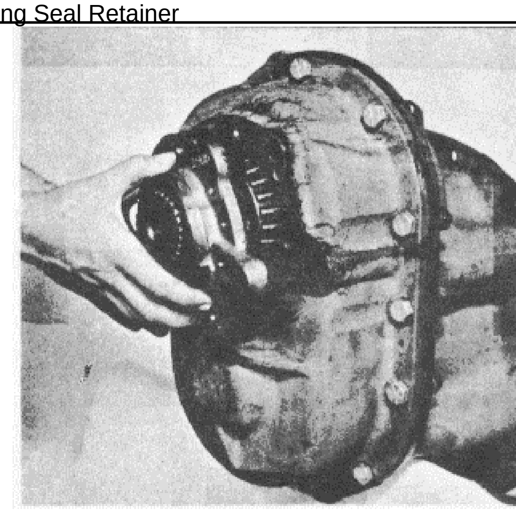


*Fig. 59*
*Installing Seal Retainer*

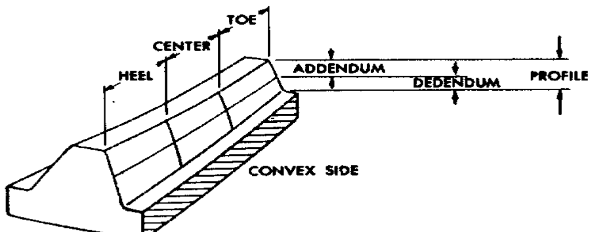
(n) Shims are used between drop gear cover and bearing cup and seal retainer.

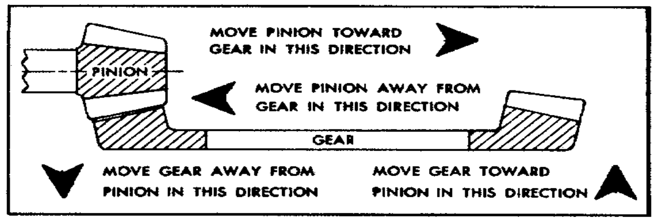
Shims are added or omitted to obtain a .004 to .006 end play on the input shaft.

Note: Bearing retainer bolts must be torqued each time shims are added or omitted.

After proper input shaft bearing adjustment is made, install input yoke. Coat entire end of input shaft with No. 2 permatex and install retaining washer and bolt. Tighten to specified torque (see torque chart, page 19 of 20). Lockwire bolt to prevent loosening.

## SPIRAL BEVEL AND HYPOID TOOTH BEARING CONTACT CHART




ALL CONTACT BEARINGS SHOWN BELOW ARE ON **RIGHT HAND** SPIRAL RING GEAR — THE DRIVE IS ON THE CONVEX SIDE OF THE TOOTH.

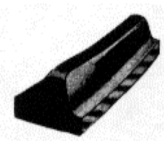


**FIG. 1**

TYPICAL PREFERRED BEARING ON BOTH SIDES OF TOOTH WHILE UNDER A LIGHT LOAD

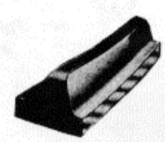


**FIG. 2**

TOE BEARING ON BOTH SIDES OF TOOTH — GEAR SET NOISY. TO MOVE BEARING TOWARD HEEL INCREASE BACKLASH WITHIN LIMITS BY MOVING GEAR AWAY FROM PINION.

**FIG. 3**

HEEL BEARING ON BOTH SIDES OF TOOTH — GEARSET NOISY AND COULD RESULT IN EARLY GEAR FAILURE. TO MOVE BEARING TOWARD TOE DECREASE BACKLASH WITHIN LIMITS BY MOVING GEAR TOWARD PINION.

**FIG. 4**

LOW BEARING ON GEAR AND HIGH BEARING ON PINION. CORRECT BY PULLING PINION AWAY FROM GEAR (INCREASE MOUNTING DISTANCE.

**FIG. 5**

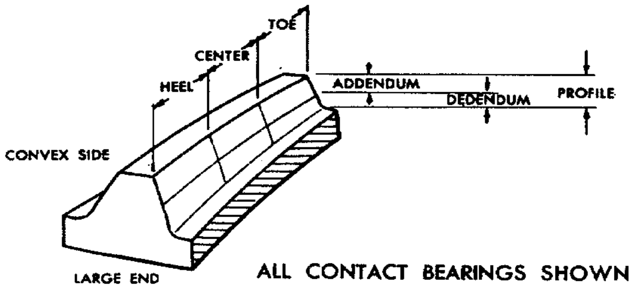
HIGH BEARING ON GEAR AND LOW BEARING ON PINION. CORRECT BY MOVING PINION IN TOWARD GEAR (DECREASE MOUNTING DISTANCE.

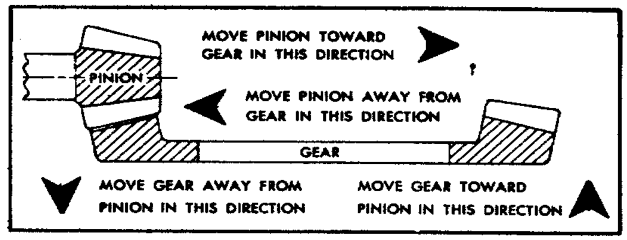
**BACKLASH**

BACKLASH SHOULD BE MEASURED WITH A DIAL INDICATOR RIGIDLY MOUNTED WITH THE STEM PERPENDICULAR TO THE TOOTH SURFACE AT THE EXTREME HEEL. SEE SHEET NO. 2 FOR BACKLASH VALUES.

*Fig. 60*
*Spiral Bevel And Hypoid Tooth Bearing Contact Chart*

## SPIRAL BEVEL AND HYPOID TOOTH BEARING CONTACT CHART




ALL CONTACT BEARINGS SHOWN BELOW ARE ON **LEFT HAND** SPIRAL RING GEAR — THE DRIVE IS ON THE CONVEX SIDE OF THE TOOTH.

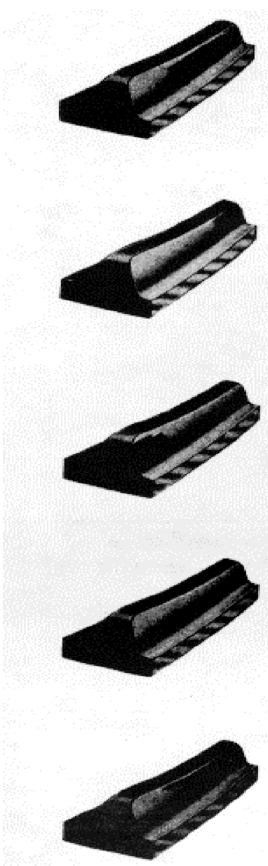


**FIG. 1**

TYPICAL PREFERRED BEARING ON BOTH SIDES OF TOOTH WHILE UNDER A LIGHT LOAD

**FIG. 2**

TOE BEARING ON BOTH SIDES OF TOOTH — GEAR SET NOISY. TO MOVE BEARING TOWARD HEEL INCREASE BACKLASH WITHIN LIMITS BY MOVING GEAR AWAY FROM PINION.

**FIG. 3**

HEEL BEARING ON BOTH SIDES OF TOOTH — GEARSET NOISY AND COULD RESULT IN EARLY GEAR FAILURE. TO MOVE BEARING TOWARD TOE DECREASE BACKLASH WITHIN LIMITS BY MOVING GEAR TOWARD PINION.

**FIG. 4**

LOW BEARING ON GEAR AND HIGH BEARING ON PINION. CORRECT BY PULLING PINION AWAY FROM GEAR (INCREASE MOUNTING DISTANCE.

**FIG. 5**

HIGH BEARING ON GEAR AND LOW BEARING ON PINION. CORRECT BY MOVING PINION IN TOWARD GEAR (DECREASE MOUNTING DISTANCE.

**BACKLASH**

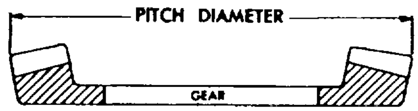
BACKLASH SHOULD BE MEASURED WITH A DIAL INDICATOR RIGIDLY MOUNTED WITH THE STEM PERPENDICULAR TO THE TOOTH SURFACE AT THE EXTREME HEEL. SEE SHEET NO. 2 FOR BACKLASH VALUES.

*Fig. 61*
*Spiral Bevel And Hypoid Tooth Bearing Contact Chart*

## BACKLASH - SPIRAL BEVEL GEARS

Do not adjust any gear set backlash less than the minimum noted on the chart below. The maximum values may be exceeded by .003 inches to .004 inches if necessary to obtain optimum tooth contact pattern.

If the mounting information on the gear set is available (some of the Clark gear-sets have specific mounting information etched on the ring gear) this takes precedence over the chart data.



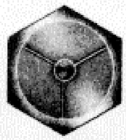

| RING GEAR PITCH DIAMETER | BACKLASH | RING GEAR PITCH DIAMETER | BACKLASH |
|---|---|---|---|
| 7.000 | .005-.010 | 20.000 | .012-.018 |
| 7.500 | .005-.010 | 20.500 | .012-.018 |
| 8.000 | .006-.011 | 21.000 | .012 -.018 |
| 8.500 | .006-.011 | 21.500 | .012-.018 |
| 9.000 | .006-.011 | 22.000 | .013 -.019 |
| 9.500 | .006-.011 | 22.500 | .013-.019 |
| 10.000 | .006- .011 | 23.000 | .013-.019 |
| 10.500 | .007-.012 | 23.500 | .013-.019 |
| 11.000 | .007-.012 | 24.000 | .013-.020 |
| 11.500 | .007- .012 | 24.500 | .014-.021 |
| 12.000 | .008-.013 | 25.000 | .014-.021 |
| 12.500 | .008-.013 | 25.500 | .014-.021 |
| 13.000 | .008-.013 | 26.000 | .014-.021 |
| 13.500 | .008-.013 | 26.500 | .015-.022 |
| 14.000 | .009- .014 | 27.000 | .015-.022 |
| 14.500- | .009- .014 | 27.500 | .015- .022 |
| 15.000 | .009- .014 | 28.000 | .015-.022 |
| 15.500 | .009- .015 | 28.500 | .015-.022 |
| 16.000 | .009- .015 | 29.000 | .016-.023 |
| 16.500 | .010-.016 | 29.500 | .016-.023 |
| 17.000 | .010 -.016 | 30.000 | .016 -.023 |
| 17.500 | .010-.016 | 30.500 | .016 -.023 |
| 18.000 | .010 -.016 | 31.000 | .017-.024 |
| 18.500 | .010 -.016 | 31.500 | .017 - .024 |
| 19.000 | .010-.016 | 32.000 | .017-.024 |
| 19.500 | .010 -.016 | 32.500 | .017-.024 |

*Fig. 62*
*Backlash Chart*

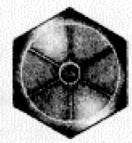
**TORQUE IN (LIBS.-FT.)**
**BOLTS, CAPSCREWS, STUDS AND NUTS**

Grade 5 Identification, 3 Radial Dashes 1200 Apart on Head of Bolt

Grade 8 Identification, 6 Radial Dashes 600 Apart on Head of Bolt



Grade 5



Grade 8

| COARSE THREADS | Dry | Lubricated or Plated | Dry | Lubricated or Plated |
|---|---|---|---|---|
| 3/8-16 | 31-34 | 23-25 | 44-48 | 33-36 |
| 7/16-14 | 49 - 54 | 37 -A41 | 70 -77 | 52- 57 |
| 1/2-13 | 75 -83 | 57 - 63 | 106 -117 | 80 - 88 |
| 9/16-12 | 109-120 | 82 - 90 | 153--168 | 115-127 |
| 5/8-11 | 150-165 | 113 -124 | 212 -233 | 159- 175 |
| 3/4-10 | 266 -293 | 200 -220 | 376-414 | 282- 310 |
| 7/8-9 | 394 - 433 | 296 - 326 | 606 -667 | 455 -- 501 |
| 1-8 | 591 - 649 | 443 - 489 | 909 -1000 | 682 - 750 |
| 1l/8 -7 | 794 - 873 | 596 - 656 | 1288 -1417 | 966 -1063 |
| 11/4- 7 | 1120 -1232 | 840 -924 | 1817-1999 | 1360 - 1496 |

| FINE THREADS | Dry | Lubricated or Plated | Dry | Lubricated or Plated |
|---|---|---|---|---|
| 3/8-24 | 35 -39 | 26-29 | 49 -54 | 37-41 |
| 7/16 - 20 | 55 - 61 | 41 -45 | 78 - 86 | 58 -64 |
| 1/2- 20 | *85* - 94 | 64 -170 | 120-132 | 90-99 |
| 9/6-18 | 121-133 | 91-100 | 171-188 | 128 -141 |
| 9/6-18 | 170 - 187 | 128 -141 | 240-264 | 180-198 |
| 3/4-16 | 297 - 327 | 223 - 245 | 420 - 462 | 315-- 347 |
| 7/-14 | 434 - 477 | 326 -359 | 668-735 | 501 -550 |
| 1--12 | 646 - 711 | 485 - 534 | 995 - 1096 | 746-821 |
| 1/8 - 12 | 891-980 | 668-735 | 1445 -1590 | 1083 - 1191 |
| 11/4-12 | 1240-1364 | 931-1024 | 2012-2213 | 1509-- 166.0 |

*Fig. 63*
*Torque Chart*

## 6.11 Differential Installation

(a) Clean the area on the differential and the housing where the two parts meet. Install a new gasket. Install the differential in the housing.

(b) Install mounting capscrews. Tighten per torque chart.

(c) Connect the U-joint to the input flange. Tighten mounting capscrews.

(d) Refer to procedure on page 4 of 20. Install rear axles.

(e) Fill differential with lubricant. Refer to Lubrication Chart for proper type and amount of lubricant to use.

(f) Raise the machine on hydraulic outriggers. Remove blocking.

(1) Insufficient Brakes
(a) Brakes need adjusting, lubricating or relining
(b) Low air pressure in the brake system (Below 60 P.S.I.).
(c) Brake valve delivery pressure below normal.
(d) Wrong size actuators and/or slack adjusters.
(e) Failure of part of dual air brake system.

(2) Brakes Apply Too Slowly
(a) Brakes need adjusting or lubricating.
(b) Low air pressure in the brake system. (Below 60 P.S.I.).
(c) Insufficient brake valve delivery pressure.
(d) Excessive leakage with brakes applied.'
(e) Restricted tubing or hose.
(f) Treadle travel restricted.

(3) Brakes Release Too Slowly
(a) Brakes need adjusting or lubricating.
(b) Brake valve not returning to fully released position.
(c) Restricted tubing or hose.
(d) Exhaust port of brake valve, quick release valve or relay valve restricted or plugged.
(e) Faulty brake valve, quick release valve, or relay valve.

(4) Brakes Do Not Apply
(a) No air pressure in system.
(b) Restricted or broken tubing or hose.
(c) Faulty brake valve.

(5) Brakes Do Not Release
(a) Brake rigging binding.
(b) Brake valve not in fully released position.
(c) Faulty brake valve or relay valve.
(d) Restricted or collapsed tubing or hose.

(6) Brakes Grab Or Erratic Brake
(a) Grease on brake linings, reline brakes.
(b) Faulty brake valve or relay valve.
(c) Brake rigging binding.
(d) High brake pressure.

(7) Uneven Brakes
(a) Brakes need adjusting. lubricating, or relining.
(b) Improper axle mounting.
(c) Grease on brake lining, reline brakes.
(d) Brake shoe return spring broken.
(e) Brake drum out of round.
(f) Brake chamber diaphragm failure.
(g) Wrong brake lining.
(h) Broken slack adjuster or foundation brake parts.

(8) Air Pressure Will Not Rise To Normal
(a) Faulty air gauge (registering incorrectly).
(b) Excessive valve or fitting leakage.
(c) Governor out of adjustment.
(d) Slipping compressor belt.
(e) Faulty compressor.
(f) Broken supply line.

(9) Air Pressure Rise To Normal Too Slowly
(a) Excessive valve or fitting leakage.
(b) Excessive reservoir volume.
(c) Clogged compressor or strainer.
(d) Engine speed too slow.
(e) Compressor discharge valve or inlet valves leaking.
(f) Compressor drive belt slipping or faulty drive coupling.
(g) Worn compressor.
(h) Excessive carbon in compressor cylinder head or discharge line.

(10) Air Pressure Rises Above Normal
(a) Faulty air gauge (register incorrectly).
(b) Governor out of adjustment.
(c) Faulty governor and safety valve.
(d) Restriction in line between governor and compressor or restricted unloading valve.
(e) Too much clearance at compressor or unloader valves or compressor unloading mechanism stuck in closed position.

(11) Air Pressure Drops Quickly With Engine Stopped And Brakes Released
(a) Leaking brake valve.
(b) Leaking tubing or hoses.
(c) Compressor discharge valves leaking.
(d) Governor leaking.
(e) Excessive leakage elsewhere in the air brake supply system.
(f) Excessive water in reservoirs.
(g) Inadequate reservoir volume, high air demand.

(12) Air Pressure Drops Quickly With Engine Stopped And Brake Fully Applied.
(a) Leaking brake chamber, actuator, roto-chamber or brake cylinder.
(b) Valve left open.
(c) Leaking brake valve.
(d) Leaking tubing or hose line.
(e) Excessive water in reservoirs. Inadequate reservoir volume.

(13) Compressor Knocks Continuously Or Intermittently
(a) Loose drive pulley.
(b) Back lash in drive gears or drive coupling.
(c) Worn or burnt out bearings.
(d) Excessive carbon deposits in compressor cylinger head.

(14) Safety Valve "Blows Off"
(a) Safety valve out of adjustment.
(b) Air pressure in the air brake system above normal due to faulty unloader mechanism or faulty governor.

(15) Excessive Oil Or Water In The Brake System.
(a) Reservoirs not being drained often enough.
(b) Compressor passing excessive oil.
(c) Compressor air stainer restricted.
(d) Excessive engine oil pressure.
(e) Back pressure from engine crankcase.
(f) Excessive oil (flooding) in compressor crankcase.

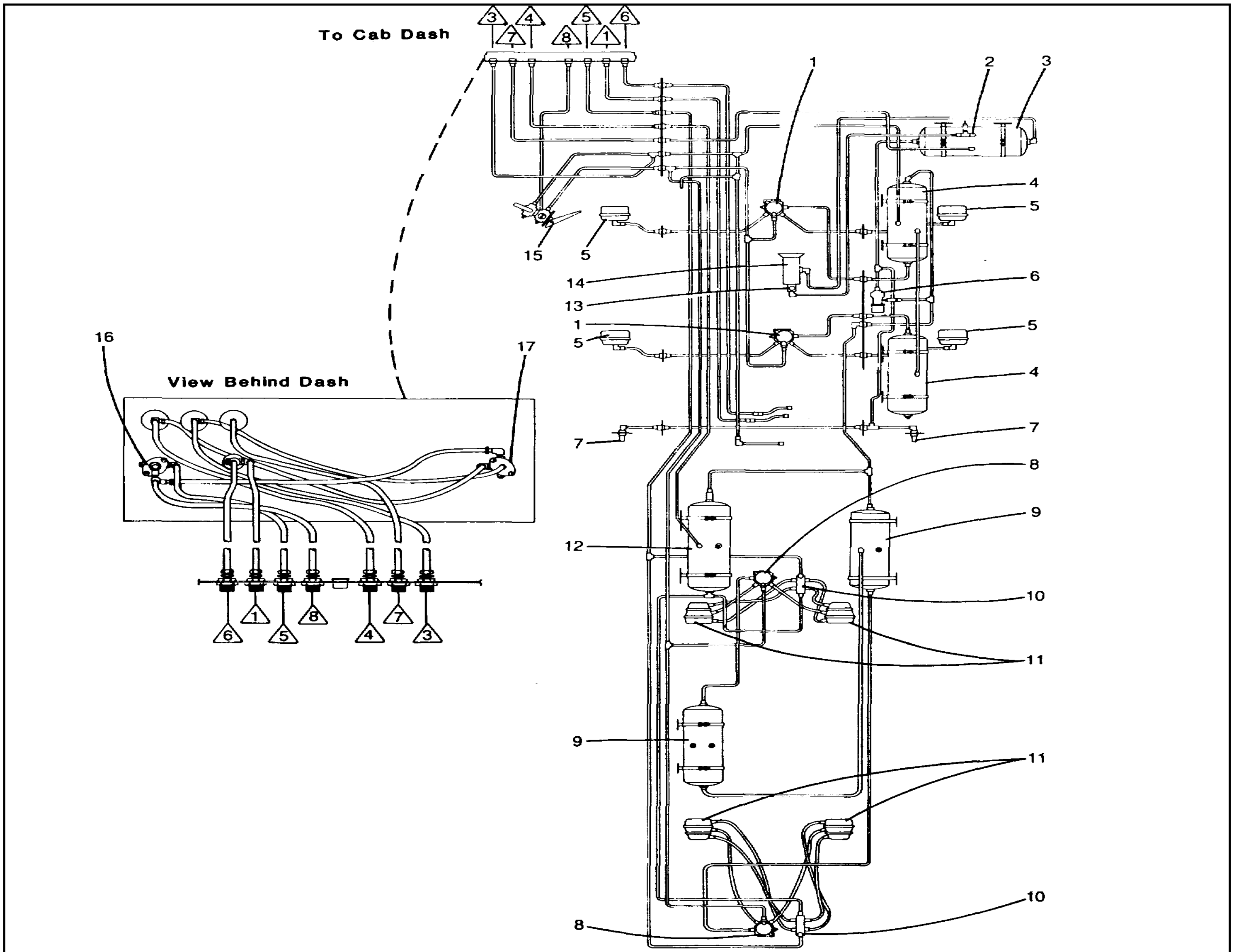



*Fig. 1*
Air Brake System

| | | | |
|---|---|---|---|
| (1) Front Relay Valves | (6) Pressure Reducing Valve | (11) Rear Brake Chambers | (16) Park/Emergency Control Valve |
| (2) Safety Valve | (7) Service Outlets | (12) Park/Emergency Reservoir | (17) Reserve Air Control Valve |
| (3) Wet Reservoir | (8) Rear Relay Valves | (13) Governor | |
| (4) Front Service Reservoirs | (9) Rear Service Reservoirs | (14) Compressor | |
| (5) Front Brake Chambers | (10) Inversion Valves | (15) Foot Brake Valve | |

### 3.1 Air Brake Control System (Refer to Fig. 1)

The 238A carrier has eight wheel air brakes. The system as a whole will be divided into several separate systems which perform individual functions: (A) a normal service brake application, (B) an emergency/park brake application, (C) the emergency/park brake reservoir. This protected reservoir stores air under pressure which is required to make an emergency stop if the normal service brake system becomes inoperative.

### 3.2 Compressor(14)

Air passes through the strainer and inlet valves and enters the cylinders where it is compressed by the pistons and forced past discharge valves into the wet reservoir (3). When the compressor regulator cuts out, a piston type unloader mechanism in the cylinder block is actuated, holding the intake valves off their seats and stopping further compression of air. When the reservoir pressure drops below the minimum governor setting, the governor (13) cuts in forcing the unloader piston down. This allows the intake valves to operate and compression will resume.

Note: Should it be necessary to drain the engine cooling system to prevent damage from freezing water, drain the compressor also.

### 3.3 Governor (13)

The governor controls the actual compression of air by the compressor (14). As the wet reservoir (3) pressure reaches approximately 150 P.S.I., the air pressure acts against a spring loaded diaphragm and piston within the governor. The movement of this piston opens a passage and allows air to flow through the governor’s operate an unloading mechanism within the compressor stopping further compression of-air.

As the reservoir pressure reduces to the minimum pressure setting of approximately 125 P.S.I., the spring loaded diaphragm and piston within the governor overcomes the air pressure and shuts off and exhaust the flow of air to the compressor unloading mechanism and compression is resumed.

### 3.4 Pressure Reducing Valve (6)

The pressure reducing valve, reduces the pressure put out by the compressor (14). Two service outlets (7) are available for tire inflation. 150 P.S.I. pressure is required. But, the remainder of the air control system does not require that high a pressure. The remainder of the system operates at a pressure reduced by the pressure reducing valve from 150 P.S.I. to approximately 110 P.S.I Pressure going into the valve is 150 P.S.I Pressure coming out of the valve is 110 P.S.I

### 3.5 Safety Valve (2)

The safety valve protects the air brake system against the possibility of excessive pressure. It is located at the wet reservoir (3) and is set at 175 P.S.I

### 3.6 Brake Chambers (5 & 11) And Slack Adjusters

The brake chambers and slack adjusters convert the energy of compressed air into a mechanical force to expand the brake shoes against the brake drum when making a braking application. This conversion takes place due to air pressure working against a diaphragm and push rod. Two types of brake chambers are used. The front wheel brakes have the conventional one chamber (5), diaphragm type while the rear wheel brakes offer a new concept, Each brake chamber (11) has three separate air cavities within: (A) service brake cavity, (B) parking or emergency brake cavity and (C) a mechanical locking cavity. The function of each will be described inseparate SM's. See index page.

### 3.7 Relay Valves (1 & 9)

The relay valves acts as a relay station to speed up the application and release of the brakes. During normal operation, the relay valve synchronizes the application of the service brake pedal with the brake chambers (5 & 11). As the foot pedal is depressed, air pressure triggers the relay valves and opens porting within which directly connects the service reservoirs (4 & 12) instantly actuating the brakes. With the release of the brake pedal the air in the brake chambers is exhausted through a quick release valve built within the relay valves.

### 3.8 Foot Brake Valve (15)

The foot brake valve controls operation of the service brakes. As the foot pedal is depressed, reservoir pressure is directed to the relay valves (1 & 9) triggering them as described previously.

### 3.9 Foot Brake Valve Maintenance

Lubricate the roller and treadle pin every 200 hours with engine oil. Lift the boot away from the plunger and put a few drops of light engine oil between the plunger and mounting plate. Avoid using too much oil as it could get on the rubber spring and cause it to deterlorate.

**Clean the exhaust check if necessary.**

3.10 Park/Emergency Control Valve (16) This control valve is normally "in". When required to make a normal parking brake application or, if necessary, make an emergency stop the control valve is pulled out. This action directs air from the emergency reservoir (8) to the rear tandem brake chambers (11).

### 3.11 Reserve Air Control Valves (17)

This control valve should normally be in the "out" position. When reserve air is required the control valve is to be pushed in.

If pressure should be lost in the front and/or rear air reservoirs, making the service brakes inoperative, the emergency brakes automatically apply. To move the vehicle a short distance, off the road or etc., pushing in on the reserve air to unlock the emergency brakes, allows the machine to be moved a short distance, and still supplies enough air to make one more emergency brake application to make a final stop of the vehicle.

### 3.12 Inversion Valves (10)

The inversion valves control and directs the flow of air to certain air cavities within the rear brake chambers (11) all dependent upon what brake application or function the air system is called upon to do.

During normal operation, the inversion valve directs air to the lock ports of the rear brake chambers. This action holds a mechanical locking mechanism in the unlocked position allowing normal operation of the service brakes. But, when the park or emergency brake is applied it is the action of the inversion valve which directs the flow of air from the emergency reservoir (8) to the parking or emergency port of the rear brake chambers.

The inversion valve also acts as a safety valve. When the pressure drops to an unsafe condition, spring tension on a piston within the valve body shifts a spool so that pressure is directed to the emergency port and cavity automatically applying the rear brakes.

### 3.13 Low Air Warning System

As long as the system air pressure remains above 60 pounds, contact points within the low pressure sending unit are held apart preventing electric current from actuating the warning buzzer. If and when air pressure drops below 60 i 6 pounds the contact points close thus operating the warning system.

THERE MUST BE AT LEAST 60 POUNDS OF AIR PRESSURE IN THE SYSTEM BEFORE MOVING THE CARRIER. While driving, periodically observe the gauge on the cab dash. If the air pressure drops to a low point or should the warning buzzer sound, immediately stop the carrier and correct the problem.

### 3.14 Air Brake System Operation

Fig. 2 illustrates the flow of air when all air controls are in their respective neutral position for normal operation. Which keeps the rear locking mechanism unlocked. The compressor is delivering maximum air pressure to the reservoirs and supply lines.

When the foot brake pedal is depressed making a normal service brake application, air pressure from the supply line passes through the foot brake valve in two directions: (A) to the front relay valves, triggering them to supply air from the front service reservoirs to the front brake chambers; and (B) to the rear relay valves, triggering them to supply air from the rear service reservoir directly to the service port of the rear brake chambers (11). (Refer to Fig. 3),

In making a NORMAL park or emergency brake application, the corresponding control valve on the cab dash is pulled out. In doing this, two things happen: (A) the supply line running through the park/emergency control valve to the inversion valves and onto the lockports of the rear brake chambers is opened to the foot brake valve. It is vented to the atmosphere any time the pedal is in the released position. With this line vented to atmosphere, a spring shifts a piston within the inversion valves causing air to be directed from the emergency reservoir to the emergency/parking port on the rear brake chambers; (B) When the supply line to the inversion valves and lockports vent to a atmosphere, a spring forces a locking mechanism to contact the brake chamber push rod.

This locking mechanism is a safety device designed to lock the push rod ONLY WHEN A LOSS of air pressure starts to move and release the rear brakes. At this time a series of rollers wedge in against the push rod causing a mechanical lock up, eliminating the requirement of air pressure to hold the machine.

Most of the before mentioned material deals only when the air system is operating ideally with no external air leaks or component malfunctions. To be realistic we must assume air leaks can develop and component failures are possible.

Should air pressure drop more than 4 P.S.I. after applying the parking brake, as may be the cause during overnight parking, the locking mechanism automatically wedges against the push rod keeping the rear brakes applied. Then as the carrier is started in the morning, air pressure is directed to the locking mechanism but cannot release the rollers because of the wedging action. To release the emergency brakes after a loss of air pressure has engaged the locking mechanism, proceed as follows:
(a) Start the carrier engine, and build up air pressure in the braking system.
(b) Push in on the parking brake valve.
(c) Make a foot brake application. Depress the pedal to the floor, and hold for a least ten seconds.
(d) Release the foot brake pedal.

In the event the system pressure drops drastically, the emergency control valve and the inversion valves automatically trip at 40 P.S.I. and apply the emergency brakes (Fig. 4). To move the vehicle after an emergency stop, to get off the highway or etc., proceed as follows:

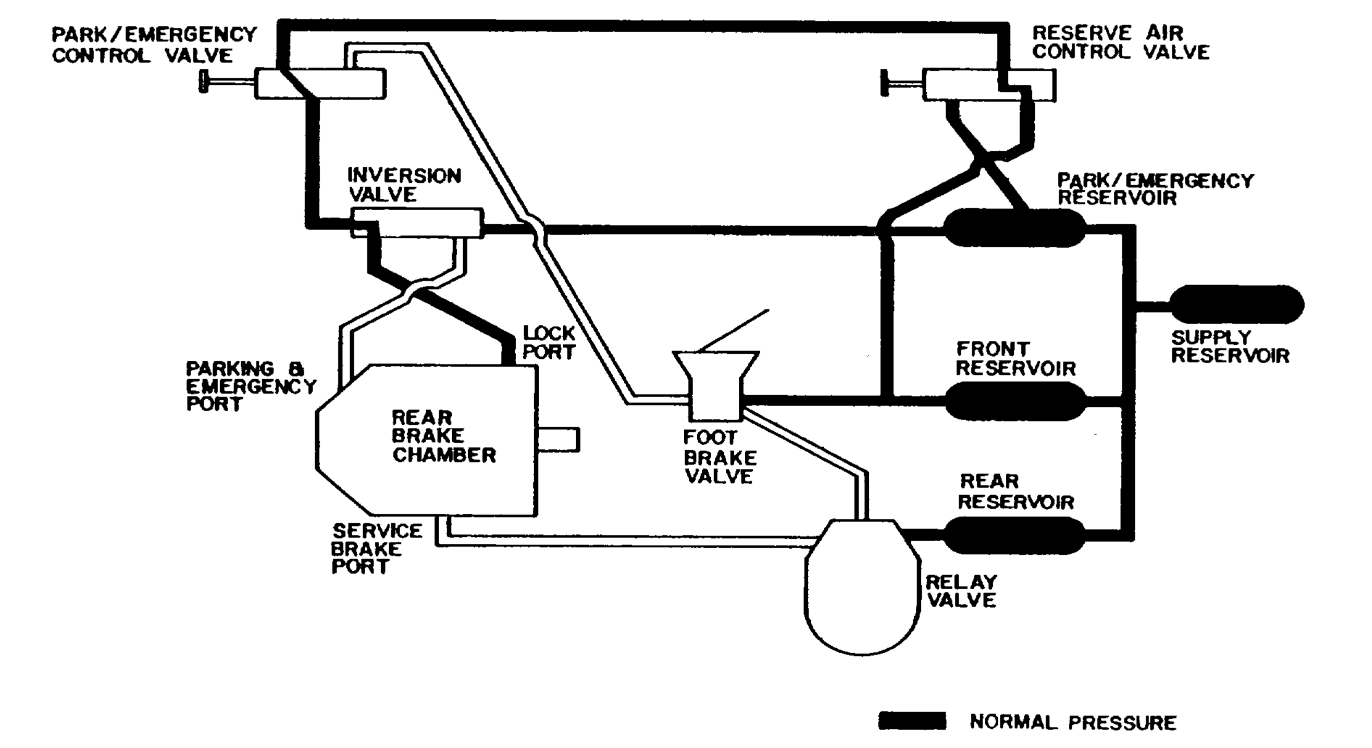



*Fig. 2 NA369-A*
*Normal Operation*

(a) Push in and hold the reserve air control valve (17).
(b) At the same time, push in on the emergency brake control valve .(16).
(c) Move the carrier off the road.
(d) Pull the emergency control valve, for one final brake application.

Important: When operating from the upper the carrier transmission must be in neutral, parking or emergency brake applied.

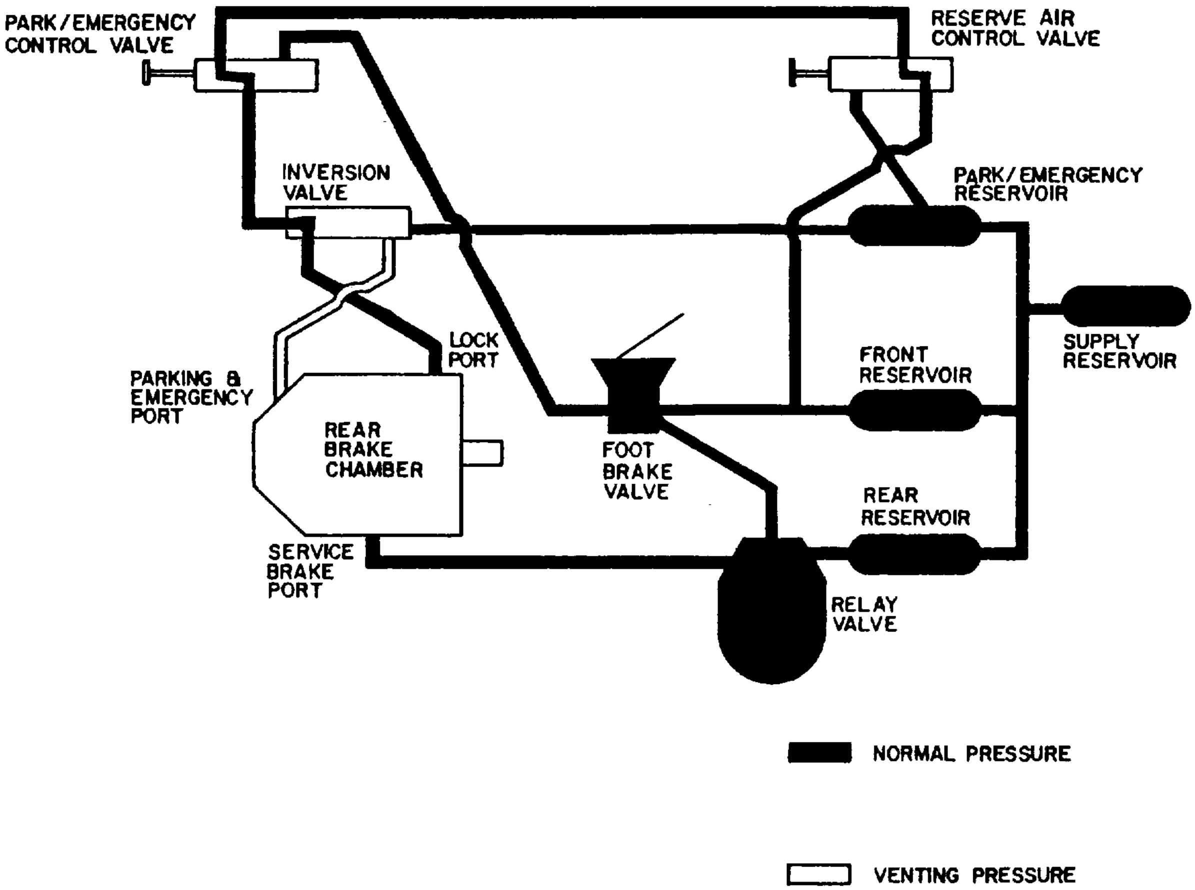



*Fig. 3 NA370-A*
*Normal Operation Applying Service Brakes*

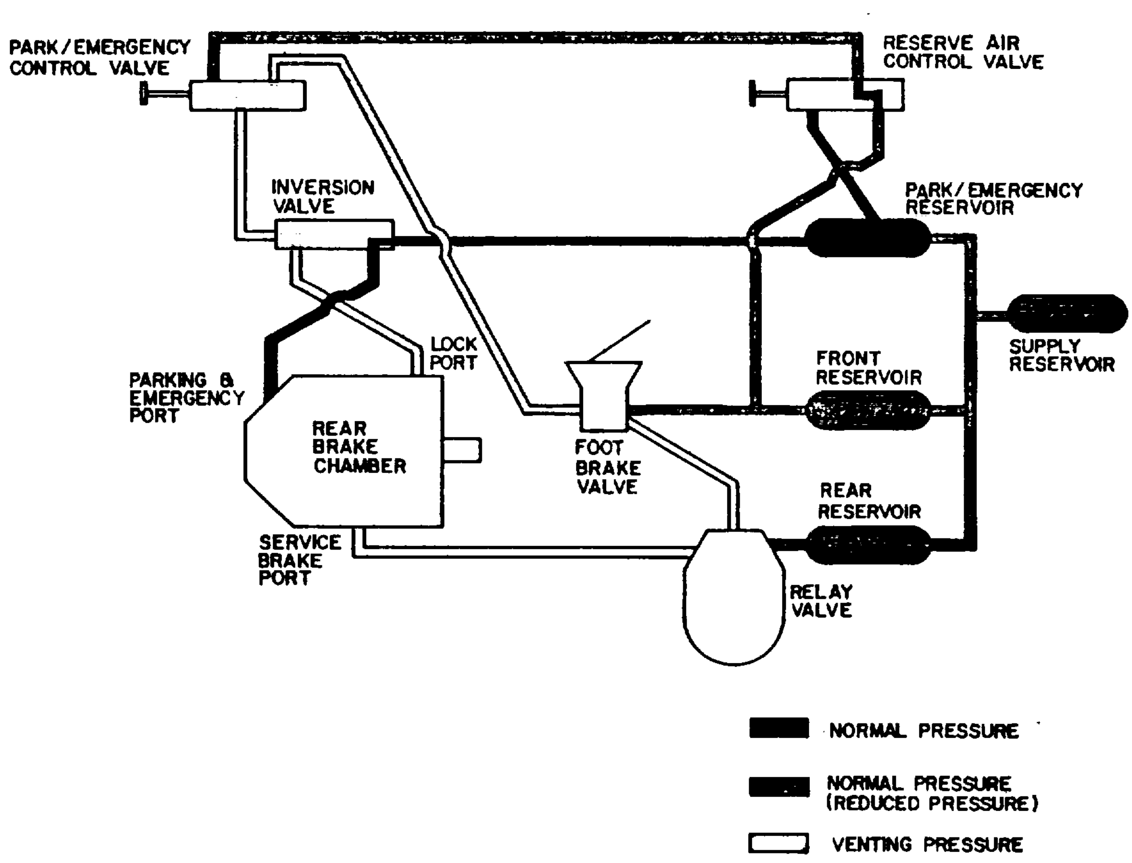



*Fig. 4*
*Normal Parking (Emergency Locking Mechanism*)

Trouble Shooting Hydraulic Outriggers

| Problem | Probable Causes |
|---|---|
| (1) Beams Won't Extend Or Retract | (1) Defective beam switch, or electrical connection.<br>2) Relief valve pressure too low on 3/8" valve stack.<br>(3) Mechanical interference between beam and housing.<br>(4) Defective solenoid valve.(Valve spool stuck, or solenoid not working). *<br>(5) Hydraulic system oil too heavy.<br>(6) Defective flow divider.<br>(7) Blockage in lines or hoses.<br>(8) Pump or power take off failure.<br>(9) Clogged inlet strainer in sump tank.<br>(10) Collapsed inlet hose. |
| (2) Jacks Won't Extend Or Retract | (1) Defective jack switch or electrical connection.<br>(2) Relief valve pressure too low on either valve stack.<br>(3) Defective blocking valve (valve spool stuck, or solenoid not work-<br>(4) Defective solenoid valve (valve spool stuck, or solenoid not working). *<br>(5) Lock valve or jack stuck. (Spool won't shuttle).<br>(6) Blockage in pilot pressure line or porting.<br>(7) Hydraulic system oil too heavy.<br>(8) Blockage in lines or hoses.<br>(9) Pump or power take off failure.<br>(10) Clogged inlet strainer in sump tank. |
| (3) Jack Extends But Won't Lift Machine | (1) Relief valve set too low.<br>(2) Defective pump.<br>(3) Leaky valve spools (solenoid and blocking valves).<br>(4) Internal leakage in jack lock valves.<br>(5) Defective cylinder packing. |
| (4) No Pressure In Beam Circuit | (1) Faulty relief valve in 3/8" valve stack.<br>(2) Faulty flow divider. |
| (5) No Pressure In Jack Circuit | (1) Faulty relief valve in either valve stack.<br>(2) Blocking valve stuck.<br>(3) Bad solenoid or wiring problems on blocking valve.<br>(4) Blockage in pilot pressure line or porting. |
| (6) No Pressure In Either Circuit | (1) Pump failure.<br>(2) Pump not engaged (P.T.O. failure, control cable broken).<br>(3) Relief valve failure in small valve stack. |
| (7) Operating Speed Too Low | (1) Incorrect engine throttle adjustment.<br>(2) Bad pump.<br>(3) Internal leakage in valve spools.<br>(4) Flow divider not operating correctly.<br>(5) Mechanical interference between beam and housing. |
| (8) Jack Settles(1) Defective lock valve. | (1) Defective lock valve<br>(2) External leak in jack circuit.<br>(3) Jack cylinder leaking internally. |
| (9) Jack Or Beam Operates With Switch In Neutral | (1) Switch shorted.<br>(2) Valve spool stuck.<br>(3) Blocking valve stuck. |
| (10) Pump Failure | (1) Over pressure operation.<br>(2) Dirty oil, clogged strainer or filter.<br>(3) Incorrect oil weight.<br>(4) Low oil level.<br>(5) Air leak in suction line. |

Note: Solenoid valves can be mechanically actuated. This check will tell you if the valve spool in an individual solenoid valve is stuck. There is a hole in the end of each solenoid with a plunger inside it. Depressing this plunger will actuate the valve.

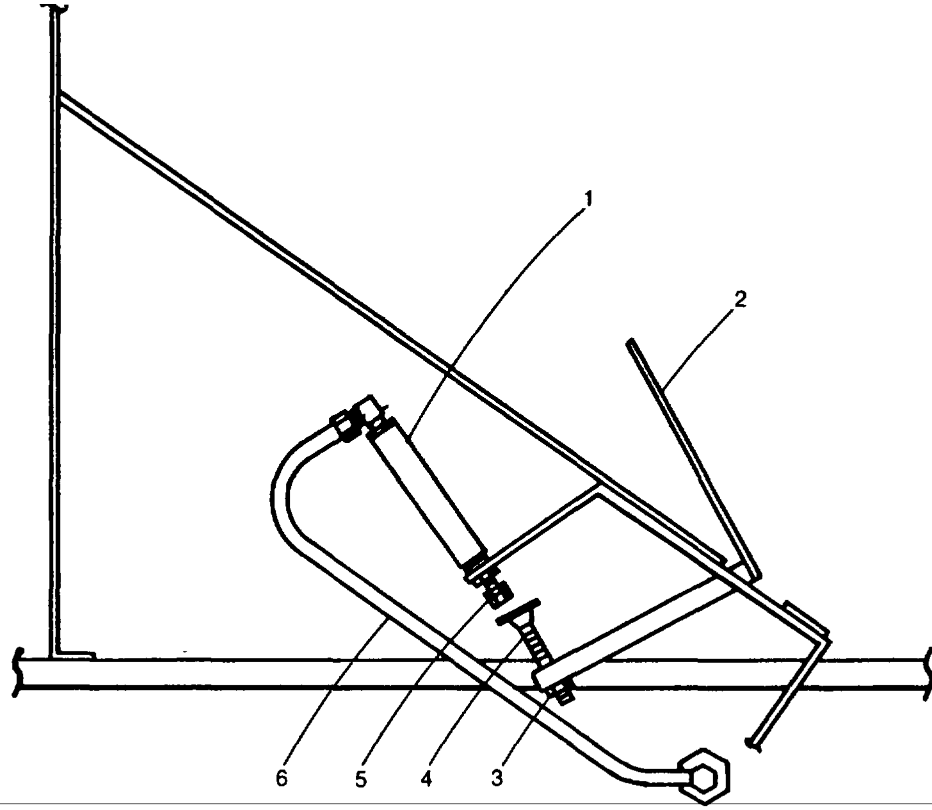



*Fig. 1*
*Outrigger Throttle Controls*

| | | |
|---|---|---|
| (1) Air Cylinder | (3) Locknut | (5) Plunger |
| (2) Accelerator Pedal | (4) Target | *(6)* Air Line |

The remote outrigger throttle push button actuates a solenoid valve in an air brake line. Air pressure from this solenoid valve operates air cylinder (1) which is attached to the carrier engine throttle. The cylinder works against the accelerator pedal (2) in the carrier cab. The throttle is two position, idle and an adjustable high speed. The high speed position is adjusted to give an engine speed of 1550 RPM when the push button is actuated.

### 9.1 Outrigger Throttle Adjustment (Fig. 1)

Adjust the throttle to give speeds shown above, with air cylinder (1) fully extended. Adjust as follows:

(a) With carrier transmission in neutral, and parking brake applied, start the carrier engine.

(b) Depress the push button, located in the outrigger control box. Wait until the engine accelerates fully, and read the engine speed off the tachometer in the carrier cab.

(c) Loosen locknut (3) on target (4). Turn target (4) in or out. until engine runs at proper speed with push button depressed.

(d) Tighten locknuts (3).

14.1 Outrigger Circuit, General

Hydraulic outriggers are standard equipment on 238A carriers. The entire system can be broken down into the following categories:
(a) Structural component system: Consisting of the beams, boxes, and pontoons. The jack cylinder is considered both a structural and a hydraulic component, and it is covered under the hydraulic system.
(b) Hydraulic system: Consisting of a pump, sump tank, oil filter, solenoid valves, lock valves, extending cylinders and jack cylinders.
(c) Control system: Consisting of a throttle switch, remote throttle system, and extend-retract switches.

**14.2 Pump**

The pump produces the volume of oil required to operate the hydraulic outrigger system. It has a built in relief valve and flow divider. The relief valve is factory adjusted to 1750 psi t 50 psi, and is not field adjustable. It is mounted on and driven by the carrier main transmission. A flexible control, under the carrier dash, shifts the pump into or out of engagement.

**14.3 Sump Tank (Fig. 1)**

Contains the oil supply for the hydraulic outrigger system. It is mounted to the carrier and has no connection with the upper sump tank. The sump tank contains a suction strainer (3) and a return oil filter (8). A magnetic plug (5) is also used to trap any metal particles in the oil.

Note: For sump tank maintenance, refer to Section 2 of the Operator's Manual.

**14.4 Solenoid Valve Stacks (Fig. 2)**

Two solenoid actuated valve stacks are used to control the outrigger system. A 3/4" valve stack controls the outrigger jack cylinders, while a 3/8" valve stack controls the outrigger beam cylinders and the front jack cylinder.

The terminology 3/4" and 3/8" doesn't refer to the actual size of the piping leading to the valve. It is a vendor reference to the volume of oil the valves can handle. However, the 3/4" stack is physically larger than the 3/8" stack. The solenoid valves are actuated by toggle switches, mounted in two outrigger control boxes. The control boxes are located on both sides of the carrier near the front outrigger beam. The control boxes also contain a switch to control the engine throttle.

*14.5 System Operation (Fig. 3)*

When the system is operating and no solenoids are actuated, a 10 GPM (37.85 liters/min.) flow of oil from the priority outlet of the pump flows to the 3/8" valve stack. If no solenoids are actuated, the oil flows on through the valve stack, rejoins the flow of oil from

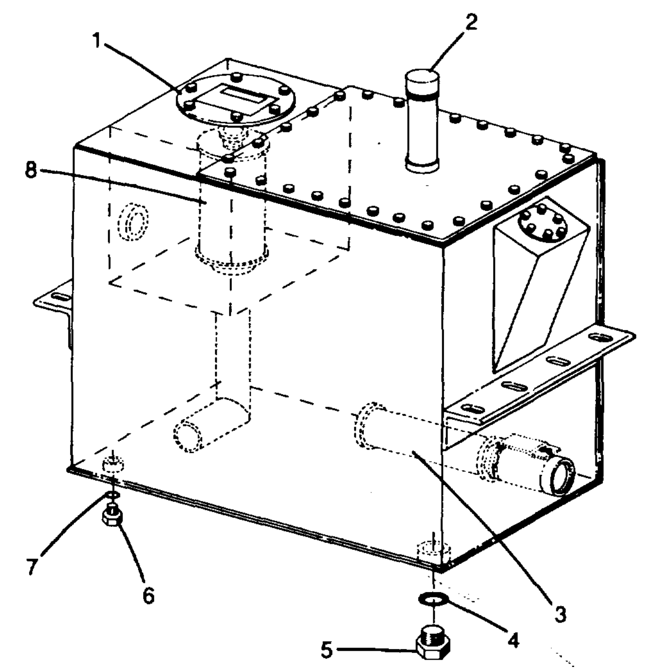



*Fig. 1*
*Outrigger Sump Tank*

| | |
|---|---|
| (1) Cover Plate | (5) Magnetic Plug |
| (2) Filler/Breather Assy. | (6) Bleed Plug |
| (3 Suction Strainer | (7 "O" Ring |
| (4) Washer | (8) Filter |

the secondary outlet, and flows into the 3/4" valve stack. If no solenoids are actuated on this valve stack, the oil flows through the stack and into a blocking valve at the end of the stack, This blocking valve diverts the flow of oil into a channel within the valve which carries the oil out of the valve and diverts it back to the sump tank.

When a 3/8" solenoid valve is actuated, up to 10 GPM is diverted out a valve port to a beam extend cylinder. Oil from other side of beam cylinder piston flows back through both valve stacks and returns to the sump tank.

W1hen a 3/4" solenoid valve is actuated(the solenoid diverts pilot pressure to move the valve spools), the blocking valve is simultaneously actuated. The blocking valve prevents the oil from returning to the sump tank, consequently building up the oil pressure needed to move the jack cylinder. While the jack cylinder is extending or retracting, the cylinder return oil flows through a port in the valve back to the sump tank.

**14.6 Troubleshooting The Outrigger System**

Refer to SM1-38-1.O.

**14.7 Relief Valves**

The relief valves are set screw adjusted, and

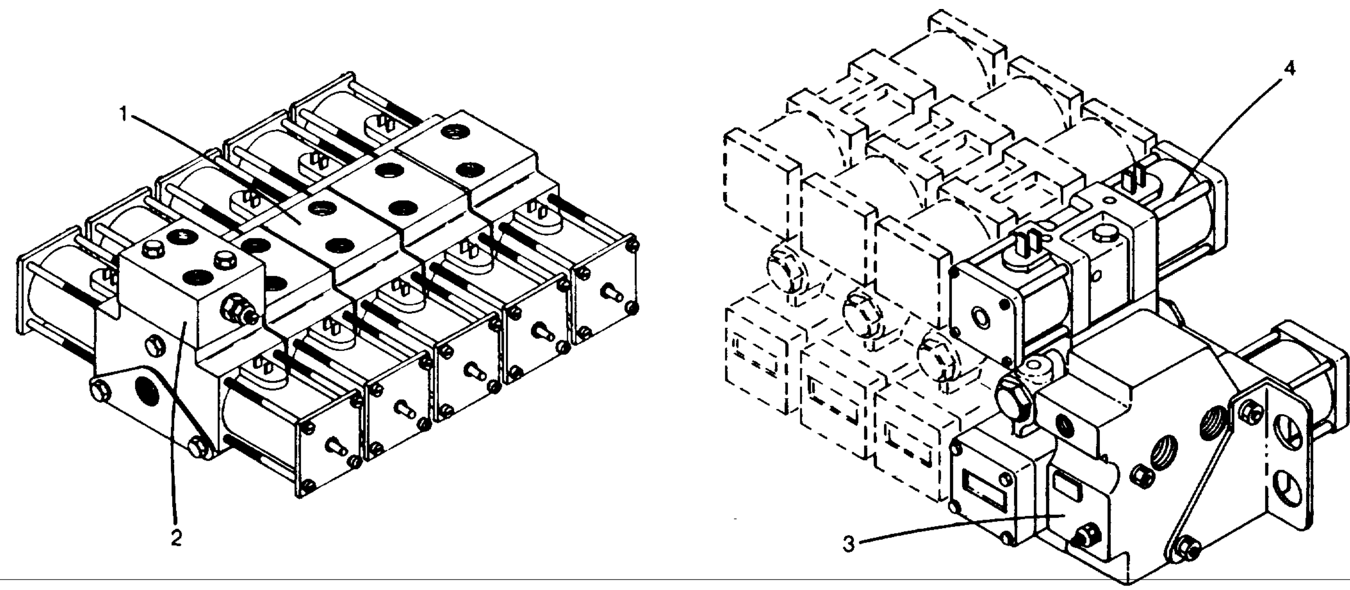



*Fig. 2*
*Solenoid Valve Stacks*
(1) 3/8" Valve Stack
(2) Front Jack And Relief Valve
(3) Blocking Valve And Relief Valve
(4) 3/4" Valve Stack

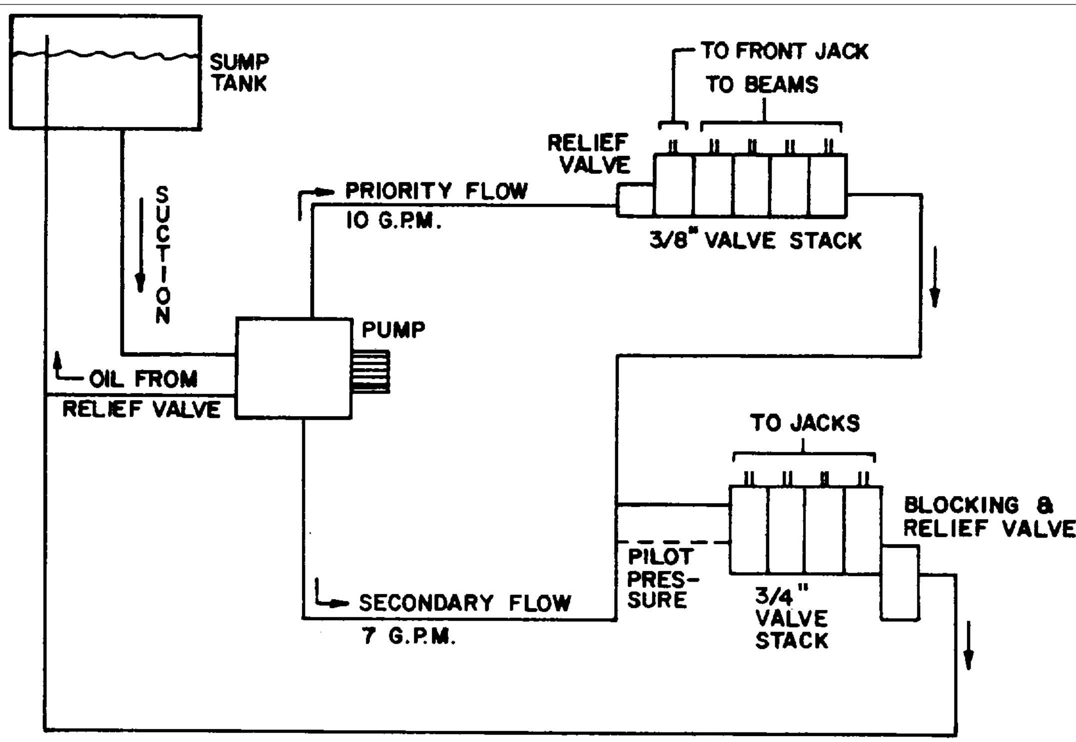



*Fig. 3*
*Outrigger Circuit Schematic*

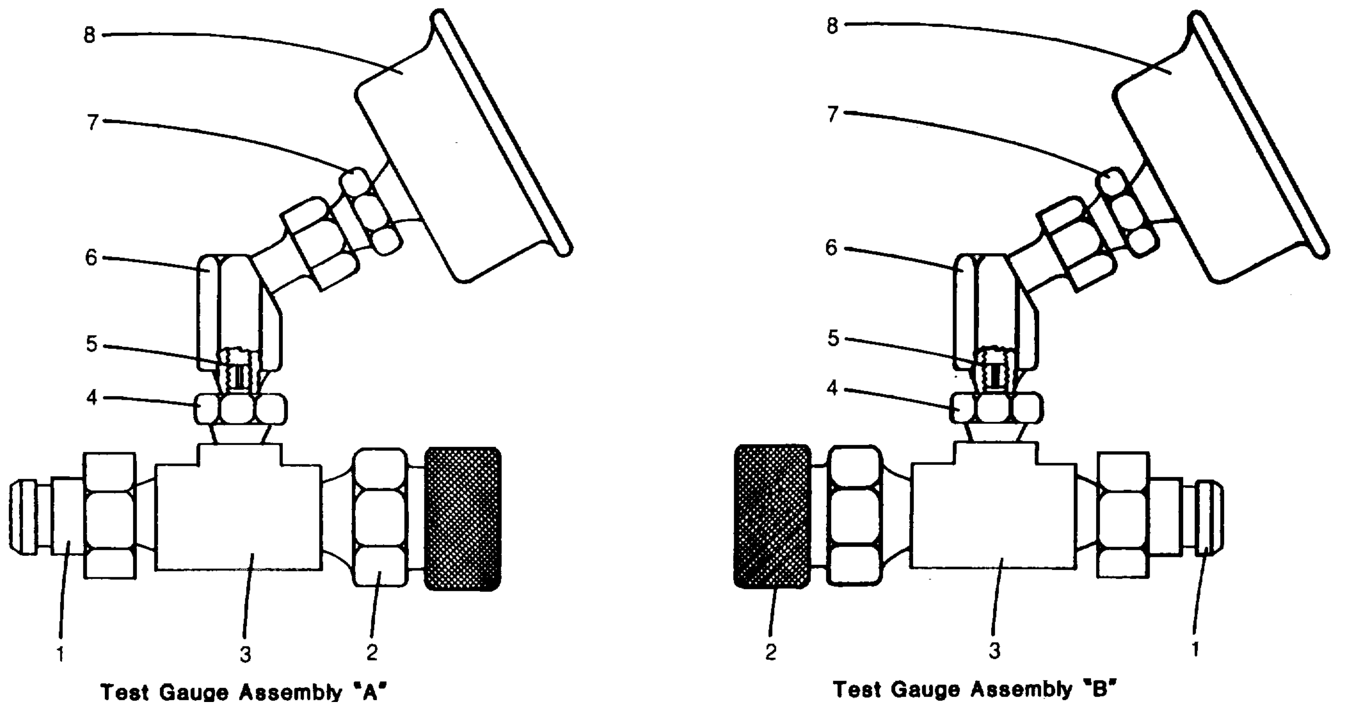



*Fig. 4 Z200-A, Z202-A*
*Pressure Check Gauges*

Test Gauge Assembly "A"

| Ref. No. | Part No. | Description |
|---|---|---|
| (1) | 18A2061 | 1/2" QD Nipple |
| (2) | 18A2062 | 1/2" QD Coupler |
| (3) | IX2260 | 1/2" Street Tee |
| (4) | IX1319 | 1/2" X 3/8" Bushing |
| (5) | | #80 Orifice (Drill 1/8" Pipe Plug) |
| (6) | IJ189 | (Drill & Tap 1/8" NPT For Installation Of Orifice) |
| (7) | IX1852 | 3/8" X 1/4" Bushing |
| (8) | | Pressure Gauge |

Test Gauge Assembly "B"

| Ref. No. | Part No. | Description |
|---|---|---|
| (1) | 18A788 | 3/4" OD Nipple |
| (2 | 18A786 | 3/4" 6D Coupler |
| (3) | IX3318 | 3/4" Street Tee |
| (4) | IX907 | 3/4" X 3/8" Bushing |
| (5) | | #80 Orifice (Drill 1/8" Pipe Plug) |
| (6) | IJI89 | (Drill & Tap 1/8" NPT For installation Of Orifice) |
| (7) | LX1852 | 3/8" X 1/4" Bushing |
| (8) | | Pressure Gauge |

they return the oil to the sump tank when the oil pressure goes above the relief valve setting. To check the relief valve settings, use the pressure gauges shown in Fig. 4.

## 14.8 Relief Valve Adjustment

The control system uses two adjustable relief valves. The main relief valve is mounted in the 3/4" valve stack and a front jack port relief valve is mounted in the 3/8" valve stack. Adjust the relief valves as follows:

**WARNING**

Fully Retract All Jacks And Beams Before Attempting To Set Pressures. Never Work On The Carrier Outrigger System When The Carrier Is Elevated And Supported Only By The Outriggers. If The Carrier Must Be Elevated On Outriggers, Securely Block The Carrier Before Working On The Outriggers. Failure To Securely Block The Carrier, May Allow It To Fall And Cause Damage Or Injury.

(a) Select one 2500 psi (17, 237 kPa) pressure gauge to adjust the relief valves. The gauge should be protected against pressure surges by an orifice or a nearly closed needle valve. Refer to Fig. 4 for examples of gauge assemblies with orifices and quick disconnects. The gauge quick disconnects plug into the carrier quick disconnects near the beam boxes.

(b) Install a pressure gauge into the right front Jack retract control line quick disconnect.

(c) Operate the jack switches until the cylinders are bottomed out.

(d) Increase the carrier engine speed by depressing the outrigger throttle button.

Set the relief valve in the 3/4" valve stack to 1550 psi + 50 psi (10, 687 + 545 psi) as follows:

The valve is set screw adjusted. First, loosen the Jam nut, turn the set screw out, then back it in until desired pressure is reached. Lock the jam nut.

(e) Install a pressure gauge in the front bumper outrigger pressure tap port. It is located in a tee connected to the lock valve.

(f) Extend the Jack and set the pressure to 500 psi (3, 447.5 kPa) as follows:

The valve is set screw adjusted. First, loosen the jam nut, turn the set screw out, and then back in until desired pressure is reached. Last, lock the jam nut.

(g) Check the front bumper jack pressure by fully extending all five jacks. Next, retract the midship jacks until the carrier horn honks.

Note: <u>If the horn does not honk by the time the midship jacks are no longer touching the pontoons, immediately re-extend the Jacks and correct the problem</u>.

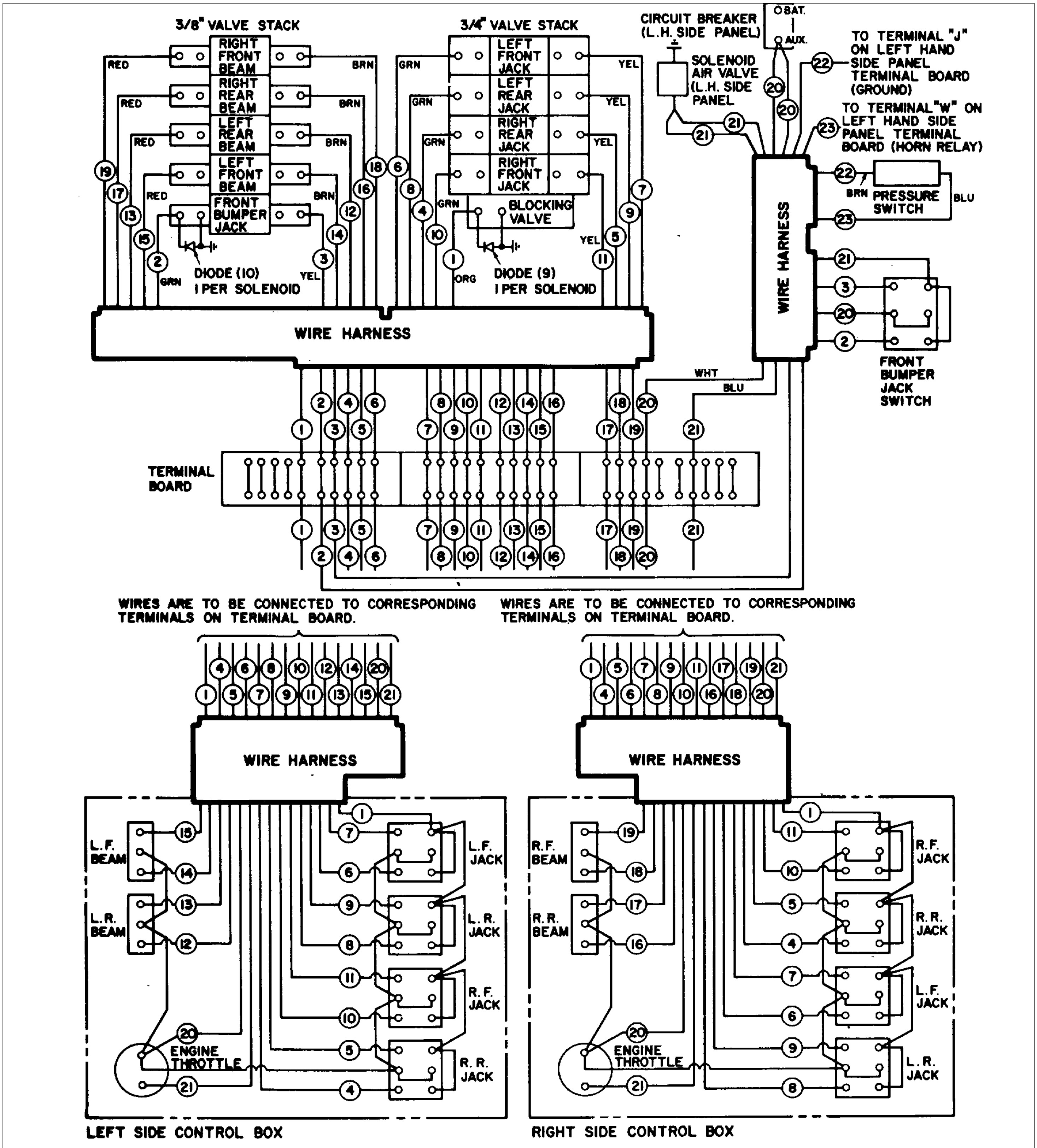



*Fig 1*
*Outrigger Electrical Wiring*

HC238A

| Wire No. | Color | Function | Wire No. | Color | Function |
|---|---|---|---|---|---|
| 1 | Orange | Blocking Valve | 13 | Red | Left Rear Beam-Extend |
| 2 | Green | Front Bumper Jack-Retract | 14 | Brown | Left Front Beam-Retract |
| 3 | Yellow | Front Bumper Jack-Extend | 15 | Red | Left Front Beam-Extend |
| 4 | Green | Right Rear Jack-Retract | 16 | Brown | Right Rear Beam-Retract |
| 5 | Yellow | Right Rear Jack-Extend | 17 | Red | Right Rear Beam-Extend |
| 6 | Green | Left Front Jack-Retract | 18 | Brown | Right Front Beam-Retract |
| 7 | Yellow | Left Front Jack-Extend | 19 | Red | Right Front Beam-Extend |
| 8 | Green | Left Rear Jack-Retract | 20 | White | Power |
| 9 | Yellow | Left Rear Jack-Extend | 21 | Blue | Throttle |
| 10 | Green | Right Front Jack-Retract | 22 | Black | Ground |
| 11 | Yellow | Right Front Jack-Extend | 23 | Black | Signal To Horn Relay From Pressure Switch |
| 12 | Brown | Left Rear Beam-Retract | | | |

*Fig. 2*
*Wiring Code*

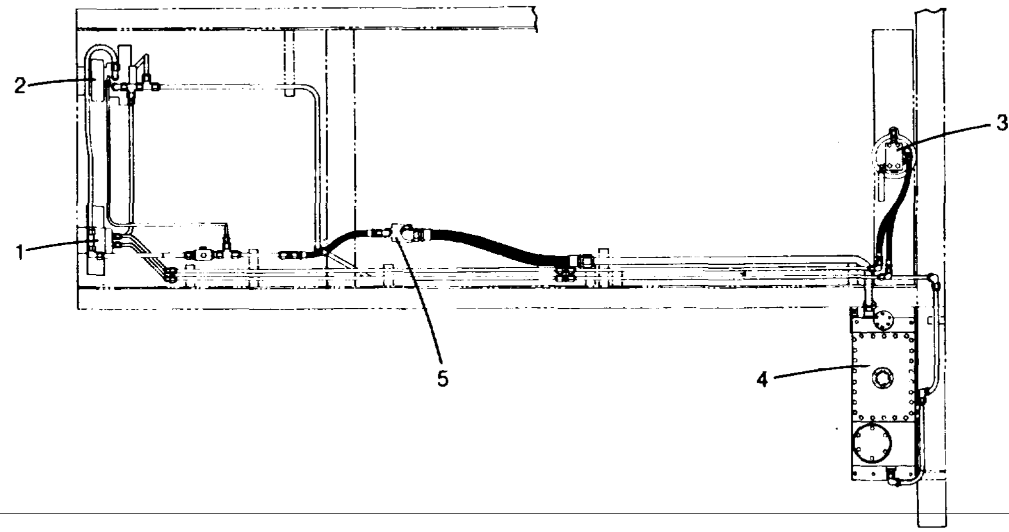



*Fig. 1*
*Hydraulic Outrigger Control System*

(1) Valve Stack (Beams and Bumper Jack)
(2) Valve Stack (Outrigger Jacks)
(3) Front Bumper Jack
(4) Sump Tank
(5) Pump

## 16.1 Hydraulic Outrigger Control Valves

For a description of how the system operates, see SM1-38-14.0.

The valve stack assembly which controls the beams and front bumper jack is direct solenoid operated (see Fig. 2). The valve stack is made up of five solenoid valves, connected by tie bolts. One of the valve assemblies, (1) in Fig. 2, includes a relief valve, which controls pressure in the front bumper outrigger system. The solenoid assemblies shift the valve spool, to direct pressurized oil to the beam or jack cylinder. There is a solenoid on each end of the spool, to move the spool in either of two directions. Pressurized oil flows out either port A or B, depending on which solenoid is energized. Springs center the spool in neutral when neither solenoid is energized.

When pressurized oil is directed out one of the ports, return oil from the cylinder flows into the other port. It is directed through porting in the valve stack. If another valve downstream is being actuated, this return oil is used as pressurized oil to operate the next cylinder.

The valve stack which controls the four side outrigger jacks is pilot operated (see Fig. 5). The valve stack is made up of four solenoid valves and a blocking valve, connected by tie bolts.

The solenoid valves shift a pilot spool, which directs pilot pressure to the main spool. There are two solenoid valves to send pilot pressure to either end of the main spool, depending on which solenoid is energized. Springs center both the pilot spool and the main spool when neither solenoid is energized.

The individual solenoid valves are open center valves. When assembled into a stack, pressurized oil is free to flow through the valve stack to the sump tank. To build pressure up in the jack cylinders when a solenoid is energized, we use a blocking valve.

When any solenoid is energized, the blocking

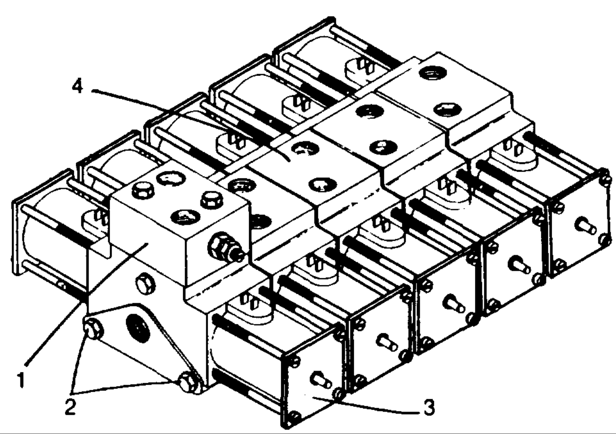



*Fig. 2*
*Valve Stack Assembly (Beams and Bumper Jack)*

(1) Relief Valve, Front Bumper Jack
(2) Tie Bolts
(3) Solenoid
(4) Solenoid Valve Assembly

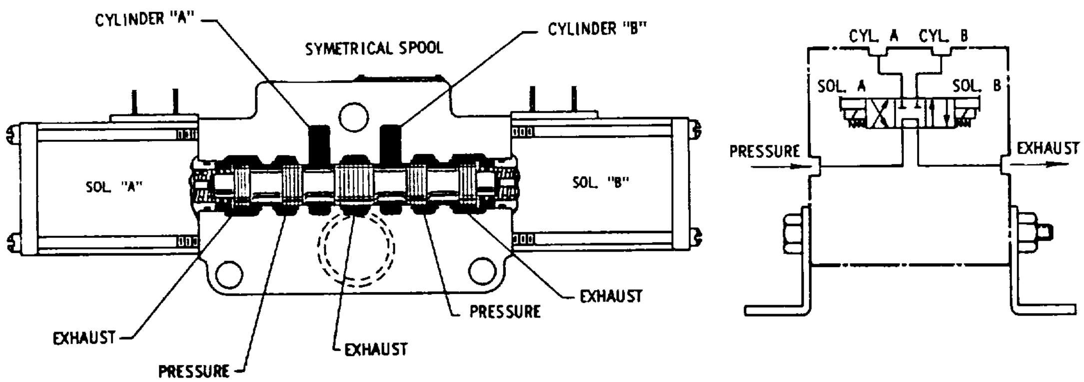



Fig. 3
Individual Solenoid Valve (Beams and Bumper Jack)

valve solenoid is also energized. The blocking valve "blocks" the flow of oil from the valve stack. Pressurized oil is then directed to the jack cylinder out either port A or B. Return oil from the cylinder enters the valve assembly, and is directed back to the sump tank.

## 16.2 Valve Stack Removal and Disassembly

(a) Park the machine on level ground. Engage park brake; shut off engine.
(b) Block the wheels so the machine can't move.
(c) Thoroughly clean the outside of the valve stack, and the hydraulic lines near it. This is to prevent entry of foreign material into the outrigger hydraulic system.

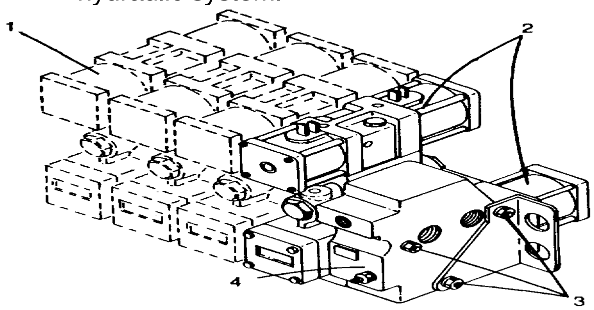



*Fig. 4*
*Valve Stack Assembly (Outrigger Jacks)*

(1) Solenoid Valve Assembly
(2) Solenoid
(3) Tie Bolts
(4) Blocking Valve

(d) Disconnect all electrical wires leading to the valve stack.
(e) Provide a drain to catch hydraulic oil. Disconnect all hydraulic lines and hoses leading to the valve stack.
(f) Remove the mounting bolts which connect the valve stack brackets to the carrier frame. Lower the assembly out of the machine.
(g) Disassemble on a clean work bench. Provide clean, lint-free cloths to lay out the parts
(h) Match mark the individual valves before disassembly.
(i) Remove the tie bolts. Disassemble the valve stack into its individual components.

## 16.3 Valve Stack Repair

The following parts are available for repair of the valve stack:
(1 Individual Complete Valve Sections
(2) Solenoid Assemblies
(3) All Seals

The individual spools are a lapped fit in their housings. They are not individually replaceable.

If a spool is sticking, sometimes it can be repaired as follows:
(a) On a beam solenoid valve, remove both solenoids. On a jack solenoid valve, remove both end caps.
(b) Remove the centering springs. Remove the spool from the valve.
(c) Examine the spool, and the bore in the housing to determine why the spool is sticking.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

If the spool is sticking due to gummy deposits, it can be carefully cleaned with solvent to remove the deposits. Replace in the housing and make sure the spool moves smoothly. In some cases, depending upon the location and

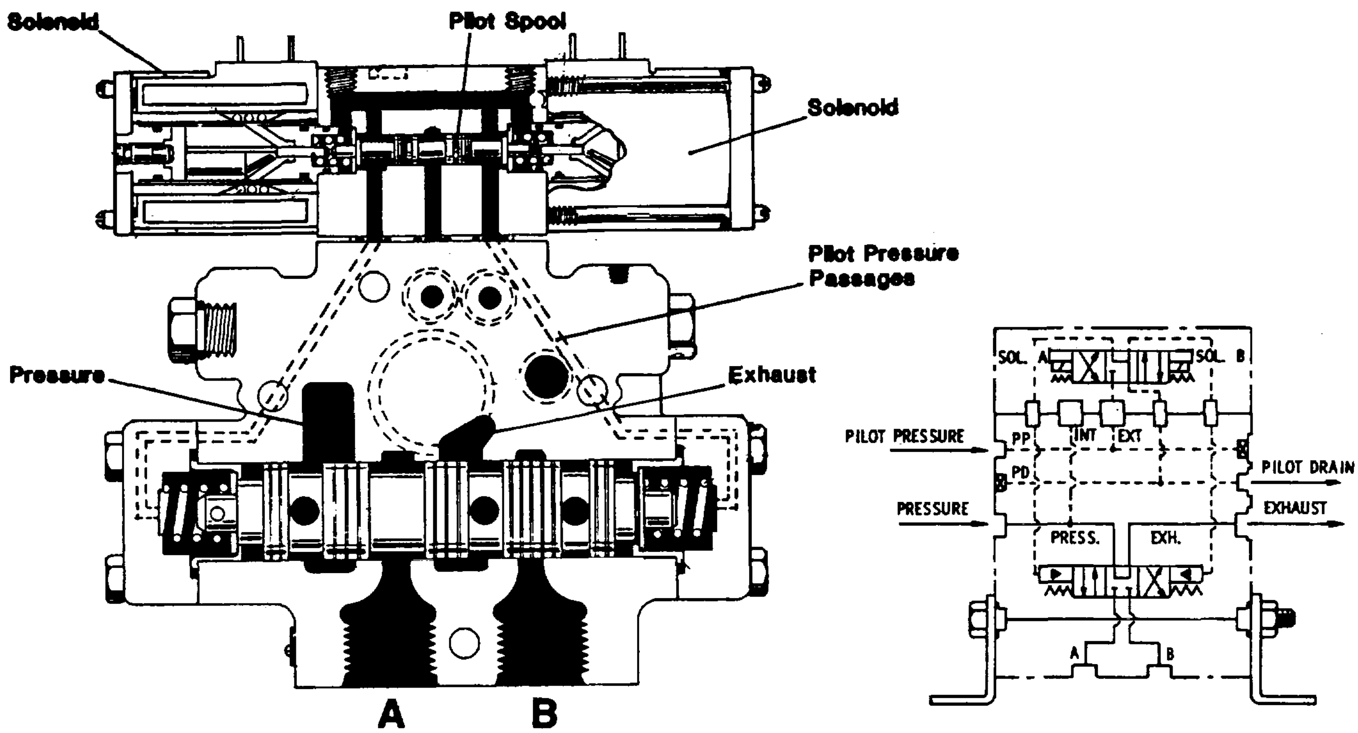



*Fig. 5*
*Individual Solenoid Valve (Outrigger Jack)*

condition of scratches, or high spots. The spool can be reconditioned by polishing and cleaning. A mechanic not acquainted with the working principles of these valves should not try this, as a non-working valve may result. Use fine emery cloth or jewelers rouge to polish the spool.

(d) Replace the spool in the housing. Make sure it moves freely and smoothly. Reassemble the centering springs, and end caps or solenoid valves.

**16.4 Valve Stack Assembly and Installation**

(a) Install the tie bolts through the mounting bracket. Install the first valve assembly.
(b) Wipe the mating surface of the valve stack clean. Install new '0' rings over the ports. Install the next valve assembly.
(c) Repeat step (b) until all valve assemblies are installed.
(d) Install the second mounting bracket. Install lockwashers and nuts on the tie bolts. Tighten to 300 in/lb. torque.
(e) Install the assembly on the machine. Install and tighten the mounting bolts.
(f) Connect all hydraulic lines to the valve stack. Connect all electrical wires to the valve stack.
(g) Refer to the Operators Manual. Operate the outrigger system to check operation of the valve stack. If there are any hydraulic leaks, fix them before operating.
(h) Check the oil level in the outrigger system. Add oil if necessary.

**16.5 Solenoid Replacement**

(a) Disconnect the wires leading to the sole-
(b) Remove the screws, which connect the solenoid to the valve assembly.
(c) Pull the solenoid away from the valve until

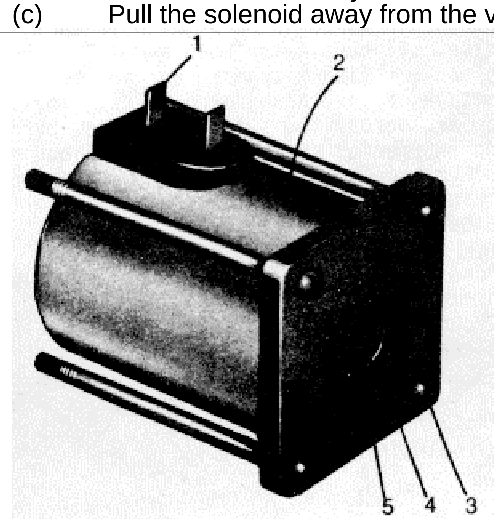



*Fig. 6*
*Solenoid Assembly*

(1) Electrical Connection
(2) Solenoid Case
(3) Screw
(4)) End Plate
(5) Actuator Pin

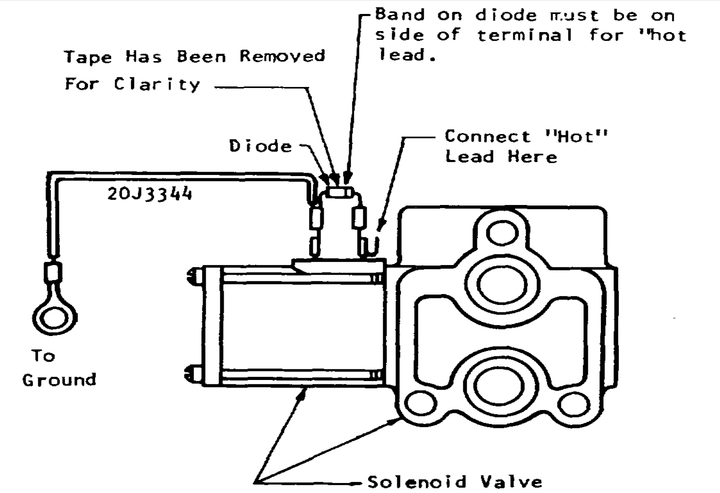


Fig. 7
Diode Assembly

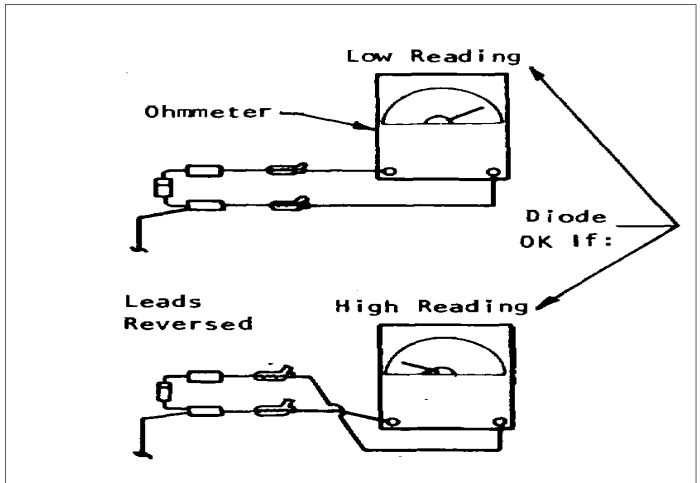


Fig. 8JR12-A
Checking Diode With Ohmmeter

it disengages.

(d) Make sure there is an 'O' ring on the protruding end of the new solenoid. Install on the valve stack by pushing, until the 'O' ring enters the hole in the valve.

(e) Install the four screws. Tighten evenly:

### 16.6 Diode Assembly

A diode is wired in parallel with each solenoid valve coil terminal. When a coil de-energizes, it can act like a transformer and build up a voltage of several hundred volts. This voltage can arc across the switch contacts, burning them and shortening switch life. The diode allows the voltage to flow to ground, rather than arcing across the switch contacts. This provides longer switch life.

Occasionally a diode may become defective, resulting in either an "open" circuit, or a shorted circuit. An open diode will have no effect on the operation of the solenoid. A shorted diode can make the solenoid inoperative by not allowing sufficient voltage to the coil. Always check the diode before deciding that the solenoid is bad.

### 16.7 Testing Diode With An Ohmmeter

One method of checking diodes is to use an ohmmeter. Use the lowest range scale on the ohmmeter.

Remove the diode from the circuit. Check by connecting the ohmmeter leads to each end of the diode and take a reading. See Fig. 8. Then reverse the connections and note the reading. If both readings are very low, or very high, the diode is defective. A good diode will read low one way and high the other.

### 16.8 Diode Installation

The diode can be installed on the solenoid in either direction. When correctly installed, the band on the diode will be toward the "hot" terminal. The tape can be removed from the diode to determine the location of the band. Retape diode after checking.

### 16.9 Checking Solenoid Valve Coils

Use an ohmmeter to check solenoid valve coils. Disconnect the wires from the coil. Connect the ohmmeter leads to the two coil terminals.

The reading should be from 1.5 to 3.5 ohms. If the reading is too high, the coil is open internally. If the reading is too low, there is an internal short.

Connect one lead to the terminal nearest the end of the coil, and the other to the case. If the reading is infinite, the coil is all right. If a low reading results, there is a short to ground, and the solenoid must be replaced.

### 16.10 Trouble Shooting the Outrigger Control System

(1) Use a voltmeter to measure the voltage in the system wiring at the coil. A minimum of 10.8 volts is required to shift the coil. Have someone trip the control switch while measuring voltage. If voltage is incorrect, determine why.

(a) Check wiring for shorts, or for an open wire.

(b) Check the control switch.

(c) Make sure all electrical connections are bright and shiny, and tight.

(2) With an ohmmeter, check the coil as explained previously. Replace the solenoid assembly if the coil tests bad.

(3) Mechanically push on the actuator pin to check for a stuck spool, or solenoid. On the outrigger jack solenoid, remove the cover plate from one end of the spool. Push on the spool to see if it is stuck. If a spool is stuck, dismantle the valve stack and repair or replace the valve section as explained earlier in this SM.

(4) If the beams operate, but none of the side jacks do, make the checks suggested above on the blocking solenoid. See Fig. 4.

(5) For more information on trouble shooting, see SM1-38-1.0.

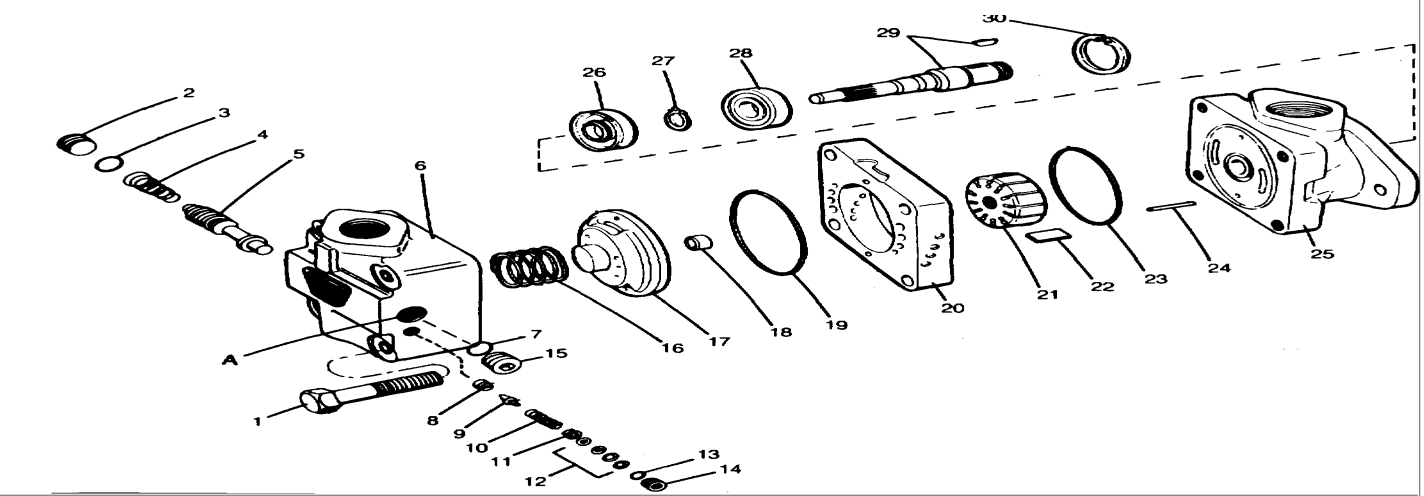



*Fig. 1*
*Outrigger Pump*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (A) | Hole Used for Piston Removal (Item 5) | (7) | ‘O’ Ring | (15) | Plug | (23) | ‘O’ Ring |
| (1) | Capscrew | (8) | Seat | (16) | Spring | (24) | Pin |
| (2) | Plug | (9) | Poppet | (17) | Pressure Plate | (25) | Body |
| (3) | ‘O’ Ring | (10) | Spring | (18) | Bushing | (26) | Shaft Seal |
| (4) | Spring | (11) | Spring Guide | (19) | ‘O’ Ring | (27) | Snap Ring |
| (5) | Piston | (12) | Shims | (20) | Ring | (28) | Bearing |
| (6) | Priority Valve Cover | (13) | ‘O’ Ring | (21) | Rotor | (29) | Shaft and Key |
| | | (14) | Plug | (22) | Vane | (30) | Snap Ring |

**WARNING**

Before Removing Any Part Or Component Of The Out-rigger System, Shut The Engine Off And Bleed All Pressure From The System

The machine uses a pump with a built-in flow divider and relief valve. Refer to Fig. 1. The basic pump is a vane type design that produces the oil pressure needed to operate the outrigger system. The pump is driven by the main transmission and shifted by a power take off unit. The power take off unit is controlled by a push-pull cable located in the cab.

## 2.1 Pump Removal

**CAUTION**

Lower The Machine Off The Outriggers Before Working On The Outrigger System. If This Is Impossible, Be- fore Proceeding, Block Securely Under Each Outrigger Beam. Use These Precautions To Keep The Machine From Lowering During Outrigger Maintenance And Repair.

(a) Drain the oil from the outrigger sump tank.
(b) Thoroughly clean off the pump exterior.
(c) Disconnect hydraulic lines leading to the pump. Immediately cap or plug all openings to prevent the entry of dirt into the system.
(d) Remove mounting capscrews securing the pump to the power take off.
(e) Remove the pump from the machine. 2.2 Disassembly Do not disassemble a pump further than necessary to correct a malfunction. During disassembly,

carefully check the identification of the parts to speed reassembly. During disassembly, use the exploded view of the pump in Fig. 1 as a guide. Proceed as follows:

Note: Pay careful attention to the relief valve parts. Handle them carefully because of their small size.

## 2.3 Cover End (Fig. 1)

(a) Place pump, cover end up, in a machinist's vise equipped with protective jaws. Clamp the vise, not too tightly, on the mounting bracket flats of the pump body. Clamping vise to the flats will prevent damage to the pump body.

(b) Remove the four cover capscrews (1). Before removing the cover (6), note the position of the cover inlet port to the body outlet port. Correct port alignment will speed reassembly. Next, remove the cover (6) and "O" ring (19).

Note: Place all disassembled parts on a clean, lint-free surface.

(c) Remove the pressure plate (17) and spring (16). Note the position of the ring (20) for correct reassembly. Next, lift off the ring and remove the locating pins (24). Remove the vanes (22) from the rotor (21) and, finally, remove the rotor from the shaft.

## 2.4 Shaft End

(a) Turn the pump body (25) over and remove the shaft key (29) and the snap ring (30) securing the bearing.

(b) To force the shaft (29) out of the body, tap the splined end of the shaft with a soft tipped hammer.

(c) Remove small snap ring (27) on the shaft behind the bearing. Support the bearing inner race to press the shaft out of the bearing.

(d) Pull the shaft seal (26) from the body with a suitable hooked tool.

## 2.5 Priority Control Valve Cover

The cover containing a flow divider (items 2-5, 7, and 15) and a relief valve (items 8-14). To disassemble these items, do the following:

## 2.6 Priority Valve Disassembly

(a) Remove the plug (2), spring (4), and "0" ring (3) from one end of the priority valve cover. Next, remove the plug (15) and "0" ring (7) from the other side of the cover.

(b) Insert a suitable tool into hole "A" on the side of the cover to remove piston (5). Slide the priority valve piston (5) from the cover.

(c) Disassemble the relief valve by removing the plug (14), shims (12), and spring guide (11).

Note: Do not remove the seat (8) unless inspection of the poppet (9) contact area reveals nicks, gouges, or signs of uneven wear. To remove the seat, thread the seat with a suitable V tap_approximately 3/8" (9.5 mm) into the seat. Next, thread a long bolt into the seat. Finally use a small gear puller to lift the bolt and seat form the bore.

## 2.7 Inspection

Clean all disassembled parts, except 'O' rings and the used shaft seal, in a clean mineral oil solvent. After drying thoroughly, lay the parts on a clean, lint-free surface. All internal oil passages in the cover, rotor, pressure plate, and body must be thoroughly cleaned. All '0' rings and the shaft seal must be replaced every time the pump is disassembled.

Note: Do not use compressed air to clean the parts unless it is filtered to remove dirt and water. Filtered compressed air is useful in cleaning spools, orifices, and cover passages.

(a) Inspection guidelines:

(1) Inspect the wearing surfaces of the body (25), pressure plate (17), ring (20), and rotor (21). Check for scoring and excessive wear. Remove light scoring marks by lapping. All parts that are heavily scored or badly worn must be replaced.

(2) Inspect the vanes (22) for burrs, wear, and excessive play in the rotor slots. If the slots are worn, replace the vanes and rotor (21).

(3) Inspect the bearings for wear and looseness. Check for cracked or pitted bearing races by rotating the bearings while applying pressure to them.

(4) Inspect the oil seal mating surface on the shaft for scoring or wear. Lightly polish the shaft to remove wear marks however, if this fails, replace the shaft.

(b) Priority Valve Cover Inspection

(1) Inspect both the priority valve piston (5) and bore for burrs. Remove burrs from the piston by lightly polishing with crocus cloth or #500 grit paper.

Note: Do not round off the sharp corners of the piston lands.

(2) Inspect the cover (6) bore for a pitted surface, wear, or scratches. If the bore is damaged, replace the cover. Do not attempt to rework the bore.

(3) Check the piston fit in the cover bore. Rotate the piston 360° while checking for any signs of binding. The piston must fit the cover and be able to move freely without binding.

(c) Relief Valve Inspection:

(1) Inspect the spring (10). The spring ends

must be pulled parallel to prevent the poppet (9) from cocking.

(2) Carefully inspect the seat contact area of the poppet (9). The poppet should have a slight wear pattern around the area of seat contact. If the wear pattern is broken, the break may create a leak between poppet and seat.

(3) Inspect the seat (8) for erosion or other defects. If any defect is detected, remove the seat (8). Seat removal instructions are given in "Priority Valve Cover Disassembly" ,Paragraph 2.6,step(c)

## 2.8 Reassembly

Coat all parts with hydraulic fluid to ease assembly and provide initial lubrication. Replace all '0' rings and shaft seal before reassembling pump. Use small amounts of petroleum jelly to hold 'O' rings in place during reassembly. To reassemble pump, do the following:

Note: New cartridge parts may arrive with burrs on their sharp edges because of rough handling during shipment. To correct this, use a stone on all sharp edges of cartridge kit replacement parts.

(a) If the relief valve seat (8) was removed, a new seat must be pressed into the body. Lubricate and insert the new seat, chamfered end first, into the cover opening. Align the seat square with the opening. To prevent damage to the seat, use a short length of brass rod to press the seat into place. Clean the relief valve bore to remove chips and filings.

(b) Align the poppet (9) square with the cover bore. Lightly tap the stem of the poppet to mate the poppet and seat. Install the spring (10), spring guide (11), shims (12), 'O' ring (13), and plug (14) in the cover.

Note: Check the relief valve setting for 1750 psi + 50 psi (12,066 kPa $^{+}$ 345 kPa). If the pressure reading is wrong, adjust the valve by adding or removing shims (12). Adding shims will raise the pressure setting; decreasing shims will lower the pressure setting.

(c) Next, insert the priority valve piston (5), small land first, into the bore of the cover Refer to Fig. 1. Install the '0' ring (7) and plug (15) on one side of the cover. On the other side of the cover, install the spring (4), '0' ring (3), and plug (2).

## 2.10 Pump Reassembly

(a) Press the shaft (29) into the front bearing (28) while supporting the bearing inner race Install the small snap ring (27) on the shaft.

Note: Before installing the shaft seal (26) on the shaft, make sure the spring side of the seal is facing toward the pump cover end of the shaft Firmly press the seal (26) on the shaft and lubricate the seal lip with petroleum jelly.

(b) Slide the shaft into the body (25) until the bearing (28) is seated. If necessary, tap lightly on the shaft end to seat the bearing. Install the snap ring (30) on the shaft.

(c) Install new '0' rings in the body (25) and cover (20). Insert the ring locating pins (24). Mount the ring (20) on the pins with the arrow pointing down to provide left hand rotation.

(d) Install the rotor (21) on the shaft and insert the vanes (22) in the rotor slots.

Note: The radius ends of the vanes must point towards the cam ring.

(e) Place the pressure plate (17) on the locating pins (24) and flat against the ring. Place the spring (16) over the pressure plate. Next install the cover, the priority valve cover fully assembled (items 2-15), with the outlet port in the correct position.

(f) Tighten the cover capscrews (1) to 75-85 ft/lb. (100.4 - 113.6 N-m) torque. Rotate the shaft (29) by hand to insure that there is no internal binding. Last, install the shaft key (29).

(g) After the pump has been completely re-assembled, pour a small quantity of clean hydraulic oil into the cover inlet port. Rotate drive shaft several turns by hand to check for free rotation and to insure complete lubrication of the cartridge parts. Cap the pump outlet and inlet ports to prevent entry of dirt and other contaminants.

## 2.11 Pump Installation

(a) Install the pump to the power take off. In- stall and tighten the mounting capscrews.

(b) Connect the hydraulic lines to the pump.

(c) Fill the outrigger sump tank with oil. Refer to Section 2 of the Operators Manual for proper type and amount of oil to use.

(d) Engage the power take off. Start the engine. Allow engine to idle with transmission in neutral.

(e) Operate the outriggers several times. Shut the engine off.

(f) Check for leaks, If any are detected, re- pair them before resuming operation.

(g) Check oil level and add oil as necessary. Refer to Section 2 of the Operators Manual for more information.

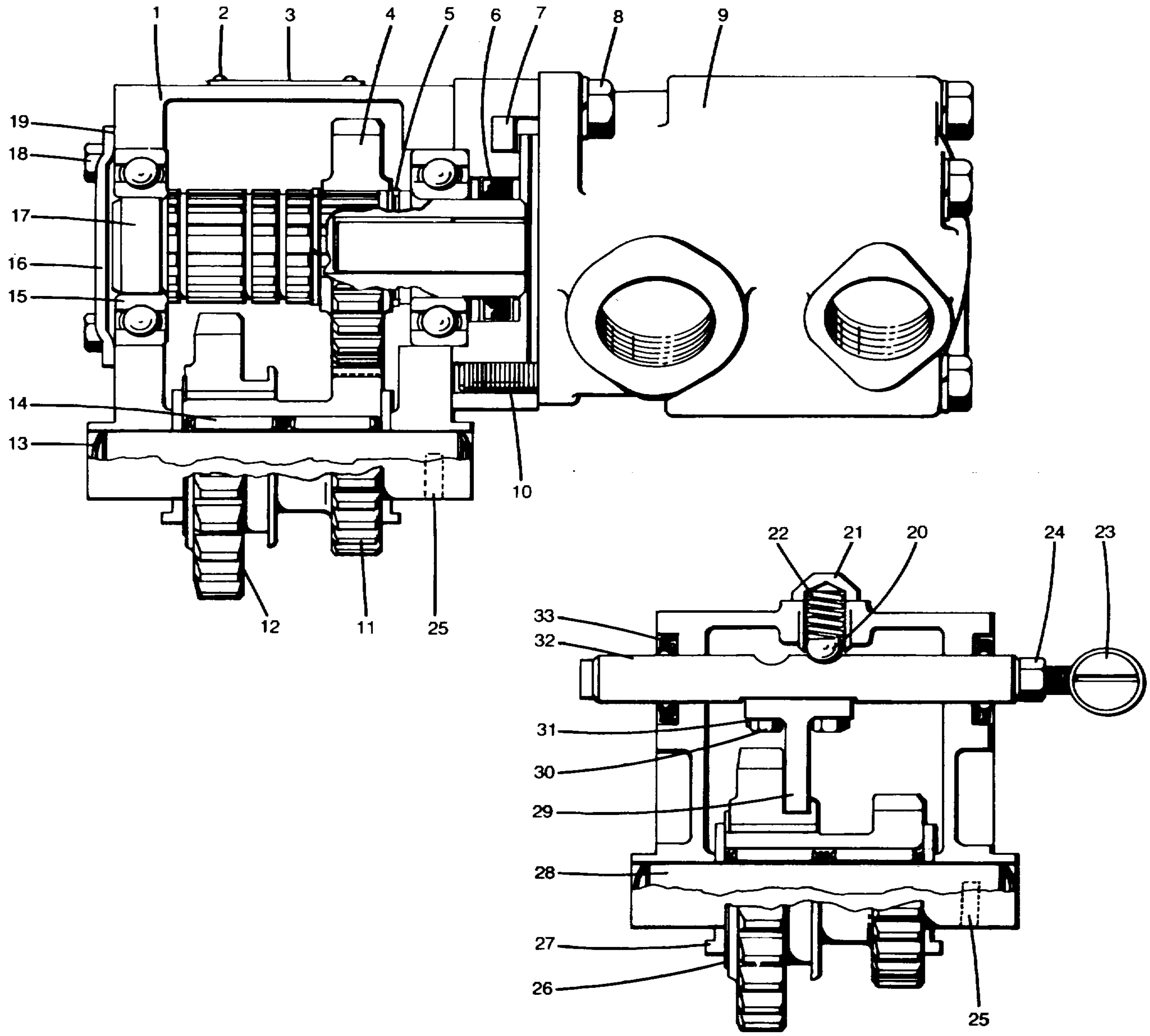



*Fig. 1*
*Power Take Off*

(1) Housing
(2) Screw
(3) Plate
(4) Gear
(5) Ring
(6) Seal
(7) Screw
(8) Capscrew
(9) Pump
(10) Adapter
(11) Gear
(12) Gear
(13) Plug
(14) Bearing
(15) Bearing
(16) Cap
(17) Shaft
(18) Capscrew
(19) Gasket
(20) Ball
(21) Retainer
(22) Spring
(23) Adjusting Screw
(24) Nut
(25) Pin
(26) Washer
(27) Washer
(28) Shaft
(29) Yoke
(30) Capscrew
(31) Lock
(32) Shaft
(33) Seal

## 1.1 Power Take Off Removal

**WARNING**

Lower Machine Off Outriggers, Or If This Is Not Possible, Block Securely Under Outrigger Beams Before Working On Outrigger System.

(a) Remove capscrews from pump mounting. Remove pump from power take off.
(b) Drain lubricant from transmission.
(c) Disconnect push-pull cable from power take off.
(d) Remove capscrews which connect power take off to transmission. Remove unit from transmission.

## 1.2 Power Take Off Disassembly

(a) To remove input gear, drive pin (25) into shaft. Drive shaft (28) from pin end far enough to remove welch plug (13) at other end of shaft. Then press shaft out of housing in opposite direction.
(b) Remove input gears (11 and 12), bearing (14), and washers (26 and 27).
(c) To remove shaft (32), remove retainer (21), spring (22), and ball (20). Be careful when removing retainer as it is under spring tension.
(d) Remove capscrews (30), and yoke (29). Remove shaft (32) from housing.
(e) Remove capscrews (18). Remove cap (16).
(f) Remove capscrews (7). Remove adaptor (10).
(g) Press shaft until bearings come out of housing. Remove bearings (15).
(h) Remove rings (5). Remove shaft and gear assembly from housing.

## 1.3 Reassembly

Follow disassembly steps in reverse. Drive pin (25) completely out of input shaft (28) before installing shaft into housing. Align holes in shaft and housing and reinstall pin.

Always inspect bearings, gears, shafts, etc., before reassembly. Replace any worn or damaged parts. Install new seals, gaskets, and welch plugs.

## 1.4 Power Take Off Installation

(a) Install unit on transmission case.
(b) Install pump on power take off.
(c) Connect push pull cable to power take off.
(d) Fill transmission with lubricant. Refer to Section 2 of the Operators Manual for proper type and amount of lubricant to use.
(e) With transmission in neutral, engage power take off. Check power take off for leaks. If any are apparent, repair before use.

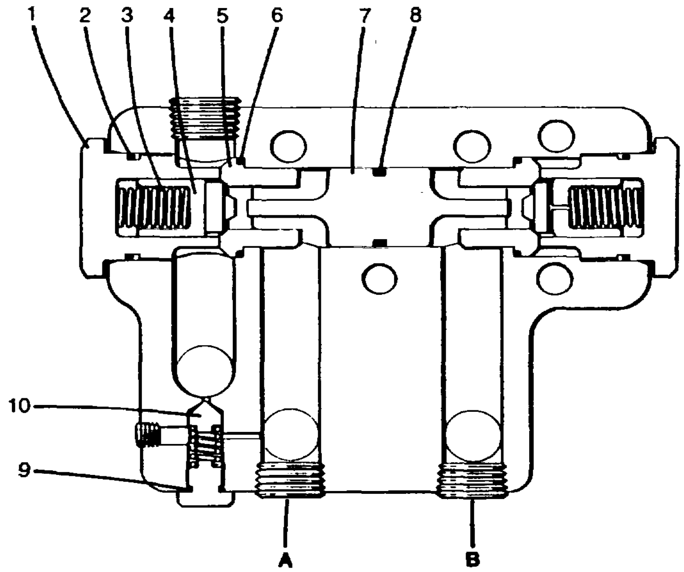



*Fig. 1*
*Outrigger Lock Valve*

| | | | |
|---|---|---|---|
| (A) Port | (2) "O" Ring | (5) Seat | (8) "O" Ring |
| (B) Port | (3) Spring | (6) "O' Ring | (9) "O" Ring |
| (1) End Cap | (4) Poppet | (7) Piston | (10) Relief Valve |

The jack cylinder lock valve is a device that hydraulically locks the outrigger jack in position unless pressure is available at one port or the other to power the jack up or down. equal or no pressure is available from the outrigger system, the poppets within the lock valve close, creating a hydraulic "lock up" between the two ends of the jack cylinder, which holds the piston within the cylinder stationary.

A thermal relief valve built into the rod side of the lock valve will pass a few drops of oil into the return line of the outrigger system if pressures within the jack should build up too high. This pressure build up could be caused by heat expansion from the sun shining on the jack.

## 3.1 Jack Cylinder Lock Valve Disassembly

External leakage around the end caps, indicates a loose end cap, or a faulty "O" ring seal under the cap. Before tearing the valve down to correct external leakage, try tightening the end caps to a torque of 50 ft/lbs. and see if the leakage stops.

Creeping down of the machine when it is sup-ported by the jacks would indicate internal leakage past the poppets within the valve. These poppets and seats are replaceable.

To disassemble the valve, proceed as follows:

(a) Fully retract the jack.
(b) Remove the end cap (1), spring (3), and poppet (4) from each end of the valve.
(c) Remove the seat (5) and "0" ring (6) from each end of the valve.
(d) Remove the piston (7) and "0" ring (8) from the valve.

Thoroughly clean and inspect all parts. Discard all "0" rings. Inspect the poppets (4) and seats (5) for nicks or scratches. If any are evident, replace them .

## 3.2 Lock Valve Reassembly

The lock valve may be reassembled as follows:

(a) Install "O" ring (8) on the piston (7). Lubricate with Cosmolube #2 or equal. Position "0" ring on shoulder in valve body.
(b) Install the piston in the body.
(c) Lubricate seat (5) and its "0" ring seal (6) with Cosmolube #2 or equal. Position "O" ring on shoulder in the valve body.
(d) Install the two seats in the valve body. Be ,certain that the milled slot in the seat is in line with ports A and B. To align the seats, remove the pipe plugs from ports A and B, and insert a 3/4" diameter rod into each port. Index the rods into the milled slots 2 in the seats. Leave the rods in place until

the end caps have been reassembled.

(e) Install "O" ring (2) on each end cap. Coat the "0" ring with Cosmolube #2 or equal.

(f) Insert spring (3) and poppet (4) into each end cap. The poppets are not alike and must be installed as shown in Fig. 1.

(g) Thread the end cap poppet assembly into the valve body. Tighten the end cap to 50 ft/lbs. torque.

**Service Manual** SM1 45-2.0 Telescoping Tubes **SM1-45-2.0**

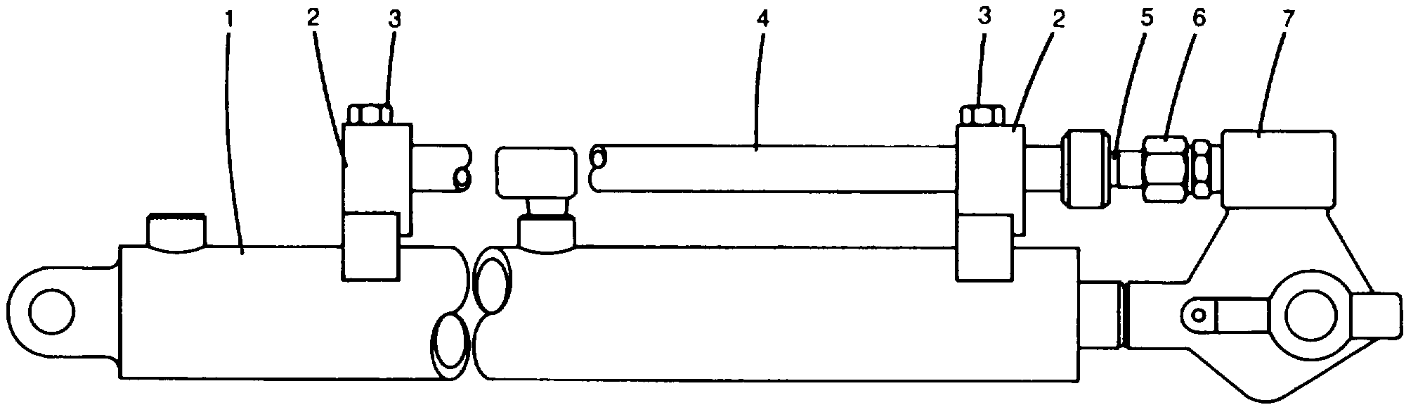



*Fig. 1*
*Telescoping Tube and Beam Cylinder Assemblies*

(1) Beam Cylinder
(2) Tube Anchor Block
(3) Capscrew
(4) Outer Manifold
(5) Inner Tube(
(6) Tube Nut
(7) Cylinder Rod Anchor Block

The telescoping tube assemblies, which are mounted on the beam cylinders (1), consist of an outer manifold (4), which is attached to the cylinder, a6d an inner tube (5) which is attached to the cylinder rod anchor block (7), and travels with it when the beams are extended and retracted.

**2.1 Telescoping Tube Removal (Refer to Fig. 1)**

(a) Remove beam cylinder as explained in SM1-45-1.0.
(b) Disconnect inner tubes (5) from rod cylinder anchor blocks (7), by loosening tube nuts (6).
(c) Remove capscrews (3) which connect tube anchor blocks (2) to the cylinder case. Remove anchor blocks (2) and tube assemblies from the cylinder. Save any shims under the anchor blocks for replacement later.

**2.2 Telescoping Tube Seal Replacement (Refer to** Fig. 2)

(a) Slide the inner tube (5) out of the outer manifold (1).
(b) Remove snap ring (3)and seal assembly (2)
(c) Install new seals (2). Replace the snap ring(3)
(d) Lubricate the inner tube with vaseline. Slip it through the seal. Be careful not to damage the seal lips.

**2.3 Telescoping Tube Installation (Refer to Fig. 1)**

(a) Install tube assembly on cylinder case. Replace any shims removed previously under the tube anchor blocks (2). Tighten mounting capscrews (3).
(b) Connect inner tubes (5) to cylinder rod anchor block (7). Tighten tube nut (6).

Note: <u>Tighten the tube nuts to the anchor block with the piston retracted, to assure proper alignment. Do not lift the cylinder assembly by the telescoping tubes, as tube damage and leakage may result.</u>

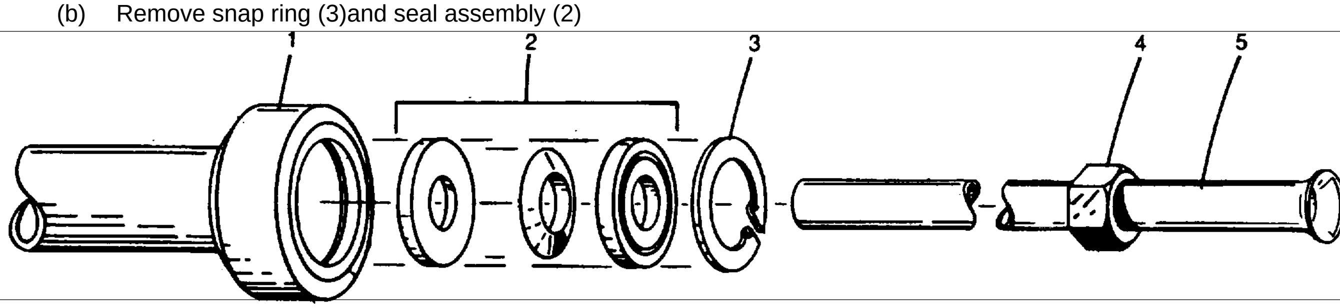



*Fig. 2*
*Telescoping Tube and Seal Assemblies*

(1) Outer Manifold
(2) Seal Assembly
(3) Snap Ring
(4) Tube Nut
(5) Inner Tube

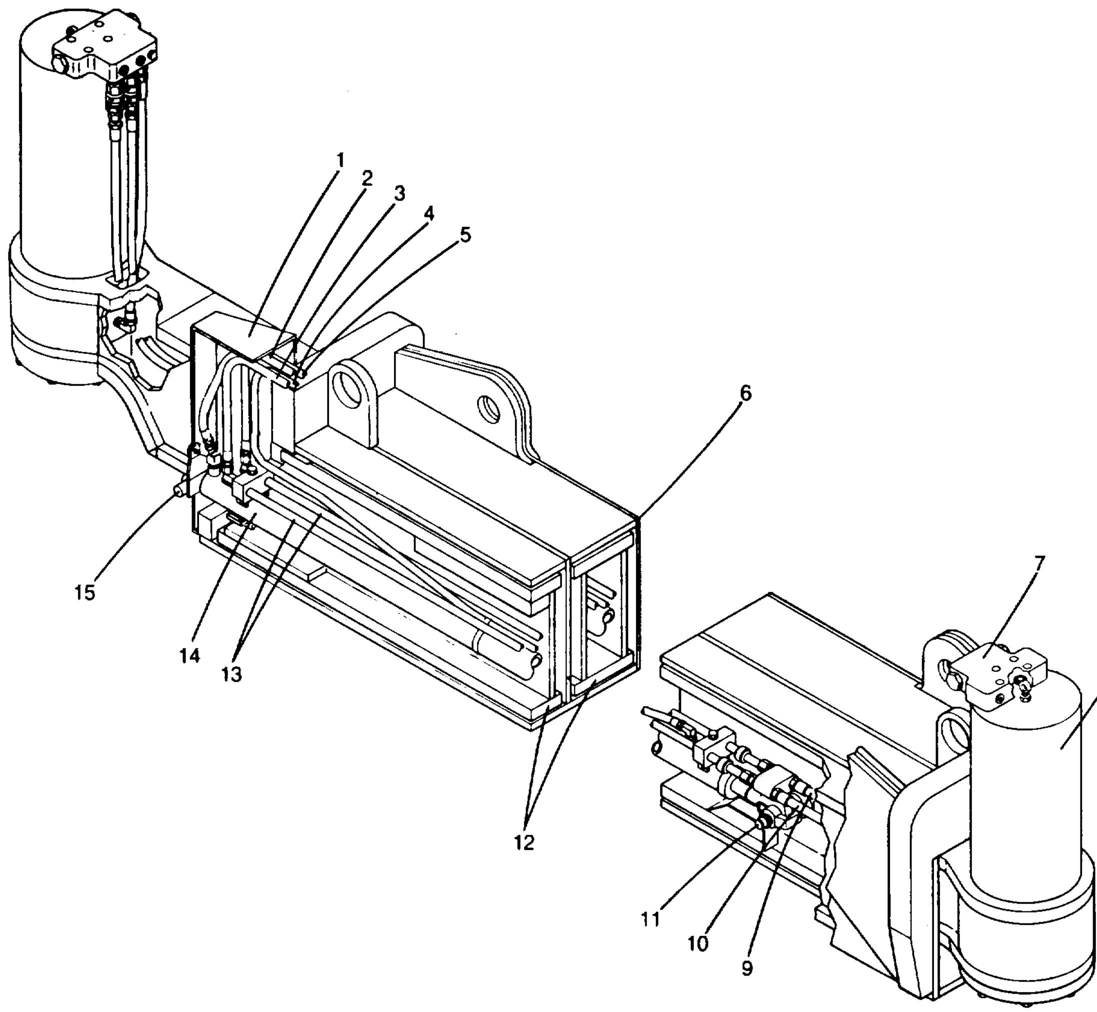



*Fig. 1*
*Outrigger Beam And Box Assembly*

| | | | | |
|---|---|---|---|---|
| (1) Cover Plate | (4) Hose | (7) Lock Valve | (10) Hose | (13) Telescoping Tubes |
| (2) Hose | (5) Hose | (8) Jack | (11) Pin | (14) Beam Cylinder |
| (3) Hose | (6) Box | (9) Hose | (12) Beam | (15) Pin |

### 3.1 Beam Cylinder Removal (Refer To Fig. 1)

(a) Remove cover plate (1).

(b) Disconnect hydraulic hoses (2), (3), (4) and (5) at the quick disconnect. Cap or plug all openings to prevent entry of foreign material. Attach a cord or wire to the hoses before removing beam. Leave the cord or wire in the box after removing beam, to pull hoses back through.

(c) Unpin the cylinder (14) from cylinder bracket by removing pin (15).

(d) Slide beam (12) out of box (6).

(e) Disconnect hydraulic hoses (9) and (10) from lock valve (7). Cap or plug all openings to prevent entry of foreign material.

Attach a cord or wire to the hoses before re- cord or wire in the beam after removing cylinder, to pull hoses back through.

(f) Remove pin (11). Slide cylinder out of the beam.

Note: Do not lift cylinder assembly by telescoping tubes.

### 3.2 Telescoping Tubes Assemblies

Refer to SM1-45-2.0.

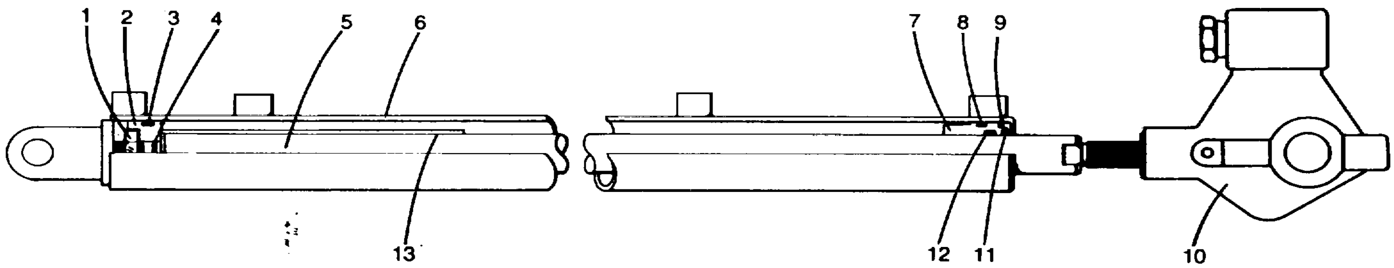



*Fig. 2*

*Beam Cylinder Assembly*

(1) Jam Nut
(2) Piston
(3) "O" Ring & Back Up Washer
(4) "O" Ring
(5) Rod
(6) Cylinder Body
(7) Gland Guide
(8) "O" Ring
(9) Retainer Ring
(10) Anchor Block
(11) Rod Wiper
(12) "O" ring & Back Up Washer
(13) Stop Tube

**3.3 Beam Cylinder Disassembly (Refer To Fig. 2)**

(a) Remove telescoping tube assemblies from cylinder (Refer to SM1-45-2.0).

(b) Unscrew and remove anchor block (10) from rod end of cylinder.

(c) Thoroughly clean exterior of cylinder to prevent entry of foreign material.

(d) Remove retainer ring (9). Pull rod (5), piston (2), and gland guide (7) from cylinder body (6) as a unit.

(e) Remove jam nut (1). Remove piston (2), stop tube (13), and gland guide (7) from rod (5). 3.4 Inspection And Parts Replacement

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(a) Thoroughly clean cylinder bore with approved solvent. Wipe dry with a LINT-FREE cloth. Carefully inspect for signs of scoring or deep scratches. If any, cylinder must be replaced. Scratches of this type are generally caused by foreign material in the hydraulic system, and cannot be field repaired.

(b) Wash the piston rod, check for damage such as dents, deep scratches, damaged chrome plating, etc. All sharp edges on each end of the rod should be removed with a fine file or whetstone to prevent damage upon reassembly. If the rod is damaged, it must be replaced.

**CAUTION**

The Piston Rod Must Be Carefully Handled And Protected To Prevent Scoring, Scratching, Etc. Never Clamp The Rod In A Vise Unless The Jaws Are Protected By A Soft Material, Such As Copper Or Lead. Never Leave The Exposed Rod Where Welding Spatter Or Other Such Material May Strike The Finished Surface.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(c) Thoroughly wash the piston in approved solvent. Remove all old seals.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(d) Thoroughly wash the gland guide in approved solvent. Remove all old seals.

**3.5 Beam Cylinder Reassembly (Refer To Fig. 2)**

Note: Lubricate all parts, including bore, with hydraulic oil before reassembling.

(a) Install "0" ring (8) in O.D. groove of gland guide (7),

(b) Install rod wiper (11) in I.D. groove of gland guide, with lip to outside.

(c) Install "0' ring and back-up washer (12) in the groove inside the gland guide.

(d) Lubricate the O.D. of the rod and the I.D. of the gland guide. Install gland guide on rod being careful not to damage seals.

(e) Install stop tube (13) on rod.

(f) Install a new "0" rings(4) in the groove on the turned down area of the rod. Be careful not to damage the "O" ring when installing it over the rod threads.

(g) Lubricate the I.D. of the piston and install on rod. Install and tighten jam nut (1). (h) Install "0" ring with a back up washer (3) on each side, in the groove on the piston.

(i) Lubricate the O.D. of the piston and of the gland guide. Install piston and then gland guide in cylinder body.

(j) install retainer ring (9).

(k) Replace telescoping tube assembly to cylinder (Refer To SM1-45-2.0).

Reinstall the beam cylinder in the outrigger box by following removal procedure in reverse.

Note: Refer to SM47-18-1.0 for proper tightening of hydraulic fittings.

The jack cylinder is a double acting cylinder. Foul are used, with one mounted at the end of each outrigger beam. The function of these jacks is to raise the machine clear of the ground and level it, for stability when making lifts with the boom.

### 3.1 Jack Cylinder Disassembly

If the jack cylinder develops an external leak or drifts down after the machine has been released, seal leakage (internal or external) is indicated. The jack cylinder may be disassembled as follows:

(a) Jack the machine up, or park it on a ramp so there is enough clearance to remove a jack cylinder.
(b) Clean an area around the lines leading to the lock valve on top of the cylinder, and between the lock valve and the cylinder. Remove the lines. Immediately cap or plug all openings to prevent entry of foreign material.
(c) Remove the lock valve from the top of the cylinder.
(d) Hook on to the lift eye in top of the jack cylinder with a helper crane or chain hoist
(e) Remove the connecting bolts from the mounting flange at the bottom of the cylinder.
(f) Lower the cylinder down and out of the out rigger beam end.
(g) Remove the snap ring (11) which hold gland (5) in the cylinder bore.
(h) Remove gland (5) from the cylinder.
(i) Slide the piston (2) and rod assembly from the cylinder body (3).
(j) Remove capscrew (1) which retains piston (2) on rod (4). Remove piston (2).
(k) Remove and discard all old seals, '0' ring and back-up rings.

Inspection and Parts Replacement:

(a) The cylinder bore should be thoroughly washed in approved solvent, and carefully inspected for signs of scoring or deep scratches. If any, the cylinder must be replaced. Scratches of this type are generally caused by foreign material in the hydraulic system, and cannot be field repair
(b) Wash the piston rod, and check for damage such as dents, deep scratches, damaged chrome plating, etc. All sharp edges on both ends of the rod should be removed with a fine file or whetstone to prevent damage upon reassembly. If the rod is damaged, it must be replaced.

**CAUTION**

The Piston Rod Must Be Carefully Handled And Protected To Prevent Scoring, Scratching, Etc. Never Clamp The Rod In A Vise Unless The Jaws Are Protect4 By Soft Material Such As Lead Or Copper. Never Lea The Exposed Rod Where Welding Spatter Or Other Such Material May Strike The Finished Surface.

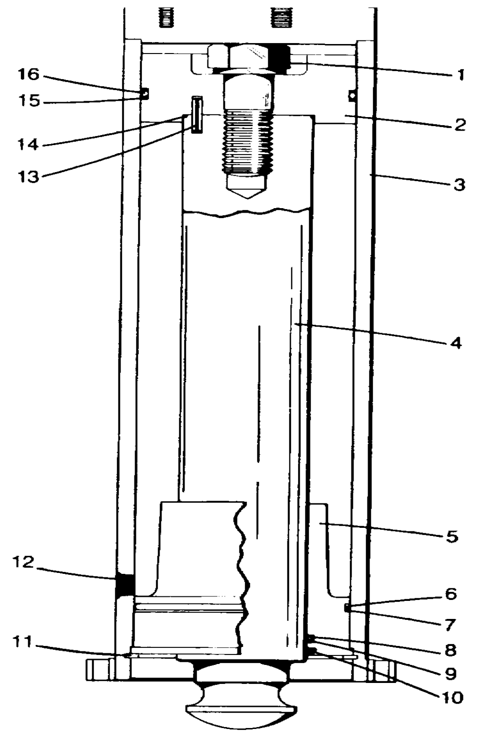



*Fig. 1* *N38-C*
*Jack Cylinder*

| | |
|---|---|
| (1) Locking Capscrew | (9) Back-up Ring |
| (2) Piston | (10) Wiper Ring |
| (3) Cylinder Body | (11) Snap Ring |
| (4) Rod | (12) Plug |
| (5) Gland | (13) Roll pin |
| (6) "O" Ring | (14) 'O' Ring |
| (7) Back-up Ring | (15) Back-up Ring |
| (8) 'O' Ring | (16) 'O' Ring |

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(c) Thoroughly wash the piston and the head in approved solvent.

### 3.3 Jack Cylinder Reassembly

(a) Install rollpin (13) in the hole in the end of the piston rod (4).
(b) Coat the static '0' ring (14) with Cosmo- lube #2 or equal, and place in the notch

at the end of the cylinder rod.

(c) Install the gland (5) on the piston rod. Install the locking capscrew (1) and tighten to 600 ft/lb. torque.

(d) Coat 'O' ring (16) with Cosmolube #2 or equal and install in the groove on the piston. Install back-up ring (15) on either side of the '0' ring.

(e) Coat the I.D. of the cylinder case with Cosmolube #2 or equal.

(f) Install piston rod assembly in cylinder body.

(g) Coat 'O' ring (6) and back-up ring (7) with Cosmolube #2 or equal and install in the groove on the outer side of gland (5). The back-up ring goes in the bottom of the groove.

(h) Coat '0' ring (8) and back-up ring (9) with Cosmolube #2 or equal and install in the groove inside the gland. The back-up ring goes in the bottom of the groove.

(i) Install the wiper ring (10) in the lower groove inside the gland.

(j) Coat the I.D. of the gland with Cosmolube #2 or equal and slide onto the piston rod. Be careful not to damage '0' ring seal inside of gland.

(k) Slide gland on into cylinder body.

(1) Install snap ring (11) which retains gland in cylinder body.

(m) Reinstall the jack cylinder in the end of outrigger beam.

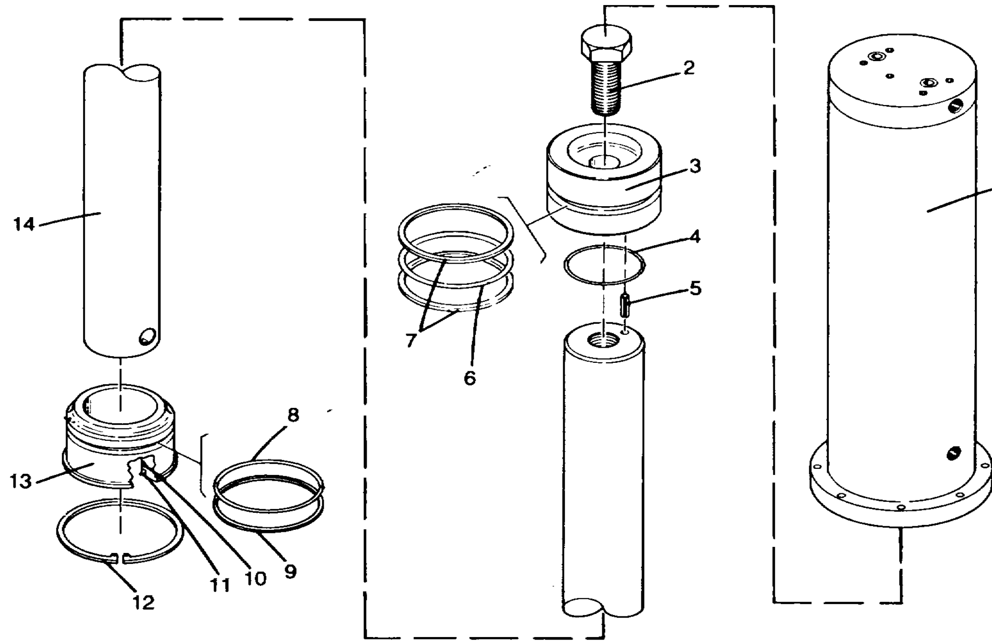



*Fig. 1*
*Front Bumper Jack Cylinder*

(1) Cylinder Body
(2) Piston
(3) Piston
(4) “O” Ring
(5) Roll pin
(6) “O” Ring
(7) Back-up Ring
(8) “O” Ring
(9) Back-up Ring
(10) “O” Ring And Back-up Ring
(11) Wiper
(12) Snap Ring
(13) Gland
(14) Piston Rod

The front bumper jack cylinder is a double act ing cylinder. Only one is used, and it is mounted on the front end of the carrier. The function of this jack is to provide lifting capacities over the front end of the carrier. This jack can be lowered only after the other four beam jacks have been lowered. Also, raise the bumper jack cylinder first before raising the four beam jacks.

Note:The front bumper jack cylinder alone is not strong enough to support the machine. The jack cylinder or carrier frame may be damaged if bumper jack cylinder operating instructions are not carefully followed.

## 9.1 Front Bumper Jack Cylinder Disassembly

If the jack cylinder develops an external leak or drifts down after the machine has been raise seal leakage (external or internal) is indicate The jack cylinder may be disassembled as follow

(a) Raise the machine up on the four beam jack cylinders to provide clearance.

(b) Clean the area around the hydraulic lines leading to the lock valve and the cylinder. Disconnect the hydraulic lines. Immediately cap or plug all openings to prevent entry of foreign material.

(c) Remove the lock valve from the top of the cylinder.

(d) Position a transmission jack or a similar heavy duty hydraulic jack below the bumper jack cylinder. Raise the jack until the piston rod (item 14 in Fig. 1) is supported by the jack.

(e) Remove the connecting bolts from the mounting flange at the bottom of the cylinder.

(f) Use the transmission jack to slowly lower the cylinder down from its carrier housing. Carefully support the cylinder to prevent it from falling after it clears the carrier housing. Lay the cylinder on the transmission jack.

**CAUTION**

Securely Support The Front Bumper Jack Cylinder During Cylinder Removal. Do Not Allow The Jack Cylinder To Fall At Any Time.

(g) Insert a lifting eye in the top of the cylinder Connect a chain hoist to the lifting eye and carefully lift the cylinder off the transmission jack. Position stable hardwood blocking to support the outrigger cylinder. Use the chain hoist to slowly lift the cylinder onto the blocking.

(h) Remove the bottom hose line elbow fitting from the side of the cylinder body (1).

(i) Remove the snap ring (item 12 in Fig. 1) from the bottom of the cylinder.

(j) Remove the piston rod (14), piston (3), and gland (13) as a unit from the cylinder body (1).

(k) Remove the gland (13) from the piston rod.

(1) Remove the piston capscrew (2) from the cylinder rod (14). Remove the piston (3) from the rod.

## 9.2 Inspection And Parts Replacement

**CAUTION**

The Piston Rod Must Be Carefully Handled And Protected To Prevent Scoring, Scratching, Etc, Never Clamp The Rod In A Vise Unless The Jaws Are Protected By Soft Material Such As Lead Or Copper. Never Leave The Exposed Rod Where Welding Splatter Or Other Such Material May Strike The Finished Surface.

(a) Wash the piston rod and check for damage such as dents, deep scratches, damaged chrome plating, etc. All sharp edges on both ends of the rod should be removed with a fine file or whetstone to prevent damage during reassembly. If the rod shows any severe damage, it must be replaced. The static "O" ring (item 4 in Fig. 1), that rides on the turned down portion of the rod, must always be replaced. Lubricate this ring with Cosmolube #2 or equivalent before installation.

(b) Whenever the cylinder is disassembled all "O" rings (items 4, 6, 8, and 10), back-up rings (items 7, 9, and 10), and the wiper (11) should be replaced. A seal kit is available containing these items. Refer to your machine’s parts book for the item number of the seal kit.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(c) Thoroughly wash the piston (3) and the glan, (13) in approved solvent.

The cylinder body bore should be thoroughly washed with approved solvent. Carefully inspect it for signs of "scoring" or deep scratches. If any are found, the cylinder must be replaced. Scratches of this type are generally caused by foreign material in the hydraulic system and cannot be field repaired.

## 9.3 Front Bumper Jack Cylinder Reassembly

(a) Install a rollpin (item 5 in Fig. 1) in the hole on the end of the piston rod (14).

(b) Coat the static "O" ring (4) with Cosmolube or equivalent. Place the "0" ring in the notch at the end of the piston rod.

(c) Install the piston (3) on the rod. Measure the length of the piston capscrew (2) before installing it. See below for capscrew torques:

| Piston Capscrew Torque | |
|---|---|
| Length | Torque |
| 3-1/4" | 1,480-1,500 ft/lbs.<br>(1977.3-2004 Nbm) |
| 3" | 600 ft/lbs.<br>(791.6 NHm) |

After determining the piston capscrew torque, install the capscrew and tighten it to the required torque.

(d) Coat the two back-up rings (7) and the "0" ring (6) with Cosmolube #2 or equivalent. Install them on the piston as shown in Fig. 1.

(e) Coat the "0" rings (items 8 and 10), back- up rings (9 and 10), and the wiper (11) with Cosmolube #2 or equivalent. Install the "O" ring (8) and back-up ring (9) in the out- side groove of the gland (13). Make sure the back-up ring goes on the bottom of the !L, groove as shown in Fig. 1. Next install the "O" ring and back-up ring (10) in the inside upper groove of the gland. Again make sure that the back-up ring goes on the bottom as shown. Finally, install the wiper (11) in the inside lower groove of the gland.

(f) Make sure that the bottom hoist line elbow fitting is removed from the side of the cylinder body (1).

(g) Coat the I.D. of the cylinder body (1) with Cosmolube #2 or equivalent.

(h) Coat the gland (13), piston (3), and piston rod (14) with Cosmolube #2 or equivalent.

(i) Install the gland (13) on the bottom end of the piston rod (14).

(j) Install the piston, piston rod, and gland in the cylinder body (1).

(k) Install the snap ring (12) to secure the gland to the cylinder body.

(1) Install the bottom hose line elbow fitting into the side of the cylinder body.

(m) Install a lifting eye in the top of the cylinder body. Connect a chain hoist to the lifting eye and move the cylinder onto a transmission jack or similar heavy duty hydraulic jack. Remove the lifting eye.

(n) Make sure all four crane outrigger jack cy- linders are fully extended. The crane must be raised to provide clearance.

(o) Move the transmission jack and cylinder benearth the front bumper jack housing on the carrier.

(p) Carefully position the jack cylinder below WJ the jack housing. Align the cylinder to allow the cylinder hose to clear the housing. Use the transmission jack to lift the cylinder into its housing. Securely support the jack cylinder during cylinder installation. Use the transmission jack to support the piston rod (14) and hold the cylinder in its housing. Install the cylinder mounting bolts and torque the bolts to 23 ft/lbs. (30.71 N m). After the bolts are installed and torqued, lower the transmission jack.

**CAUTION**

Securely Support The Jack Cylinder During Cylinder Installation. Do Not Allow The Cylinder To Fall At Any Time.

(q) Install the lock, valve on the top of the jack cylinder.

(r) Reconnect the front bumper jack cylinder hydraulic lines.

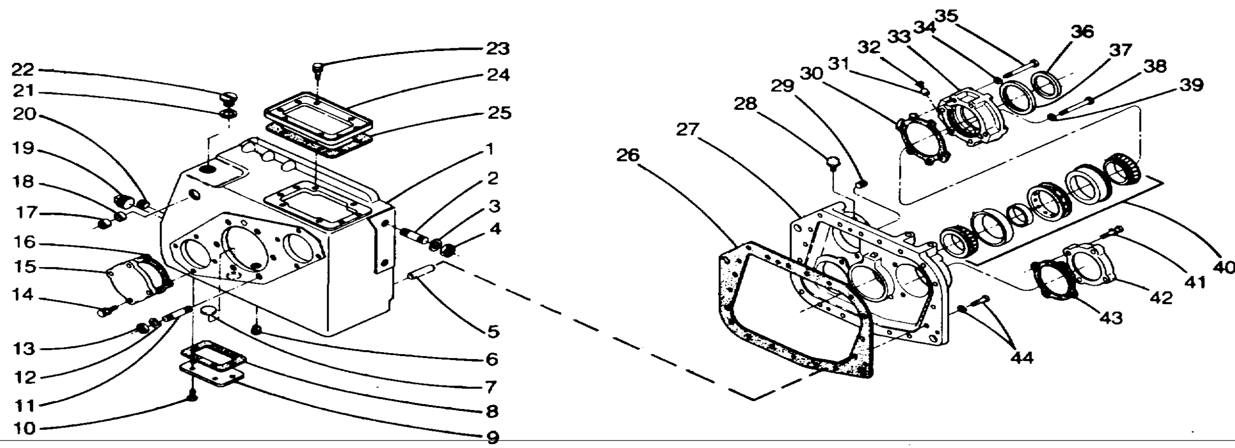


*Fig. 1*
*Main and Rear Housing Assembly*

(1) Case
(2) Stud
(3) Lockwasher
(4) Nut
(5) Dowel Pin
(6) Plug
(7) Magnet
(8) Gasket
(9) PTO Cover
(10) Capscrew
(11) Stud
(12) Lockwasher
(13) Nut
(14) Capscrew
(15) Cover
(16) Gasket
(17) Seal
(18) Oil Seal
(19) Plug
(20) Plug
(21) Gasket
(22) Plug
(23) Capscrew
(24) PTO Cover
(25) Gasket
(26) Gasket
(27) Rear Housing
(28) Breather
(29) Plug
(30) Gasket
(31) Bushing
(32) Plug
(33) Rear Bearing Cover
(34) Lockwasher
(35) Capscrew
(36) Speedometer Drive Kit
(37) Oil Seal
(38) Capscrew
(39) Gasket
(40) Bearing
(41) Capscrew
(42) Rear Bearing Cover
(43) Gasket
(44) Capscrew & Washer

## 1.1 Transmission Removal

(a) Set carrier parking brakes. Shift main transmission to neutral.

(b) Disconnect shift cable from creeper transmission. Drain creeper transmission lubricant

(c) Remove capscrews which connect drive shaft universal joints to flanges on creeper transmission. Remove drive shaft

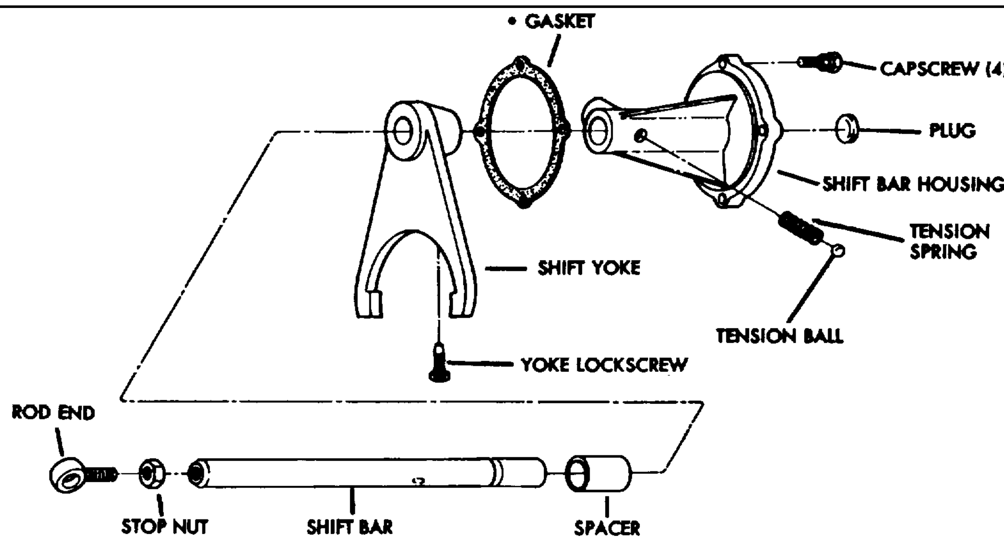



*Fig. 2*
*Shifting Control Assembly*

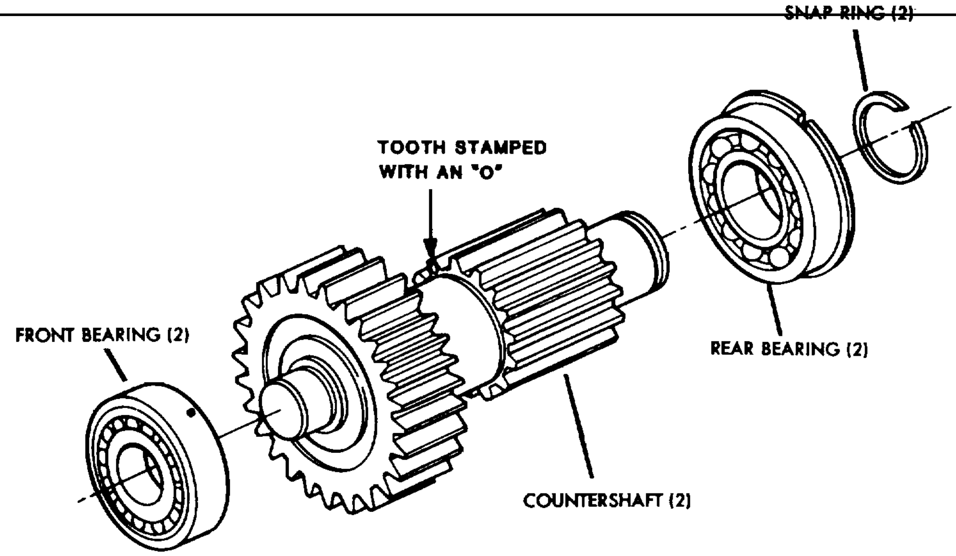



*Fig. 3*
*Countershaft Assembly*

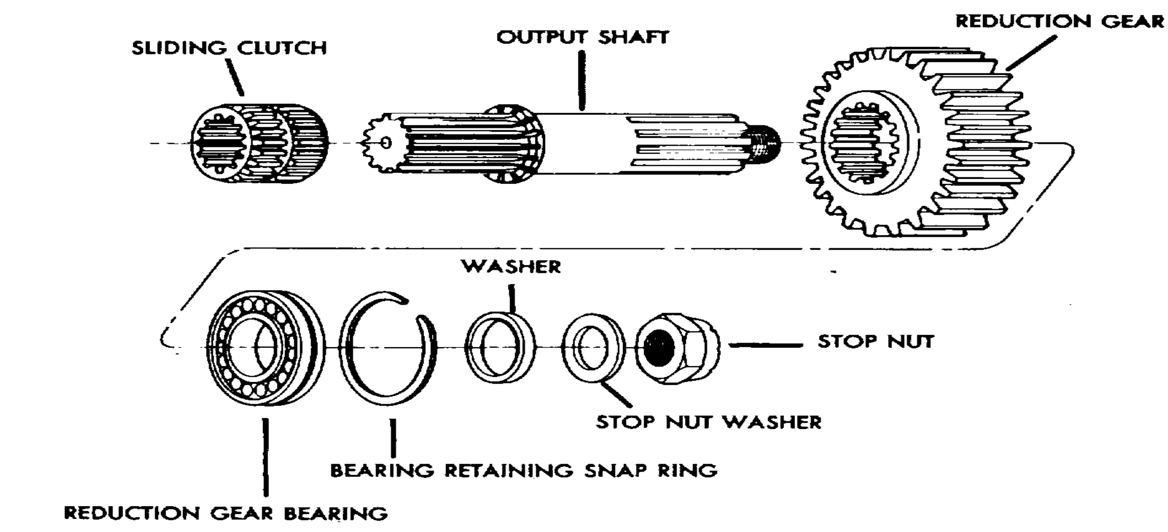



*Fig. 4*
*Output Shaft and Reduction Gear Assembly*

(d) Support transmission with blocking and jacks Remove mounting capscrews.

(e) Lower transmission out of carrier frame. Be careful; transmission weighs approximately 350 pounds.

(f) Thoroughly clean exterior of transmission before disassembly.

**1.2 Transmission Disassembly**

**1.3 Removal of Companion Flange**

(a) Brace against the outside of the flange with a tool and use a large breaker bar to remove the elastic stop nut from each shaft. shaft.

(b) Remove the washer and flange from each shaft

Note: <u>If a special tool is not available, the stop nuts may be removed by putting the transmission in direct gear, installing a breaker bar on the stop nut of both input and output shafts and removing the nuts by bracing them against each other.</u>

**1.4 Removal of Rear Plate from Front Case**

(a) Loosen the stop nut and turn the rod end from the end of the shift bar (see Fig. 2).

(b) Remove the 19 capscrews attaching the rear

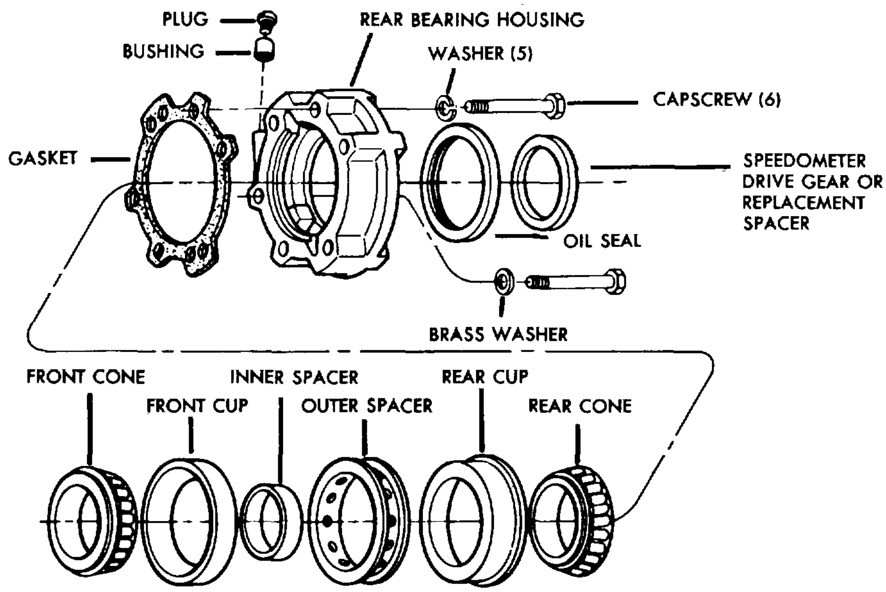



*Fig. 5*
*Rear Bearing Assembly*

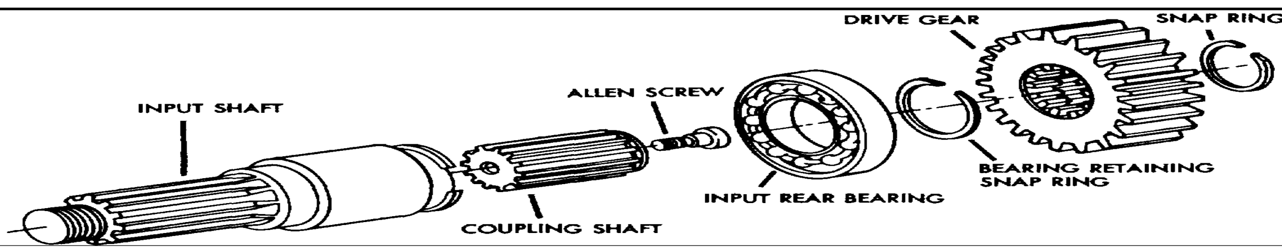



*Fig. 6*
*Input Shaft and Drive gear Assembly*

(c) Insert 3 puller screws in the three tapped plate to the front case. holes in the mounting flange of the rear plate and tighten evenly to move the plate to the rear approximately 1/2" to break the gasket seal.

(d) Attach a chain hoist to the rear plate and move the plate evenly to the rear and off the front case dowel pins. Mount the rear plate in a vise in the upright position.

### 1.5 Removal of the Shifting Control Assembly (Fig.

(a) Cut the lockwire and remove the yoke lock-screw

(b) Remove the spacer from the front of the shift bar.

(c) Put a rag over the bore in the shift bar housing to prevent loss of the tension spring and ball. Pull the shift bar sharply forward and from the housing.

(d) Remove the yoke from the sliding clutch. Remove the sliding clutch from the splines of the output shaft

(e) Tip the housing to remove the tension spring and ball.

### 1.6 Removal of the Countershaft Assemblies (Fig. 3)

(a) Use a three-jaw puller or equivalent to remove the front bearing from each countershaft.

(b) Remove the two countershaft rear bearing covers (33 in Fig. 1).

(c) Remove the snap ring from the rear of each countershaft.

(d) Use a soft bar and mallet to drive the countershaft assemblies forward and from the rear bearings.

(e) Use a soft bar to tap the bearings to the rear and from the rear plate bores.

### 1.7 Removal and Disassembly of Output Shaft and Reduction Gear Assembly (Fig. 4)

(a) Use a soft bar and mallet to drive the output

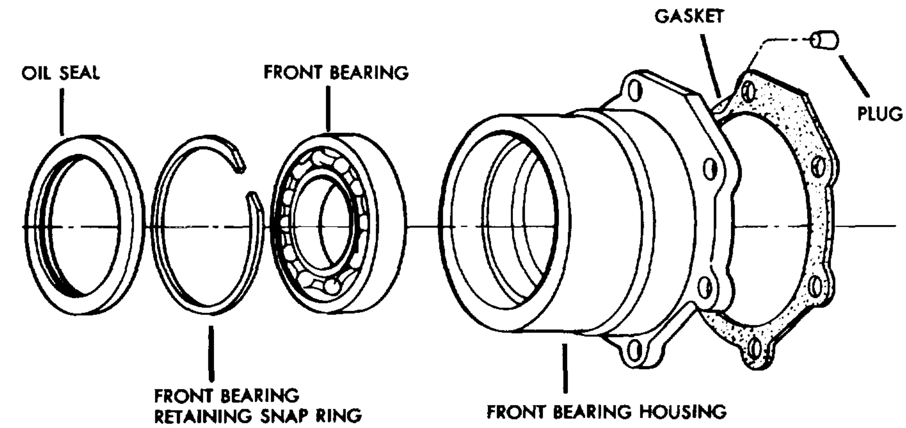



*Fig. 7*
*Front Bearing Housing Assembly*

shaft forward and from the rear bearing assembly.

(b) Remove the bearing inner spacer (washer) from the shaft.

(c) Remove the snap ring from the groove in the inner diameter of the reduction gear.

(d) Use a soft bar to tap the reduction gear from the output shaft (away from the bearing).

(e) Using the INNER RACE of the reduction gear bearing as a base, press the rear bearing front cone from the output shaft. This will free the reduction gear bearing and washer.

**1.8 Removal of Rear Bearing Assembly (Fig. 5)**

(a) Remove the six capscrews attaching the rear bearing housing to the rear plate.

(b) Remove the rear bearing housing, rear bearing cone and speedometer drive gear or replacement spacer from the rear plate.

(c) Use a soft bar to tap the front bearing cap and outer spacer forward and out of the rear plate bore.

(d) From inside the plate, tap the rear bearing cup to the rear and from the rear plate bore.

Note: If necessary, remove the oil seal from the housing with a hammer and punch. Removal procedure will damage the seal and removal should not be attempted unless replacement of the seal is planned.

**1.9 Removal and Disassembly of the Input Shaft** and Drive Gear Assembly (Fig. 6):

(a) Remove the snap ring from the groove in the rear of the coupling shaft.

(b) Pull the drive gear to the rear and from the splines of the coupling shaft.

(c) Use a soft bar and mallet to drive the input shaft to the rear and from the front bearing assembly.

(d) Remove the snap ring from the input shaft.

(e) Press the input shaft rear bearing from the shaft

(f) mount the input shaft in a vise with the threaded end down and use an allen wrench to remove the allen screw located in the hub of the coupling shaft. It will be necessary to turn the allen wrench with a crescent or open-end wrench.

Note: Don’t clamp the shaft in the vise by the threads.

**1.10 Removal and Disassembly of the Front Bearing** Housing Assembly (Fig. 7):

(a) Remove the six nuts attaching the housing to the front case and pull the housing from the studs.

(b) If necessary to remove the oil seal or front bearing, use a crows foot or equivalent to pry the oil seal from the housing bore.

Note: Removal procedures will most likely damage the oil seal and removal should not be attempted unless replacement of the seal is planned.

(c) Remove the snap ring from the groove in the inner diameter of the housing.

(d) Use a soft bar to tap the bearing forward and from the housing.

(e) For reassembly purposes, remove the two countershaft front bearing covers.

Note: Remove PTO gear covers, filler and drain plugs, breather and miscellaneous items if necessary. Removal of the seal and scraper in the shift bar bore will most likely damage the parts and removal should not be attempted unless replacement of the parts is planned.

**1.11 Inspection**

Before reassembling the transmission, the individual parts should be carefully checked to eliminate those damaged from previous service This inspection procedure should be carefully followed to insure the maximum of wear life from the rebuilt unit. The cost of a new part is generally a small fraction of the total cost of downtime and 1 should the use of a questionable part make additional repairs necessary before the next regularly scheduled overhaul.

Recommended inspection procedures are set forth in the following checklist:

Bearings:

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A We Ventilated Area, Away From Flame.

(1) Wash all bearings in clean solvent. Check balls, rolls, and races for pits and spalled areas. Replace bearings which are pitted or spalled.
(2) Lubricate bearings which are not spalled or pitted and check for axial and radial clearances. Replace bearings with excessive clearances.
(3) Check fits of bearings in case bores. I outer races turn freely in the bores, the case should be replaced.

Gears:

(1) Check operating gear teeth for pitting o the tooth faces. Gears with pitted teeth should be replaced.
(2) Check all engaging gear teeth. Gears with teeth worn, tapered or reduced in length from clashing in shifting should be replaced.
(3) Check axial clearances of gears. Where excessive clearance is found, check gear snap ring, washer, spacer and gear hub for excessive wear.

Splines:

(1) Check splines on all shafts for wear. If sliding clutch gears, companion flange or clutch hub have worn into the sides of the splines, the shafts in this condition should be replaced.

Gray Iron Parts:

(1) Check all gray iron parts for cracks and breaks. Replace or repair parts found to be damaged. Heavy castings may be welded or brazed providing the cracks do not extend into bearing bores or bolting surfaces.

Shifting Bar Housing Assembly:

(1) Check yoke for wear at pads. Replace if worn.
(2) Check yoke for alignment. Straighten if sprung.
(3) Check yoke for excessive wear; replace worn yoke.
(4) Check lockscrew in yoke. Tighten and re- wire if found loose.
(5) If housing has been dismantled, check neutral notch of shifting bar for wear from interlock ball. If indented at points adjacent to the neutral notch, the bar should be replaced.

Bearing Covers:

(1) Check covers for wear from thrust of adjacent bearing. Replace covers worn and grooved from thrust of bearing outer race.
(2) Check bores of covers for wear. Replace those worn oversize.

Oil Seals:

(1) Check oil seal in front bearing cover. If sealing action of lip has been destroyed, replace the seal.
(2) Check oil seal in mainshaft rear bearing cover. If sealing action of lip has been destroyed, replace seal.

Sliding Clutch:

(1) Check yoke and yoke slot in sliding clutch for extreme wear or discoloration from heat.
(2) Check engaging teeth of sliding clutch for partial engagement pattern.

## 1.12 General Precautions for Reassembly

Make sure that interiors of case and housings are clean. It is important that dirt be kept out of transmission during reassembly. Dirt is abrasive and can damage polished surfaces of bearings and washers. Use certain precautions, as listed below, during reassembly.

(1) Gaskets - Use new gaskets throughout the transmission as it is being rebuilt. Make sure all gaskets are installed, as omission of gasket can result in oil leakage or misalignment of bearing covers. See "Location of Gaskets" heading.
(2) Capscrews - To prevent oil leakage, use shellac on all capscrews. See torque rating chart for recommended torque.
(3) Assembly - Refer to the disassembly illustrations as a guide to reassembly.
(4) Initial Lubrication - Coat all thrust washers and splines of shafts with Lubricate during installation to provide initial lubrication, preventing scoring and galling.
(5) Bearings - Use of flanged-end bearing drivers is recommended for the installation of bearings. These drivers apply equal force to both races of bearing, preventing damage to balls and races and maintaining correct bearing alignment with shaft and bore. If tubular or sleeve type driver is used, apply force only to inner race.
(6) Universal Joint Companion Flanges - Pull the companion flanges tightly into place with the stop nuts, using 450-500 ft/lb. Of torque. Make sure the speedometer gear has been installed on yoke. If a speedometer gear is not used, a replacement spacer of the same width must be used. Failure to pull the yoke or flange tightly into place will permit the shaft to move axially with resultant damage to the rear bearing.

**1.13 Reassembly of Input and Coupling Shaft** Assembly (Fig. 6):

(a) Mount the input shaft in a vise with the threaded end down. Do not secure the shaft in the vise by the threads. Apply a drop of Grade AVV Loctite to the threads of the allen head screw.

(b) Install the coupling shaft in the input shaft with the large bore facing up.

(c) Secure the coupling shaft to the input shaft with the allen head screw. It will be necessary to turn the allen wrench with an open end or crescent wrench.

**1.14 Reassembly of Front Bearing Housing (Fig. 6,** 7)

(a) Install the rear bearing on the input shaft against the shoulder on the shaft. Note: Heating the bearing will facilitate installation. Do not heat bearing over 275°F.

(b) Install the snap ring in the groove on the input shaft.

(c) Install the front bearing in the bearing housing with a bearing driver or by tapping carefully on the bearing inner race with a soft bar.

(d) Install the front bearing retaining snap ring in the groove in the housing. Make sure the snap ring is in the groove and not just against the shoulder in the housing bore.

(e) Use an oil seal driver to install the front seal. The side of the seal with the seam should face into the housing, and the front of the seal should be flush with the face of the housing.

(f) Install the front bearing housing on the front case studs with the oil feed port on the mounting surface of the bearing housing aligned with the oil port in the front of the case. Secure with six nuts and lock- washers.

(g) From the inside of the case, start the in- put shaft assembly into the bearing housing bore with a soft bar. Use a soft bar and mallet to drive the shaft forward until the rear bearing seats against the shoulder in the bore.

(h) Install the drive gear on the shaft with the clutching teeth facing towards the rear of the case.

(i) Install snap ring in the groove on the coupling shaft.

Note: <u>If previously removed, reinstall the two PTO covers, all plugs and the shift bar seal and scraper. Do not install the two countershaft front bearing covers at this time.</u>

**1.15 Reassembly of Output Shaft and Reduction** Gear Assembly (Fig. 4 and 5):

(a) Install the reduction gear bearing in the hub of the reduction gear with snap ring in the bearing facing up. Use a bearing driver or tap carefully on the outer race of the bearing with a soft bar.

(b) Install the snap ring in the groove in the hub of the reduction gear.

(c) Mark any two teeth on the reduction gear and then mark the two teeth directly opposite.

(d) Place the output shaft on a bench with the threaded end up and install the reduction gear on the shaft with the clutching teeth of the gear facing down.

(e) Install the washer on the shaft and against the gear with the larger bevel on the inner diameter of the washer facing down.

(f) Install the bearing front cone on the shaft and against the washer with the taper facing up.

Note: <u>Heating the bearing will facilitate installation. Do not heat the bearing over 275° F.</u>

(g) Install the bearing inner spacer on the shaft.

**1.16 Installation of the Output Shaft and Rear** Bearing Assembly (Fig. 5):

(a) Install the bearing front cup in the rear plate bore, taper facing up.

(b) Place the bearing outer spacer on the front cup and tap evenly into the rear plate bore.

(c) Place the bearing rear cup on the outer spacer and tap evenly into the bore until the rear cup lip seats against the plate.

(d) Place the rear plate over the output shaft assembly.

Note: <u>If the rear cup lip moves away from the plate, hold the lip in position against the plate by bolting a countershaft bearing cover on the plate mounting surface so that an edge of the cover holds the lip of the bearing cup against the rear plate.</u>

(e) Install the bearing cone on the shaft, taper facing down.

Note: <u>Heating of the bearing will facilitate installation. Do not heat bearing over 2750F.</u>

(f) If previously removed, install the oil seal in the rear bearing housing flush with the surface, seam of the seal facing into the housing.

Note: <u>On units equipped with a speedometer drive gear, install the gear on the shaft prior to installation of the rear bearing housing.</u>

(g) Install the rear bearing housing on the rear plate with the six retaining capscrews The capscrews with the brass washer is installed in the capscrew bore intersecting the speedometer bore. Note: The rear bearing housing may be installed with the speedometer bore on either the left or right hand side of the plate. Make sure that either notch in the mounting surface of the housing is lined up with the oil port in the mounting surface of the plate (the untapped hole).

**1.17 Timing and Installation of Countershaft** Assemblies (Fig. 3):

(a) Mark the tooth which is stamped with an 'O' on the reduction gear on each countershaft.
(b) Place one of the countershaft assemblies in position inside the plate with the marked tooth meshed between two of the marked teeth on the reduction gear.
(c) Use a soft bar to start the countershaft rear bearing on the shaft and in the case bore.
(d) Use a bearing driver and mallet to complete installation of the countershaft rear bearing; repeat the procedure for installation of the remaining countershaft.
(e) Install the snap ring in the groove at the rear of each countershaft.
(f) Install the two countershaft rear bearing covers.

**1.18 Installation of the Shifting Controls (Fig. 2):**

(a) Install the tension spring in the bore of the shift bar housing.
(b) Install the tension bar over the spring, and use a screwdriver or equivalent to hold the tension ball down and insert the end of the shift bar with three notches into the housing until the neutral (middle) notch is over the tension spring and ball.
(c) Install the sliding clutch gear on the out- put shaft and place the shift yoke in position with the long hub on the yoke facing the rear plate.
(d) Place the shift housing and bar in position, passing the shift bar through the yoke hub. Note that the tension spring housing faces to the outside of the hub.
(e) Turn the shift bar until the lockscrew bore aligns with the lockscrew bore of the shift yoke. A click will be heard when the tension ball seats in the neutral notch.
(f) Install the yoke lockscrew. Tighten and wire securely.
(g) Install the spacer on the shift bar and against the yoke with the bevel on the inner diameter of the spacer facing the yoke.
(h) Secure the shift bar housing to the rear plate with the four retaining capscrews. If previously removed, install the plug in the end of the shaft.

**1.19 Installation of the Rear Plate (Fig. 1):**

(a) Attach a chain hoist to the rear plate and move the plate evenly into the front case, first guiding the shift bar into the front case bore, and then installing the rear plate bores on the front case dowel pins. Turn the input shaft as necessary to mesh with the countershaft assemblies.
(b) Secure the rear plate to the front case with the 19 remaining capscrews.
(c) Use a soft bar to start the countershaft front bearings on the shafts and into the case bores. Use a bearing driver to complete the installation. The beveled inner diameter of each bearing faces into the case.
(d) Install the two countershaft front bearing covers.

**1.20 Final Installation of the Shifting Controls:**

(a) If previously removed, install the stop nut on the rod end and turn the rod end into the end of the shift bar.
(b) Set the rod end in the desired position and lock in place by tightening the jam nut against the shift bar.

**1.21 Installation of Companion Flanges:**

(a) Install the flange on the input shaft. Install the washer and elastic stop nut on, the threads of the input shaft.
(b) On units not equipped with a speedometer drive gear, install the spacer on the output shaft and in the rear bearing housing.
(c) Install the flange on the output shaft. Install the washer and elastic stop nut on the threads of the shaft.
(d) Hold the flange in position and tighten elastic stop nut on each shaft to 450-500 ft/lb. torque.

Note: If a tool is not available to hold flange in position, the stop nuts may be installed by putting the transmission in direct gear and bracing against one shaft while tightening the nut on the other shaft. Repeat the procedure for tightening the opposite stop nut.

**1.22 Installation in Machine:**

(a) Raise transmission into place with jacks. Install transmission mounts and mounting capscrews.
(b) Install drive tubes. Install companion flange capscrews.
(c) Connect shift cable to transmission. Adjust as explained in the Operators Manual.
(d) Fill transmission with lubricant. Refer to Section 2 of the Operators Manual for proper type and amount of lubricant to use.

**1.23 Torque Ratings**

Recommended torque ratings, location and thread sizes of capscrews and nuts are listed below. Capscrew lengths are given for reference purposes as a guide for installation at proper locations.

Correct torque application is extremely important to assure long transmission life and dependable performance. Over-tightening or under-tightening can result in a loose installation and, in many instances, cause damage to transmission gears, shafts and bearings. Do not torque capscrews dry.

TORQUE CHART

| CAPSCREWS | | | |
|---|---|---|---|
| Location | Qty. | Size | Torque Ft/Lb. |
| PTO Cover (large) | 8 | 7/16-14 x 1 | 50-65 |
| PTO Cover (small)* | 6 | 3/8-16 x 3/4 | 18-23 |
| Countershaft Front Bearing Covers | 8 | 3/8-16 x 1 | 35-45 |
| Countershaft Rear Bearing Covers | 8 | 3/8-16 x 1-1/2 | 35-45 |
| Rear Plate Case | 16 | 3/8-16 x 1-1/2 | 35-45 |
| | 1 | 3/8-16 x 3 | 35-45 |
| | 2 | 3/8-16 x 2 | 35-45 |
| Rear Bearing Housing | 5 | 3/8-16 x 3 | 35-45 |
| | 1 | 3/8-16 x 3 Eslock | 35-45 |
| Shift Bar Housing | 4 | 3/8-16 x 1-1/4 | 35-45 |
| | NUTS | | |
| Mounting Studs | 4 | 5/8-18 | 170-185 |
| Front Bearing Housing | 6 | 1/2-20 | 170-185 |
| Companion Flanges | 2 | 2-3/4-16 | 450-500 |

*Note: Installing the capscrews with more than 23 ft/lb. of torque will force the corners of the PTO cover *away* from the case with resultant oil leakage

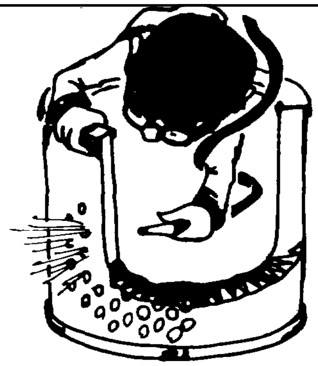



*Fig. 1*
*Cleaning With Compressed Air*

Although air cleaner elements are normally considered expendable, proper and careful cleaning can extend their life. Service intervals may vary from once a day to once a year, depending upon the dust conditions the engine is working in. Work out a schedule which is frequent enough to avoid down time for service on the job. Over servicing is common, and can be costly. The air cleaner should be serviced as follows:

(a) Empty the dust cap at regular intervals. These intervals may vary from 4 to 600 hours depending upon dust condition. Do not allow the dust level in the cup to build up closer than 1/2 inch from the slot in the dust cup baffle.
Stop the engine and remove the dust cap. Remove the baffle from the dust cup and empty the dust. Replace the baffle in the dust cup, making sure the baffle is properly seated. Check the dust cup sealing edge for damage. Check the dust cup gasket if so equipped. Replace the dust cup and make sure it is properly positioned on the air cleaner body. On horizontally mounted models, the proper cup position is indicated by the arrows located on the bottom of the cup. Also, the slot in the dust cup baffle must be at the top.

(b) Remove the main element from the air cleaner. Washing in water or blowing with compressed air are two accepted methods of cleaning the element If the element regularly contains amounts of soot or oil, washing in water is best. If the contaminant is mostly dust, either method works well. Elements cleaned with air can be put back in service immediately.

**CAUTION**

Washed Elements Must Be Dried Before Use.

Some elements are partially covered by plastic sleeve and fins. The covered portion of the filter can be cleaned with air or water without removing the sleeve. Use a stiff fiber (not wire) brush to remove oil and grease deposits from the fins. Do not remove the plastic sleeve and fins from the element.

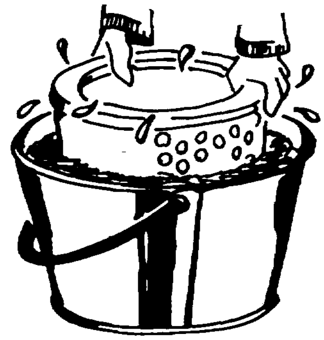



Fig. 2
Cleaning Element With Water

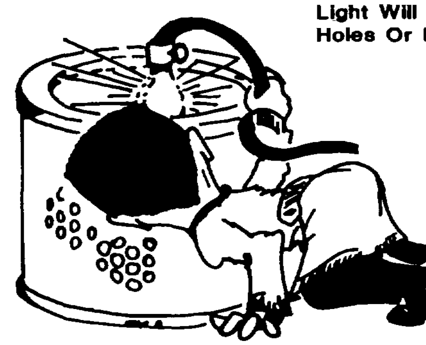



*Fig. 3*
*Inspecting The Element*

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

(1) Cleaning With Compressed Air (Fig. 1): Direct a jet of clean, dry air from the inside of the element, perpendicular to the pleats. Pressure at air nozzle must not exceed 30 psi
Move the air jet up and down along the pleats, slowly rotating the element until no more dust is being removed. Be careful not to rupture the element with the nozzle of the air jet.

(2) Cleaning With Water (Fig. 2): Filter elements can be cleaned by washing with water and a good non sudsing detergent, If compressed air is available, first direct a jet of clean, dry air from the inside of the filter element. When the loose dust and soot is removed the element is ready to be washed.

Use 2 ounces of detergent per gallon of water for washing elements. Dissolve the detergent in a small amount of cool water. Then add warm (100° F.) water until the proper mixture is reached.

Soak the element in the solution for at least 15 minutes. Agitate the element for 2 minutes to loosen and remove the dirt.

Rinse the element with clean water until the water coming through the element is clean. The water pressure should not be over 40 p.s.i Thoroughly air dry the element before using.

(c) After cleaning the filter element, inspect for damage (Fig. 3). Look for dust on the clean air side, the slightest rupture, or damage gaskets. A good way to detect ruptures In the element is to place a lighted light bulb inside the element and look toward the light from the outside. Any hole in the element, even a tiny one, will pass dirt to the engine and cause unnecessary wear.

(d) Inspect the air cleaner when servicing the elements. Replace any parts that are missing, worn, or damaged. Inspect the following items:

(1) Air cleaner mounting bands (loose, miss-ing nuts and bolt, breaks).
(2) Welded joints and seams on air cleaner body and inlet and outlet tubes.
(3) Connections between air cleaner and engine.
(4) Restriction tap plug, (loose or missing).
(5) Dust cup or' end cover, (holes, dents, sealing edge damaged).
(6) Dust cup retaining clamp, (broken, threads stripped).
(7) Dust cup gasket (if used) damaged.
(8) Gasket washer on element wing nut or bolt, (missing, worn, or installed backwards).
(9) Gasket on main element, (damaged).
(10) Plastic sleeve and fins, (plugged, damaged).

(e) The following general rules on service and care of air filters should be followed at all times.

(1) The elements should be replaced after one year or six cleanings, whichever occurs first.
(2) Store filter elements where they are protected from dust and potential damaged.
(3) If the sealing surface of the elements open end is damaged to the extent that a good air seal cannot be guaranteed, discard the element and install a new or cleaned element.
(4) Keep spare elements (new or cleaned) on hand to reduce vehicle downtime for servicing.
(5) When replacing filter elements, be absolutely sure that the proper size and model element is used.

The cylinder block (Fig. 1) serves as the main structural part of the engine. Transverse webs provide rigidity and strength and ensure alignment of the block bores and bearings under load.

The cylinder block is a wet type above the cylinder liner ports and a dry type below the cylinder liner ports. The water jacket and air box are sealed of by two seal rings compressed between the cylinder liner and the grooves in the block.

An air box between the cylinder banks and extending around the cylinders at the air inlet port belt conducts the air from the blower to the cylinders. Air box openings on each side of the block permit inspection of the pistons and compression rings through the air inlet ports in the cylinder liners The air box openings in the cylinder block assemble are approximately 1-7/8" x 3-1/8" and are covered with cast covers.

The camshaft bores are located on the inner side of each cylinder bank near the top of the block.

The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all movie parts of the engine, eliminating the need for external piping

The top surface of each cylinder bank is grooved to accommodate a block-to-head oil seal ring. Also, each water or oil hole is counterbored to provide for individual seal rings. The same size seal rings are used at all counterbored oil and water holes in the cylinder block.

Each cylinder liner is retained in the block by a flange at its upper end. The liner flange rests on an insert located in the counterbore in the block bore. An individual compression gasket is used at each cylinder.

When the cylinder heads are installed, the compression gaskets compress sufficiently to form a tight seal between the heads and the cylinder block.
Since the cylinder block is the main structural part of the engine, the various sub-assemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand (Fig. 2) provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction 900 or 180° where it is locked in place and then, if desired, tipped back with either end or the oil pan side up.

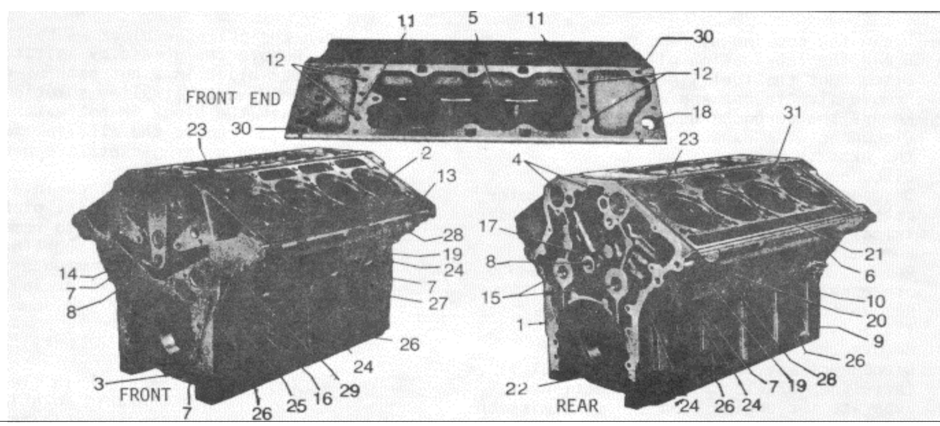



*Fig. 1 Cylinder Block*

1. Cylinder Block
2. bore for Cylinder Liner
3. Front Main Bearing Cap
4. Bores for Camshafts
5. Air Box
6. Water into Block
7. Water Drain
8. Main Oil Gallery
9. Oil Passage from Pump to Oil Filter
10 Oil Passage from Oil Cooler to Engine
11. Oil Supply Passages to Blower
12. Oil Drain Passage from Blower
13. Oil Drain from Cylinder Head
14. Oil Drain Passages
15. Oil Passage (Idler Gear Bearing)
16. Crankcase
17. Crankcase Breather Cavity
19. Air Box Drain
20. Inspection Hole Opening
21. Water Passages to Cylinder Head
22. Rear Main Bearing Cap
23. Oil passage to Cylinder Head
24. Oil Gallery
25. Oil Gallery
26. Dipstick Hole or Oil Return passage to Crankcase
27. Core Hole for Water Jacket
28. Water jacket Drain - Rear
29. Water jacket Hole
30. Oil Gallery Passage to End Bearing
31. Cylinder Head Bolt Hole

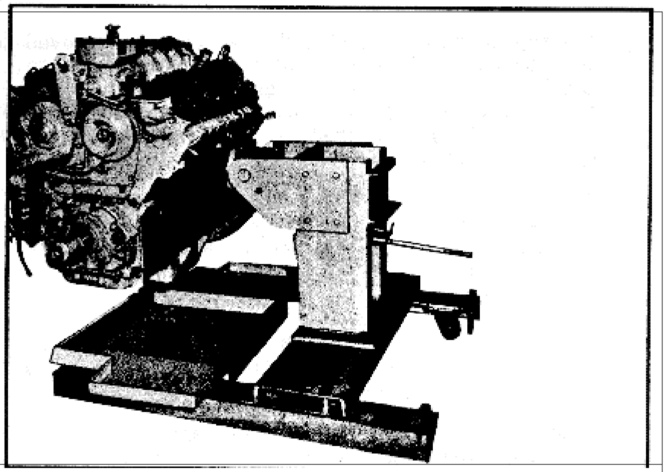


*Fig. 2*
*Engine Mounted on Overhaul Stand*

### 2.1 Remove and Disassemble Engine

Before mounting an engine on an overhaul stand, it must be removed from its base and disconnected from the transmission or other driven mechanism. Details of this procedure will vary from one application to another. However, the following steps will be necessary.

(1) Drain the cooling system.
(2) Drain the lubricating oil.
(3) Disconnect the fuel lines.
(4) Remove air cleaner and mounting brackets.
(5) Remove the turbocharger.
(6) Disconnect the exhaust piping and remove the exhaust manifolds.
(7) Disconnect the throttle controls.
(8) Disconnect and remove the starting motor, battery-charging generator and other electrical equipment.
(9) Remove the air compressor.
(10) Remove the radiator and fan guard and other related cooling system parts.
(11) Remove the air box drain tubes and fittings.
(12) Remove the air box covers.
(13) Disconnect any other lubricating oil lines fuel lines or electrical connections.
(14) Separate the engine from the transmission or other driven mechanism.
(15) Remove the engine mounting bolts.
(16) Use a chain hoist and suitable sling attached to the engine lifting brackets to lift the engine from its base.

**CAUTION**

Check The Fastenings Carefully To Be Sure The Engine Is Securely Mounted To The Overhaul Stand Before Releasing The Lifting Sling. Severe Injury To Personnel and Destruction Of Engine Parts Will Result If Engine Breaks Away From Overhaul Stand.

(17) Mount the engine on the overhaul stand. Use overhaul stand J 6837-01 with adaptor J 8601-01.
(18) With the engine mounted on the overhaul stand, remove all of the remaining sub-assemblies and parts from the cylinder block.

The procedure for removing each sub-assembly from the cylinder block, together with disassembly, inspection, repair and reassembly of each, will be found in the various SM's of this manual.

After stripping, the cylinder block must be thoroughly cleaned and inspected.

### 2.2 Clean Cylinder Block

Scrape all gasket material from the cylinder block. Then remove all oil gallery plugs and core hole plugs (except cup plugs) to allow the cleaning solution to contact the inside of the oil and water passages. This permits more efficient cleaning and eliminates the possibility of the cleaning solution attacking the aluminum core hole plug gaskets.

If a core hole plug is difficult to remove, hold a 3/4" drift against the plug and give it a few sharp blows with a one pound hammer. With a 1/2" flexible handle and a short extension placed in the countersunk hole in the plug, turn the plug slightly in the direction of tightening. Then turn it in the opposite direction and back the plug out.

Clean the cylinder block as follows:

(1) Remove the grease by agitating the cylin-der block in a hot bath of commercial heavy-duty alkaline solution.
(2) Wash the block in hot water or steam clean it to remove the alkaline solution.
(3) If the water jackets are heavily scaled, proceed as follows:
  (a) Agitate the block in a bath of inhibited commercial pickling acid.
  (b) Allow the block to remain in the acid bath until the bubbling stops (approximately 30 minutes).
  (c) Lift- the block, drain it and re- immerse it in the same acid solution for 10 minutes.
  (d) Repeat Step 'C' until all scale is removed.
  (e) Rinse the block in clear hot water to remove the acid solution.
  (f) Neutralize the acid that *may* cling to the casting by immersing the block in an alkaline bath.
  (g) Wash the block in clean water or steam clean it.

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(4) Dry the cylinder -6ock with compressed air
(5) Make certain that all water passages, oil galleries and air box drain openings have been thoroughly cleaned.

Note: The above cleaning procedure may be used on all ordinary cast iron and steel parts of the engine. Mention will be made of special cleaning_ procedures whenever necessary.

(6) After the block has been cleaned and dried, coat the threads of the plugs with sealant and, using new gaskets, reinstall the core hole plugs. Tighten the 2-1/2"-16 plugs to 230-270 ft/lb. (312-366 N.m) torque using plug installer J 23019.

A water inlet adaptor plug and gasket replaces the rear (flywheel housing end) 2-1/2" core hole plug in the cylinder block air box floor on engines with an aftercooler (refer to SM1-63- 44.0). Use tool J25275 to install or remove the adaptor plug. Tighten the adaptor plug to 230-270 ft/lb. (312-366 N.m) torque.

Note: Excessive torque applied to tapered pipe plugs may result in cracks in the water jacket. If for any reason the cup plugs in the water jackets were removed, install new plugs as follows:

(a) Clean the cup plug holes and apply Perma-tex No. 1 sealant, or equivalent, to the outer diameter of the plugs.

(b) Drive the plugs in place with handle J 7079-02 and adaptor J 24597 (for 2-1/2" diameter cup plugs) or adaptor J 21850 (for 1-5/8" diameter cup plugs).

## 2.3 Pressure Test Cylinder Block

After the cylinder block has been cleaned, it must be pressure tested for cracks or leaks by either one of two methods. In either method, it will be necessary to make a steel plate of 1/2" stock to cover each cylinder bank of the block. The plates will adequately seal the top surface of the block when used with new cylinder liner compression gaskets and water hole seal rings. It will also be necessary to use water hole cover plates and gaskets to seal the water openings in the sides of the block. One cover plate should be drilled and tapped to provide a connection for an air line so the water jackets can be pressurized.

Method 'A':

This method may be used when a large enough water tank is available and the cylinder block is completely stripped of all parts.

(1) Make sure the seal ring grooves in the cylinder bores of the block are clean. Then install new seal rings in the grooves (above the air inlet ports).

(2) Apply a light coating of hydrogenated vegetable type shortening or permanent type antifreeze solution to the seal rings.

(3) Place liner inserts in the cylinder block counterbores. Slide the cylinder liners into the block, being careful not to roll or damage the seal rings. Install new compression gaskets and water hole seal rings in the counterbores in the block.

(4) Secure the plates to the block with 11/16"-11 bolts and flat washers. Tighten the bolts to 250-260 ft/lb. (339-352 N-m) torque.

(5) Seal off the water inlet and outlet holes air tight. This can be done by using steel plates and suitable rubber gaskets held in place by bolts. Drill and tap one cover plate to provide a connection for an air line.

(6) Immerse the block for twenty minutes in a tank of water heated to 80-200°F (82-93°C).

(7) Apply 40 psi (276 kPa) air pressure to the water jackets and observe the water in the tank for bubbles which will indicate the presence of cracks or leaks in the block. A cracked cylinder block must be replaced by a new block.

(8) After the pressure test is completed, remove the block from the water tank. Then remove the plates, gaskets, liners, and inserts and blow out all of the passages in the block with compressed air.

(9) Dry the cylinder liners and inserts and coat them with oil to prevent rust.

Method 'B':

This method may be used when a large water tank is unavailable, or when it is desired to check the block for cracks without removing the engine from the equipment which it powers. However, it is necessary to remove the cylinder heads, blower, oil cooler, air box covers and oil pan.

(1) Attach sealing plates and gaskets as in Method 'A'. However, before attaching the last sealing plate, fill the water jacket with a mixture of water and one gallon of permanent type antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.

Note: Do not use a methoxy propanol base antifreeze as it is detrimental to the water seals.

(2) Install the remaining sealing plate and tighten it securely.

(3) Apply 40 psi (276 kPa) air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks which may exist.

(4) At the end of the test period, examine the cylinder bores, air box, oil passages, crankcase and exterior of the block for presence of the water and antifreeze mixture which will indicate the presence of cracks. A cracked cylinder block must be replaced by a new block.

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(5) After the pressure test is completed, re-move the plates and drain the water jacket. Then remove the liners and seal rings and blow out all of the passages in the block with compressed air.

(6) Dry the cylinder liners and inserts with compressed air and coat them with oil to prevent rust.

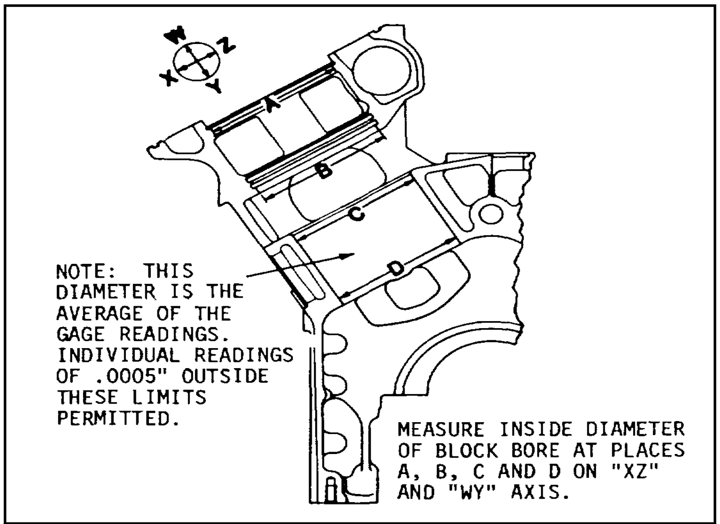



*Fig. 3*
*Cylinder Block Bore Measurement Diagram*

**2.4 Inspect Cylinder Block**

After cleaning and pressure testing, inspect the cylinder block.

Since most of the engine cooling is accomplish by heat transfer through the cylinder liners to the water jacket, a good liner-to-block contact must exist when the engine is operating. When ever the cylinder liners are removed from an engine, the block bores must be inspected.

(1) Check the cylinder block bores:

(a) Measure the bore of each cylinder with cylinder bore gage J 5347-01 which has a dial indicator calibrate in .0001" increments. Make sure the seal ring grooves in the cylinder block bores are thoroughly clean. Then inspect the grooves and lands for evidence of pitting and erosion. Seal rings are used in the two grooves above the air inlet ports. If the grooves are eroded to the extent that sealing is affected, the block must be replaced.

(b) Measure each cylinder block bore, at the positions indicated in Fig. 3, o axis $^{90°}$ apart. If the diameter doe not exceed 5.3615" (new) or 5.3625" (used) at position 'A', 5.3380" (new or 5.3390" (used) at position 'B' (lower two seal ring lands), 5.2170" (new) or 5.2180" (used) at position 'C' and 5.2175" (new) or 5.2180" (used) at position 'D', and a sealing problem has not occurred at position 'B', the block may be reused. The above measurements are average gage readings at each position. Also, the taper and out-of-roundness must not exceed .0010".

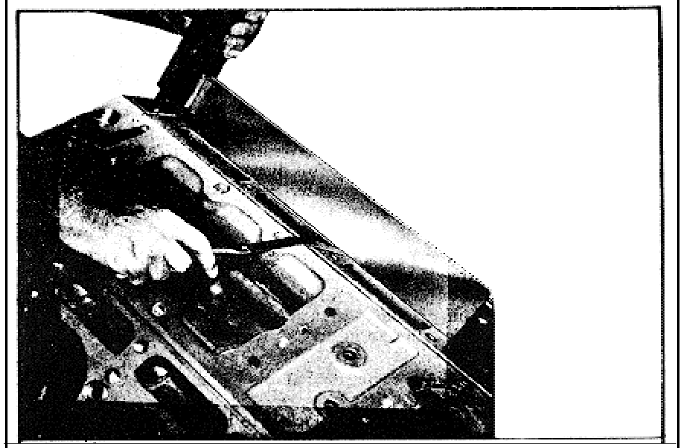


*Fig. 4*
*Checking Top Surface of Cylinder block*

Note: Dial bore gage setting master tool J 23059-01 may be used for setting the cylinder bore gage.

(2) Check the top of the block (cylinder head contact surfaces for flatness with an accurate straight edge and a feeler gage (Fig. 4). The cylinder head deck surfaces of the block must not vary more than .003" transversely and not over .006" longitudinally. It will be difficult to prevent water, oil and compression leaks if these surfaces exceed these tolerances.

(3) Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth (Fig. 5). The depth must be either .4755" to .4770" or .4905" to .4920" and must not vary more than .0015" throughout the entire circumference.

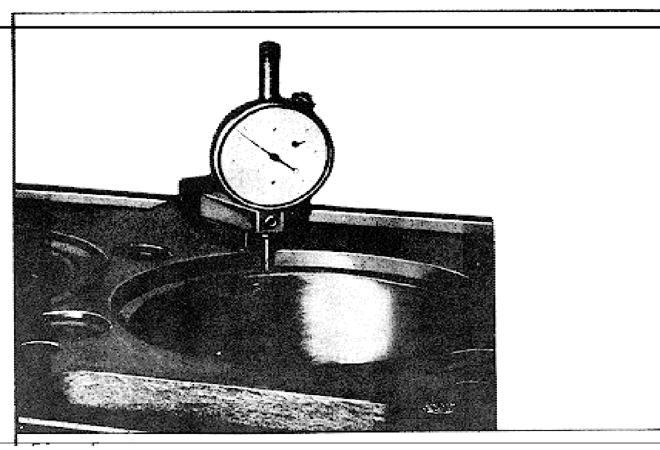


*Fig. 5*
*Checking Depth of Counterbore with Tool J 22273*

There must not be over .0015 inch difference between any two adjacent cylinder counter- bores when measured along the cylinder longitudinal centerline of the cylinder block, with the possible exception of the .4905 - .4920 inch deep counterbores.

(4) Check the main bearing bores as follows:

(a) Check the bore diameters with the main bearing caps in their original positions. Lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Then install and tighten the 11/16"-11 bolts to 230-240 ft/lb. (312-325 N.m) torque. When making this check, do not install the main bearing cap stabilizers. The specified bore diameter is 4.812" to 4.813". If the bores do not fall within these limits, the cylinder block must be rejected.

Important: Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

Note: Bearing caps are numbered to correspond with their respective positions in the cylinder block. It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The number of the front main bearing cap is also stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 main bearing ca is always located at the end opposite the flywheel end of the cylinder Fig. 6).

(b) Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a finished replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap

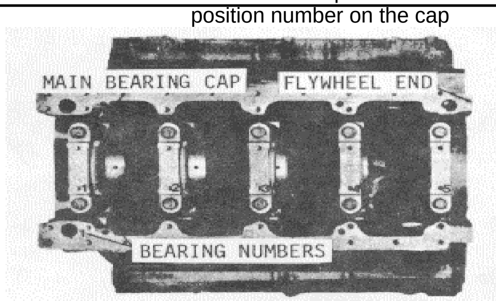



*Fig. 6 Cylinder Block Markings*

The finished bearing caps, machined for the crank- shaft thrust washers, are to be used in the rear bearing position.

(c) Main bearing bores are line-bored with bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured in place and the bolts tightened to 250-260 ft/lb. (339-352 N-m) torque. If a main bearing bore is more than .001" out of alignment, the block must be line-bored (see SM1-63-30.0) or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat, or other damage.

(d) If the main bearing bores are not in alignment when a replacement bearing cap is used, the block must be line- bored (see SM1-63-30.0). Install the bearing caps in their original positions (without the bearing cap stabilizers) and tighten the bolts to 230-240 ft/lb. (312-325 N-m) torque. Line-bore the block, but do not remove more than .001" stock. After boring, all bores must be within the specified limits of 4.812" to 4.813".

(5) Refer to the "Cylinder Block Plugging Chart" (see SM1-63-73.0) and install the necessary plugs and dowels.

(6) Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .630" from the cylinder block. The dowels used to retain the crankshaft thrust washers in the rear main bearing cap must extend .110" to .120" from the surface of the bearing cap.

Note: A stepped dowel pin is available to replace loose pins in the rear main bearing cap. Before installing the stepped pins, rebore the dowel holes in the bearing cap with a No. 11 (.1910") or No. 12 (.1890"-drill. After pressing the pins into the bearing cap, remove all burrs from the base of the dowel pins to ensure proper seating of the thrust washers.

(7) Examine the cylinder head retaining bolt holes. If the threads are damaged, use a tap to "clean-up" the threads or install a helical thread insert.

(8) The tapped holes in the water-below-port cylinder blocks may be tapped with a 11/16" thread tap. The unplugged bolt holes must have the thread extending 1.850" below the block surface. If the bolt hole in the block is plugged, the plug must be a minimum of 1.960" below the surface of the block and threaded the full distance. When replacing a bolt hole plug in the water- below-port block, refer to "Shop Notes"

in SM1-63-30.0.

(9) Check the remaining cylinder block surfaces and threaded holes. Check all of the mating surfaces, or mounting pads, for flatness, nicks and burrs. Clean up damaged threads in tapped holes with a tap or install helical thread inserts, if necessary.

(10) After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil. If the block is to be stored for an extended period of time, spray or dip it in a polar type rust preventive such as Valvoline Oil Company's "Tectyl 502-C" or equivalent. Castings free of grease or oil will rust when exposed to the atmosphere.

2.5 Assemble and Install Engine

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

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Note: Before a reconditioned or new service replacement cylinder block is used, steam clean it to remove the rust preventive and blow out the oil galleries with compressed air.

(1) Mount the cylinder block on the overhaul stand.

(2) If a new service replacement block is used, stamp the engine serial number and model number on the right-hand side of the cylinder block. Also stamp the position numbers on the main bearing caps (Fig. 6) and the position of the No. 1 bearing on the oil pan mounting flange of the block.

(3) Install all of the required cylinder block plugs and drain cocks. Use a suitable non- hardening sealant on the threads of the plugs and drain cocks. Install the plugs flush with or below the surface of the block.

Note: Make sure the cup plug, which blocks the oil cooler adapter inlet from the adapter outlet, is installed in the vertical passage.

(4) Clean and inspect all engine parts and sub-assemblies and, using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. The procedures for inspecting and installing the various parts and sub-assemblies are outlined in the following SM's of this manual.

(5) Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.

(6) Complete the engine build-up by installing all remaining accessories, fuel lines, electrical connections, controls, etc.

(7) Operate the engine on a dynamometer, following the RUN-IN procedure outlined in SM1- 63-67.0.

(8) Reinstall the engine in the equipment which it powers.

A flat steel plate, one bolted to each end of the cylinder block (Fig. 1), provides a support for the flywheel housing at the rear and the balance weight cover at the front of the engine. The rear end plat has a 3 inch diameter breather hole for crankcase ventilation. Gaskets are used between the block and each end plate.

3.1 Inspection

When an end plate is removed, it is essential that all of the old gasket material be removed from both surfaces of the end plate and the cylinder block. Clean the end plate as outline under "Clean Cylinder Block" in SM1-63-2.0.

Inspect both surfaces of each end plate for nicks, dents, scratches or score marks and check the end plates for warpage. Check the plug nuts in the end plates for cracks or damaged threads. If nicks or scratches on the sealing surfaces of the end plates are too deep to be cleaned up, or the plug nuts are damaged, replace the end plates or plug nuts.

When installing a plug nut, support the end plate on a solid flat surface to avoid distort the plate. Then press the nut in the end plate until the head on the nut seats on the end plate.

3.2 Install End Plates

(1) Affix new gaskets to the ends of the cylinder block. Also attach the small round gasket to the corner at the front end of the cylinder block.

Note: <u>If the flywheel housing does not have a pressure pad, use Permatex No. 2, or equivalent non-hardening sealer, at the upper right rear of the block face and corresponding area on the rear end plate.</u>

(2) Attach the front end plate to the cylinder block with bolts and lockwashers. Tighten

(3) Insert the right bank camshaft end bearing through the SMALL bearing bore in the end plate and into the bore of the block to accurately align the end plate with the cylinder block as shown in Fig. 2.

Note: <u>The holes in the front and rear end plates for the camshaft end bearings are not the same size. The smaller hole is accurately machined for alignment purposes and is always located on the right side of the engine as viewed from the rear.</u>

(4) With the bearing in place, tighten the 1/2"-13 end plate-to-cylinder block bolts to 71-75 ft/lb. (96-102 N.m) torque. Tighten the 3/8"-16 bolts to 30-35 ft/lb. (41-47 N.m) torque. Then remove the cam- shaft bearing which served as a pilot while attaching the front end plate.

(5) Install the rear end plate in the same manner as outlined above for the front end plate.

(6) Install the 5/8"-11 x 1" bolt on the right rear side of the end plate. Tighten it to 137-147 ft/lb. (186-200 N.m) torque. Note: <u>Attach the small cover to the cylinder block side of the rear end plate with two bolts and copper washers prior to installing the end plate. Use a new gasket between the cover and the end plate.</u>

(7) <u>Trim off any excess gasket material.</u>

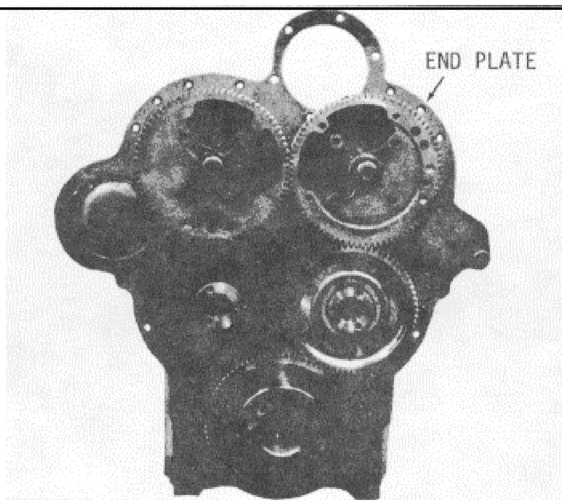


*Fig. 1 Cylinder Block Rear End Plate*

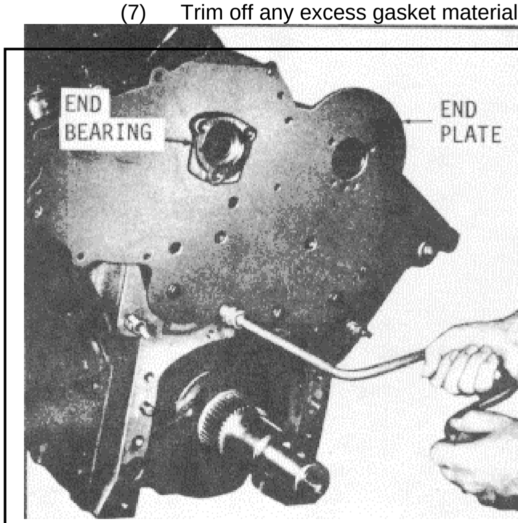


*Fig. 2 Installing Front End Plate*

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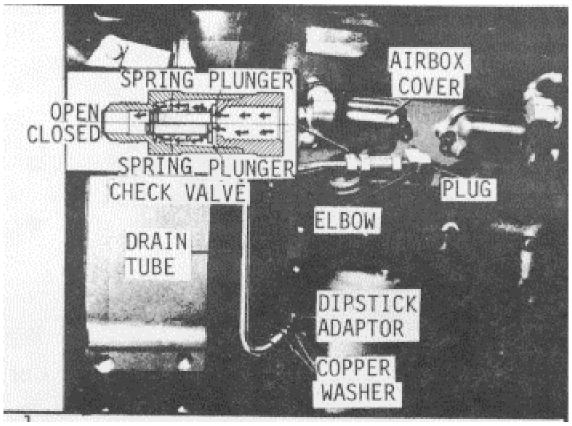


*Fig. 1 Air Box Drain Tube and Check Valve*

During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil fumes, condenses and settles on the bottom of the air box. This condensation is removed by the air box pressure through air box drain tubes (Fig. 1) mounted on the sides of the cylinder block.

Air box drains must be kept open at all times, other- wise water and oil that may accumulate will be drawn into the cylinders.

The air box drain tubes are routed to the crankcase at the rear dipstick holes at each side of the engine, rather than to the atmosphere (Fig. 1).

In conjunction with the new drain tubes, a check (control) valve has been installed in the air box drain fitting on each side of the engine to allow drainage only at low air box pressures.
The check valve cutaway (Fig. 1) shows the valve operating at engine idle speed. As the engine speed and air box pressure increase, the valve moves for- ward and seats, blocking air flow.

To accommodate the drain tubes, a dipstick adapter which has a 1/4" drilled return opening is used at the dipstick hole. The adapter on the side opposite the dipstick is closed for the dipstick, but is open for the air box drain tube. For sealing, a copper washer is used on each side of the drain tube flange (union) at the dipstick adapter. Tighten the dipstick adapter to 50-60 ft./lbs. (68-81 N-m).

4.1 Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Operators Manual).

Inspect the check valve for proper operation as follows:

(1) Disconnect the drain tube between the check valve and the air box drain tube nut at the air box cover.
(2) Run the engine and note the air flow through the valve at idle speed.
(3) If the check valve is operating properly, there will be no airflow at engine speeds above idle.

To check the air box pressures on an engine with the drain tubes, use air box covers with a tapped hole for a fitting.

(1) Remove the plug in the cover.
(2) Install a fitting and short drain tube.
3) Attach a manometer to the end of the drain tube and check the air box pressure as stated in SM1-63-69.0

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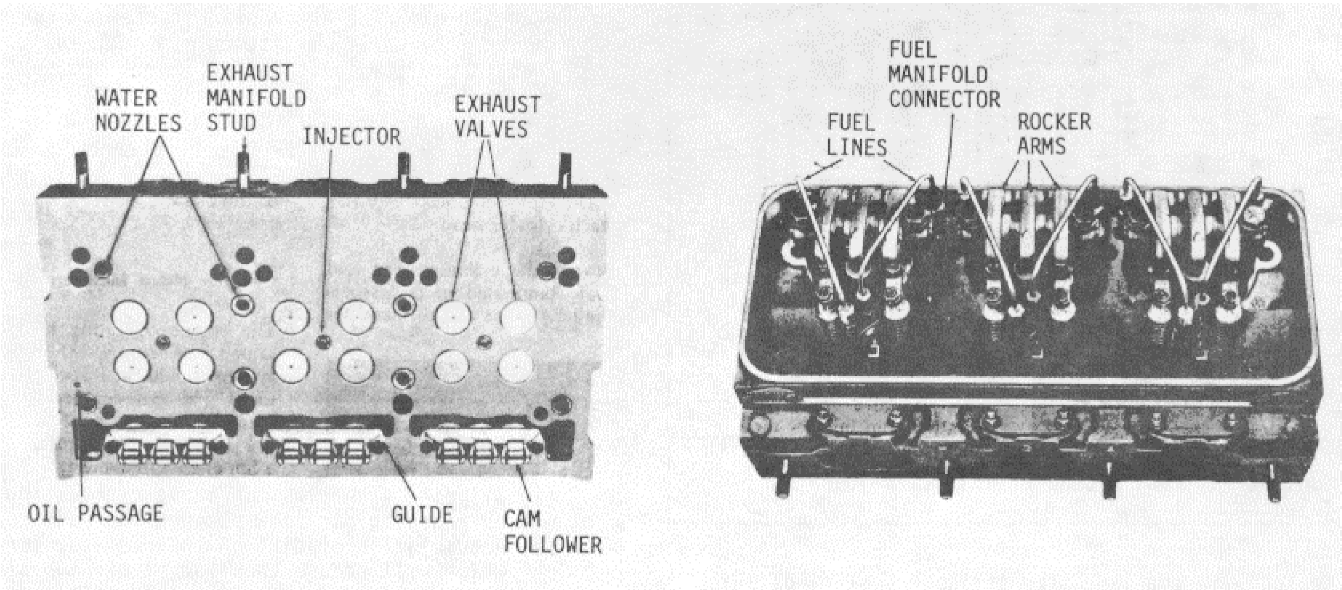


*Fig. 1Typical Cylinder Head Assembly*

The cylinder head (Fig. 1 and 2), one on each cylinder bank, is a one-piece casting securely held to the cylinder block by special 11/16"-11 bolts and hardened washers.

The exhaust valves, fuel injectors and the valve and injector operating mechanism are located in the cylinder head. The four exhaust valves (per cylinder) are arranged in a trapezoidal configuration, with two valves set farther apart than the others.

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of valves under varying conditions of temperature and materially prolong the life of the cylinder head.

To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube (Fig. 3) which passes through the water space in the cylinder head. The lower end of the injector tube is pressed into the cylinder head and flared over; the upper end is flanged and sealed with a seal ring. The sealed upper end and flared lower end of the injector tube prevent water and compression leaks.

The exhaust passages from the exhaust valves of each cylinder lead through a single port to the exhaust manifold. The exhaust passages and the injector tubes are surrounded by engine coolant.

In addition, cooling of the above areas is further ensured by the use of water nozzles (Fig. 4) pressed into the water inlet ports in the cylinder head.

The nozzles direct the comparatively cool engine coolant at high velocity toward the sections of the cylinder head which are subjected to the greatest heat.

The fuel inlet and outlet manifolds are cast as an integral part of the cylinder heads. Tapped holes are provided for connection of the fuel lines at various points along each manifold.

The water flow is all internal on the end outlet cylinder heads.

To seal compression between cylinder head and the cylinder liner, separate laminated metal gaskets are provided at each cylinder. Water and oil passages between the cylinder head and cylinder block are

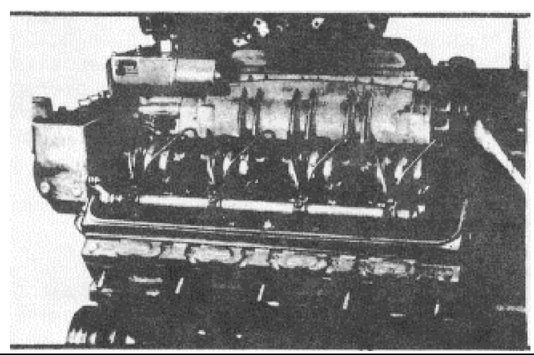

*Fig. 2 Cylinder Head Mounting*

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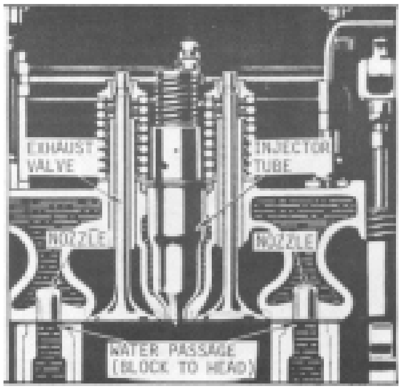


*Fig. 3 Coolant Passages Around Exhaust Valves and Fuel Injectors*

sealed with the same size silicone seal rings which fit into counterbored holes in the block. A synthetic rubber seal fits into a milled groove near the perimeter of the block.

5.1 Cylinder Head Maintenance

The engine operating temperature should be maintained between 160-185°F (71-850C) and the cooling system should be inspected daily and kept full at all times. The cylinder head fire deck will overheat and crack in a short time if the coolant does not cover the fire deck surface. When necessary, add water SLOWLY to a hot engine to avoid rapid cooling, which can result in distortion and cracking of the cylinder head (and cylinder block).

Abnormal operating conditions or neglect of certain maintenance items may cause cracks to develop in the cylinder head. If this type of failure occurs, a careful inspection should be made to find the cause and avoid a recurrence of the failure.

Unsuitable water in the cooling system may result in lime and scale formation and prevent proper cooling. The cylinder head should be inspected around the exhaust valve water jackets. This can be done by removing an injector tube. Where inspection discloses such deposits, use a reliable non-corrosive scale remover to re- move the deposits from the cooling system of the engine, since a similar condition will exist in the cylinder block and other components of the engine. Refer to Operators Manual for engine coolant recommendations.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and also result in loss of engine coolant. The tubes must be tight to be properly seated. Refer to SM1-63-33.0.

If a coolant leak develops at an injector hole tube, swaging tool J 28611 may be used to repair the leak without removing the cylinder head. Pressurize the cooling system at the radiator to verify existence of the leak. Then remove the injector and insert the tool in the injector tube. Strike the tool moderately two or three times with a one pound hammer. This will expand the top edge of the tube, increasing the "crush" on the seal ring. Install the injector and pressurize the cooling system again to determine if the leak has been stopped.

Overtightened injector clamp bolts may also cause head cracks. Always use a torque wrench to tighten the bolts to the specified torque.

Other conditions which may eventually result in cylinder head cracks are:

(1) Excess fuel in the cylinders caused by leaking injectors.
(2) Slipping fan belts can cause overheating by reducing air flow through the radiator.
(3) Accumulation of dirt on the radiator core which will reduce the flow of air and slow the transfer of heat from the coolant to the air.
(4) Inoperative radiator cap, which will result in loss of coolant.

5.2 Remove Cylinder Head

Certain service operations on the engine require removal of the cylinder head:

(1) Remove and install pistons.
(2) Remove and install cylinder liners.
(3) Remove and install exhaust valves.
(4) Remove and install exhaust valve guides.
(5) Recondition exhaust valves and valve seat inserts.
(6) Replace fuel injector tubes.
(7 Install new cylinder head gaskets and seals.
(8) Remove and install a camshaft.

Due to the various optional and accessory equipment used, only the general steps for removal of a cylinder head are covered. If the engine is equipped with accessories that affect cylinder head removal, note the position

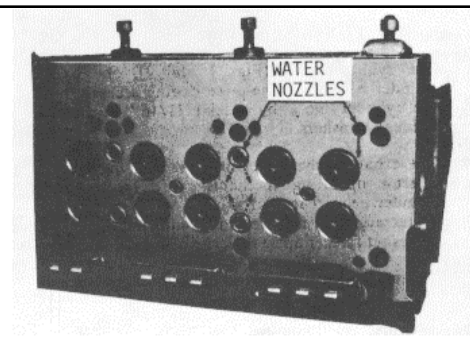


*Fig. 4 Location & Position of Water Nozzles in Cylinder Head*

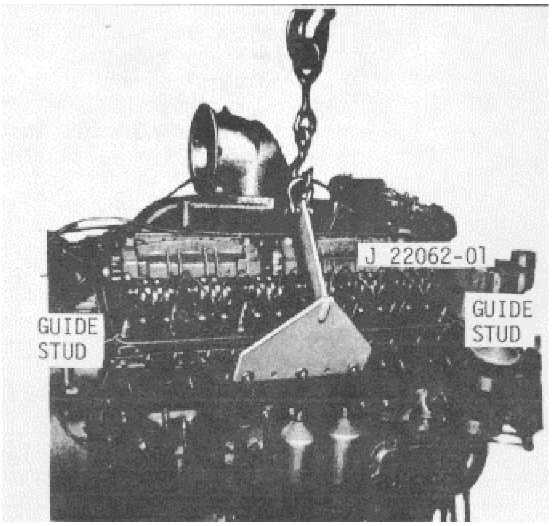


Fig. 5 Removing or Installing Cylinder Head

of each before disconnecting or removing them to insure correct reinstallation. Then remove the cylinder head as follows:

(1) Drain the cooling system.

(2) Remove the connections from the exhaust manifold to the turbocharger. Remove the turbocharger, if necessary.

(3) Disconnect the fuel lines at the cylinder head.

(4) Loosen the hose clamps and remove the hose attached to the thermostat housing cover.

(5) Loosen the hose clamps at each end of the water bypass tube and remove the tube.

(6) Remove the thermostat housing assembly.

(7) Clean and remove the valve rocker cover and governor cover.

(8) Disconnect the fuel rod from the injector control tube lever and the governor. Remove the fuel rod.

(9) Loosen the fuel rod cover hose clamps. Then slide the hose up on the fuel rod cover toward the governor.

(10) Remove the exhaust manifold.

(11) Remove the water manifold.

(12).Remove the injector control tube and brackets as an assembly.

(13) If the cylinder head is to be disassembled for reconditioning of the exhaust valves and valve seat inserts, or for a complete over- haul, remove the fuel pipes and injectors at this time. Refer to SM1-63-32.0 for removal of the injectors.

(14) Check the torque on the cylinder head bolts before removing the head. Then remove the bolts and washers and lift the cylinder head from the cylinder block with tool J 22062-01 (Fig. 5). If interference is en- countered between the rear end of the right-bank cylinder head and any of the flywheel attaching bolts, loosen the bolts. Checking the torque before removing the head bolts and examining the condition of the compression gaskets and seals after the head is removed may reveal the causes of any cylinder head problems.

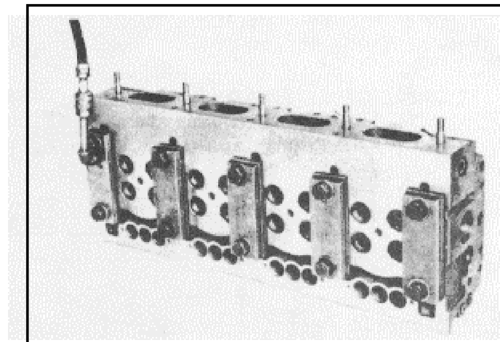

*Fig. 6 Cylinder Head Prepared for Pressure Testing*

Note: When placing the cylinder head assembly on a bench, protect the cam followers and injector spray tips, if the injectors were not removed, by resting the valve side of the head on 2 inch wood blocks.

(15) Remove and discard the cylinder head compression gaskets, support shims and the oil seals and water seals.

(16) After the cylinder head has been removed, drain the lubricating oil from the engine. Draining the oil at this time will remove any coolant that may have worked its way to the oil pan when the head was removed.

5.3 Disassemble Cylinder Head

If complete disassembly of the cylinder head is necessary, refer to SM1-63-6.0 and 1-63-7.0 for removal of the exhaust valve and injector operating mechanism.

5.4 Clean Cylinder Head

After the cylinder head has been disassembled and all of the plugs (except cup plugs) have been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tubes and water nozzles. Then clean the cylinder head in the same manner as outlined for cleaning the cylinder block (SM1-63-2.0).

**WARNING**

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Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean all of the cylinder head components with fuel oil and dry them with compressed air.

| Engine | Maximum Longitudinal Warpage | Maximum Transverse Warpage |
|---|---|---|
| 6V | .0055" | .0040" |

Table 1

5.5 Inspect Cylinder Head

(1) Before a cylinder head can be reused, it must be inspected for cracks. Five pre- scribed methods for checking a cylinder head for cracks are as follows:

Note: If any method reveals cracks, the cylinder head should be considered unacceptable for reuse.

Magnetic Particle Method: The cylinder head is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which cause the magnetic particles in the powder or solution to gather there, effectively marking the crack. The cylinder head must be demagnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it uses fluorescent magnetic particles which glow under a "Black Light". Very fine cracks, especially on discolored or dark surfaces, that may be missed using the Magnetic Particle Method will be disclosed under the "Black Light".

Fluorescent Penetrant Method: A highly fluorescent liquid penetrant is applied to the area in question. Then the excess penetrant is wiped off the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection to find the crack is carried out using a "Black Light".

Non-Fluorescent Penetrant Method: The test area being inspected is sprayed with "Spot check" or Dye Check. Allow one to thirty minutes to dry. Remove the excess surface penetrant with clean cloths premoistened with. cleaner/remover. DO NOT flush surface with cleaner/remover because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developer thoroughly until agitator rattles. Invert spray can and spray short bursts to clear valve. Then spray this developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

The above four methods provide basic instructions.

Pressure Check Method: Pressure check the cylinder head as follows:

(a) To seal off the water holes in the cylinder head, assemble tool set J 28454 as follows (Fig. 6.)

(1-1) Install the rubber stoppers on the bridges.

(aa) Large stoppers are installed on the long center bridge feet opposite the notch and on the long end bridge feet closed together.

(bb) Small stoppers are installed opposite the large stoppers on center bridge and end bridge feet and on all short - bridges.

(2-2) Install the necessary parts, loosely, on the cylinder head.

(3-3) Tighten the hold down bolts until the stoppers start to distort. A 5 lb.-ft. (7 N-m) torque is usually sufficient.

Note: Do not over-tighten the hold down bolts. The rubber stopper could distort enough to seal both the inner and outer diameter of the water nozzles. If the outer diameter is sealed, a leak from the outer diameter would not be detected.

(4-4) Install the air supply plate.

Note: Do not hook onto the pressure checking tool, or any part of it, to move the cylinder head from one location to another. If this is done it could result in permanent damage to the tool.

(b) Install scrap or dummy injectors to ensure proper seating of injector tubes.

Dummy injectors may be made from old injector nuts and bodies -- the injector spray tips are not necessary. Tighten the injector clamp bolts to 20-25 ft/lb. (27-34 N-m) torque.

(c) Apply 40 psi (276 kPa) air pressure to the water jacket. Then immerse the cylinder head in a tank of water, previously heated to 180-200°F (82-930C), for about twenty minutes to thoroughly heat the head. Observe the water in the tank for bubbles which indicate a leak or crack. Check for leaks at the top and bottom of the injector tubes, oil gallery, exhaust ports, fuel manifolds and at the top and bottom of the cylinder head.

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(d) Relieve the air pressure and remove the cylinder head from the water tank. Then remove the plates, gaskets and injectors and dry the head with compressed air.

(e) If the pressure check revealed any cracks, install a new cylinder head.

(2) Check the bottom (fire deck) of the cylinder head for flatness:

(a) Use a heavy, accurate straight-edge and feeler gages, tool J3172, to check for

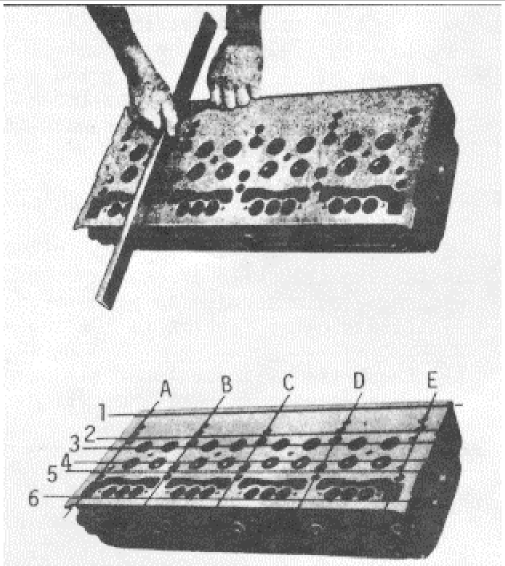


*Fig. 7 Checking Bottom Face of Cylinder Head*

transverse warpage at each end and between all cylinders. Also check for longitudinal warpage in six places as shown in Fig. 7. Refer to Table 1 for maximum allowable warpage.

(b) Use the measurements obtained and the limits given in Table 1 as a guide to determine the advisability of reinstalling the head on the engine or of re- facing it. The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

(c) If the cylinder head is to be refaced, remove the injector tubes prior to machining. Do not remove more than .020" (total) of metal from the fire deck of any cylinder head. The distance from the top deck to the bottom (fire deck) of the cylinder head must not be less than 3.536" (Fig. 8). Stamp the amount of stock removed on the face of the fire deck near the outer edge of the head, in an area not used as a sealing surface.

Note: When a cylinder head has been refaced, critical dimensions such as the protrusion of valve seat inserts, exhaust valves, injector tubes and injector spray tips must be checked and corrected. The push rods must also be adjusted to prevent the exhaust valves from striking the pistons after the cylinder head is reinstalled in the engine. Also, deburr the water nozzles.

(3) Install new injector tubes (SM1-63-33.0) if the old tubes leaked or the cylinder head was refaced.

Note: If the engine overheated, injector tubes in both cylinder heads must be re- placed.

(4) Inspect the exhaust valve seat inserts and valve guides (refer to SM1-63-7.0). HC238A

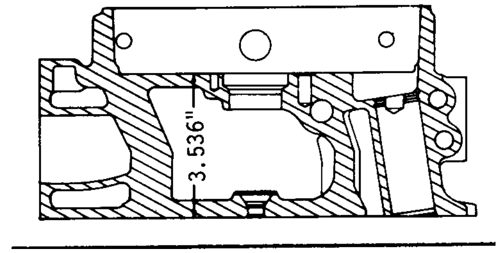


*Fig. 8 Minimum Distance Between Top and Bottom Faces of Cylinder Head*

(5) Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. Measure the bore diameters with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer, record and compare the readings of the cam followers and bores to determine the follower-to-bore clearances (refer to SM1-63-70.0). The can follower-to-cylinder head clearance must not exceed .006" with used parts (refer to SM1-63-70.0 for specifications). If the bores are excessively scored or worn, replace the cylinder head.

(6) Check the water hole nozzles to be sure they are not loose. If necessary, replace the nozzles as follows: Note: If the engine overheated, water nozzles must be replaced in both cylinder heads.

(a) Remove the old nozzles.

(b) Make sure the water inlet ports in the cylinder head are clean and free of scale. The intermediate nozzle holes are reamed and must not be cleaned with a drill. This could result in leakage of water into the lubricating oil. Use a soft bristle brush to clean the intermediate water nozzle holes.

(c) Install new nozzles with installing tool J 24857.

(d) Figure 4 shows the location and position of the nozzles in the cylinder head. The nozzles must be .004" recessed to flush with the bottom face of the cylinder head and the sealing area of the cylinder head around the nozzles flat within .002".

(7) Replace broken or damaged studs. Apply sealant to the threads of new studs and drive them to 10-25 ft/lb. (14-34 N.m) torque (water manifold cover studs) or to 25-40 ft/lb. (34-54 N-m) torque (exhaust manifold studs).

(8) Pilot sleeves are used in the mounting bolt hole at each end of the cylinder head (on the camshaft side of the head). Make sure the sleeves are flush or recessed be- low the fire deck of the cylinder head. Replace damaged sleeves. The sleeves, which act as a hollow dowel to provide a closer fit between the mounting bolts and the cylinder head, help to guide the head

in place without disturbing the seals and gaskets.
(9) Inspect all other components removed from the cylinder head.

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If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of all rust preventive compound, particularly inside the integral fuel manifolds, before installing the plugs. A simple method of removing the rust preventive compound is to immerse the head in mineral spirits or fuel oil, then scrub the head and go through all of the openings with a soft bristle brush. A suitable brush for clean- ing the various passages in the head can be made by attaching a 1/8" diameter brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

A service replacement cylinder head includes the exhaust valve guides, valve seat inserts, water nozzles, injector tubes, pilot sleeves, bridge guides, valve spring seats and the necessary plugs. In addition, shims strips, studs, cover plates, gaskets, lockwashers and nuts are provided to seal the water outlet openings that are not required on certain engines. A length of flexible fuel hose and fittings are also included where required.

5.6 Assemble Cylinder Head

After cleaning and inspection, assemble the cylinder head as follows:

(1) Refer to the "Four Valve Head Plugging Chart" and install the necessary plugs and tighten them to the specified torque (SM1- 63-74.0). Drive headless plugs flush to .0625" below the surface of the cylinder head. The 3/8" socket head oil gallery plug at each end of the head, must not protrude more than .0625" and a .2187" diameter rod placed in the vertical oil feed hold must pass the inner face of the plug. Note: Coat the threads of the plugs with Loctite Pipe Sealant with Teflon.

(2) After the following parts are cleaned and inspected and replaced if necessary, re- install them in the old cylinder head or transfer them to the new cylinder head.

(a) Exhaust valves, valve seat inserts, and springs (SM1-63-7.0).

(b) Cam followers, guides, push rods, springs, retainers, rocker arms, shafts, brackets and other related parts (SM1- 63-6.0).

(c) Place new washers on the fuel connectors. Then install the connectors and tighten them to 40-45 ft/lb. (54-61 N.m) torque.

(d) The fuel injectors, fuel pipes, injector V control tube assembly and water manifold if used, can be installed at this time, or after the cylinder head is installed on the engine.

5.7 Pre-Installation Inspection

Make the following inspections just prior to installing the cylinder head whether the head was removed to service only the head, or to facilitate other repairs to the engine.

(1) Check the cylinder liner flange heights with relationship to the cylinder block (SM1 -63-20.0).

(2) Make sure the piston crowns are clean and free of foreign material.

(3) Make sure that each push rod is threaded into its clevis until the end of the push rod projects through the clevis. This is important since serious engine damage will be prevented when the crankshaft is ro- tated during engine tune-up.

(4) Check the cylinder block and cylinder head gasket surfaces, counterbores and seal grooves to be sure they are clean and free of foreign material. Also check to ensure that there are no burrs or sharp edges in the counterbores.

(5) Inspect the cylinder head bolt holes in the block for accumulation of water, oil or any foreign material. Clean the bolt holes l~ thoroughly and check for damaged threads.

Note: The 2.00" diameter cup plug (thermostat housing end) in a new service head for the engine must be removed prior to installation to prevent blocking the coolant flow out of ti head.

5.8 Install Cylinder Head

(1) Install the water and oil seal rings, support shims and compression gaskets as follows:

(a) Place a new compression gasket on top of each cylinder liner. New compression gaskets are color coded (red, black, or no-paint) on the outside diameter to identify gaskets in a particular thickness range. Only gaskets of one color code should be used under any one cylinder head. It is also important that the liner height be checked (refer to SM1-63-20.0). There must not be over .0015"


*Fig. 9 Cylinder Head Support Shims in Place*

difference between any two adjacent liners when measured along the cylinder longitudinal center line.

(b) To prevent end cylinder head bolt breakage, support shims (Fig. 9) are attached at each end of the cylinder block (two per cylinder bank). Remove the adhesive paper and place the support shims, adhesive side down, in position at each end of the cylinder block. Note: The scallop in the shim placed at the rear of the block must be at the oil supply hole (Fig. 9).

(c) Place new seal rings in the counterbores of the water and oil holes in the cylinder block. Silicone-composition water hole seals can be damaged if they move out of position in the cylinder block counterbore during engine rebuild. In turn, damaged seals can allow engine coolant to contaminate lube oil and cause serious engine damage. To prevent this, a spray adhesive may be used to hold seals in place if the following precautions are taken.

(1-1) Attach a mask or template to the cylinder block fire deck to minimize over spray.

(2-2) Using a high-tack, spray type adhesive suitable for synthetic rubber seals (3M Company Super- Tack Gasket Adhesive #8082, or equivalent), spray a light, uniform coating of adhesive into the seal counterbores. Keep the adhesive off of adjacent block surfaces and wipe off any that gets on the fire deck or liner bores.

(3-3) Allow the adhesive to dry to a high-tack consistency (stickiness) before installing the seal. This permits the evaporation of the liquid propellant used with the adhesive.

Note: Do not apply adhesive directly to the seal. The adhesive will coat the I.D. of the seal and spray propellant may cause the seal to swell temporarily.

(d) Install a new oil seal in the groove at the perimeter of the cylinder block. The seal must lay flat in the groove and must not be twisted or stretched when in- stalled. Installing the seal strip in the groove with the colored stripe facing away from the cylinder bores can improve its sealing capabilities. Note: 3M Company Super-Tack Gasket Adhesive #8082 or equivalent may also be used to hold the peripheral head-to-block oil seals in place during engine rebuild.

Note: Never install used compression gaskets or seals.

(2) To install the cylinder head on the engine without disturbing the gaskets and seals, install guide studs J 24748 in two outboard corner bolt holes in the cylinder block. Do not install guide studs in the bolt holes which line up with the pilot sleeves in the head.

(3) Attach lifting tool J22062-01 to the cylinder head and lift the head into position above the cylinder block.

(4) Make a final visual check of the compression gaskets, seals and shims to ensure that they are in place before the cylinder head is lowered. This is a very important check. Gaskets and seals which are not seated properly will cause leaks and "blow-by" and result in poor engine performance and damage to the engine. Shim strips not in place can result in broken cylinder head bolts.

(5) Wipe the bottom of the cylinder head clean. Then lower the head until it is about 1/2" from the surface of the cylinder block.

(6) Apply a small amount of International Compound No. 2, or equivalent, to the threads and underside of the head of all cylinder head attaching bolts. Then install a bolt and washer through each piloting sleeve at the inboard corners of the head and thread them finger tight into the cylinder block. Continue to tighten these bolts (finger tight) as the head is lowered into position on the cylinder block. Note: Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

(7) After the head is in place, remove the guide studs and the lifting fixture and install the remaining bolts and washers, running the bolts down snug (15-20 ft/lb. or 20-27 N-m torque) with a speed handle.

(8) Tighten the 11/16"-ll bolts to 250-260 ft/lb. (339-352 N.m) torque, in increments of 50 ft/lb (68 N.m) torque, in the sequence shown in Fig. 10. Repeat the tightening sequence at least once, because the first bolts tightened in the sequence tend to lose significant clamp load during tighten- ing of the remaining bolts. Apply a steady pressure for two or three seconds at the prescribed torque to allow the bolts to turn while the gaskets yield to their final designed thickness. Begin on the cam follower side of the head to take up tension in the push rod springs. Tighten the bolts to the high side of the torque specification but do not exceed the limit or the bolts may stretch beyond their elastic limits. Attempting to tighten the bolts in one step may result in trouble and consequent loss of time in diagnosis and correction of difficulties, such as compression leaks, when the engine is put into operation.

Note: Tightening the cylinder head bolts will not correct a leaking compression gasket or seal. The head must be removed and the damaged gasket or seal replaced.

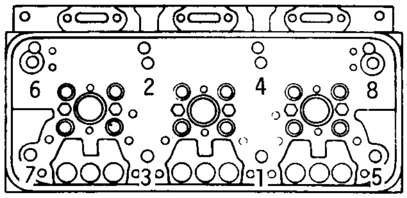


*Fig. 10 Cylinder Head for 6V Engine*

(9) If the fuel injectors were not previously installed, refer to SM1-63-32.0 and install them at this time.

(10) Adjust the exhaust valve bridges as outlined in SM1-63-7.0.

(11) Tighten the rocker arm bracket bolts to the specified torque (SM1-63-70.0).

(12) Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 ft/lb. (16-20 N.m) torque.

Note: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

(13) Set the injector control tube aseembly in place on the cylinder head and install the attaching bolts finger tight. When posi- tioning the control tube, be sure the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. With one end of the control tube return spring hooked around an injector rack control lever and the other end hooked around a control tube bracket, tighten the bracket bolts to 10-12 ft/lb (14-16 N-m) torque.

(14) After tightening the bolts, revolve the injector control tube to be sure the return spring pulls the injector racks out (no-fuel position) after they have been moved all the way in (full-fuel position). Since the injector control tube is mounted in self-aligning bearings, tapping the tube lightly will remove any bind that may exist. The injector racks must return to the no-fuel position freely by aid of the return spring only. Do not bend the spring. If necessary, replace the spring.

(15) Install the fuel rods. Then slide the fuel rod cover hoses in place and tighten the clamps.

(16) Connect the fuel lines.

(17) Install the thermostat housing and thermostat.

(18) Install the water bypass tube, hoses and clamps.

(19) Install the thermostat housing cover, hose and clamps.

(20) Install. the exhaust manifold and connect the exhaust piping.

(21) Install any other equipment that was previously removed.

(22) Refer to the Operators Manual under "Preparation for Starting Engine First Time" and fill the cooling system and lubrication system.

(23) Before starting engine, perform an engine tune-up as outlined in SM1-63-68.0.

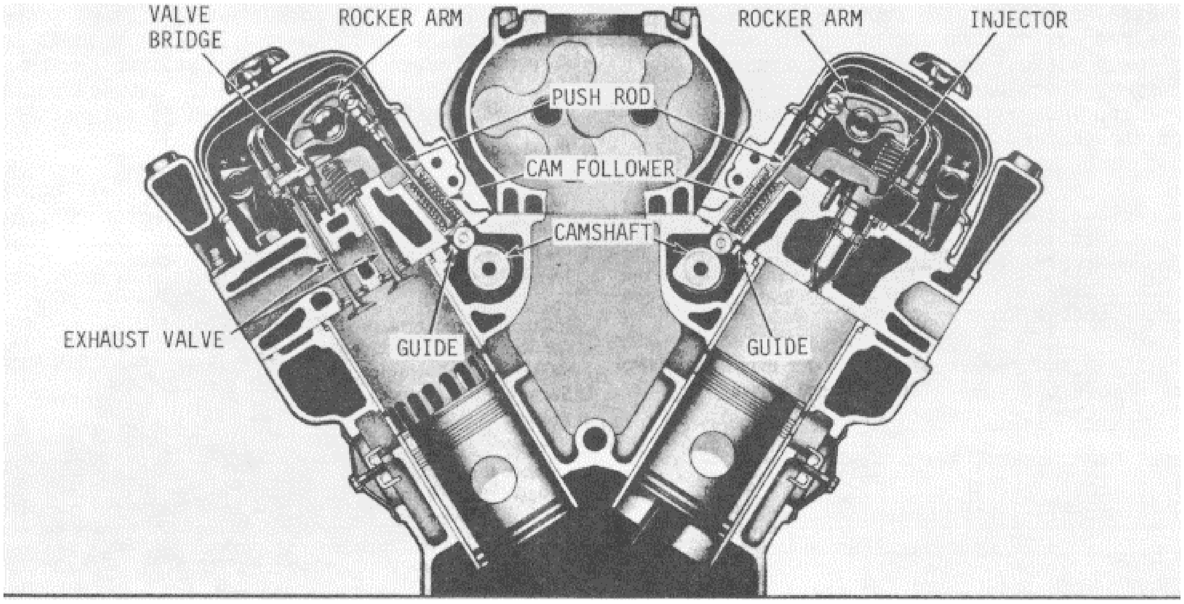


*Fig. 1 Valve and Injector Operating Mechanism*

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust valves and the center arm operates the fuel injector.

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Removal of the two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and the exhaust valve springs.

The rocker arms are operated by a camshaft through cam followers and short push rods extending through the cylinder head (Fig. 1).
Each cam follower operates in a bore in the cylinder head. A guide for each set of three cam followers is attached to the bottom of the cylinder head to retain the cam followers in place and to align the cam follower rollers with the camshaft lobes.

A coil spring, inside of each cam follower, maintains a predetermined load on the cam follower to ensure contact of the cam roller on the camshaft lobe at all times.

## 6.1 Lubrication

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage on the camshaft side of the cylinder head, which connects with the main oil gallery in the cylinder block. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft to lubricate the rocker arms (Fig. 2).

Overflow oil from the rocker arms lubricates the exhaust valves, valve bridges and cam followers.

The oil then drains from the top deck of the cylinder head through oil holes in the cam followers, into the camshaft pockets in the cylinder block and back to the oil pan.

The cam follower rollers are lubricated with oil from the cam followers, oil picked up by the camshaft lobes and by oil emitted under pressure from milled slots in the camshaft intermediate bearings.

## 6.2 Service

Some service operations may be performed on the valve and injector operating mechanism without removing the cylinder head:

(1) Adjust valve clearance.
**(2)** Replace a valve spring.
(3) Replace or adjust an exhaust valve bridge or replace a valve bridge guide.
(4) Replace a rocker arm.
(5) Replace a rocker arm shaft or bracket.
(6) Replace a fuel injector.

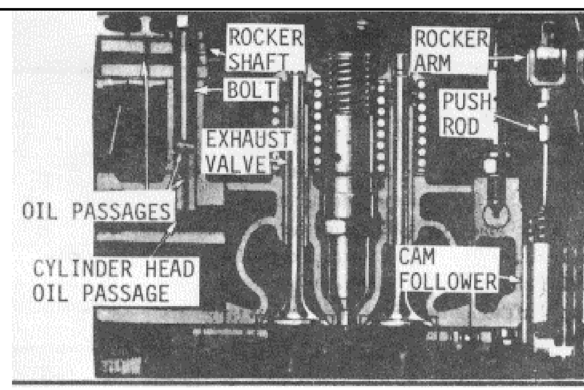


*Fig. 2 Lubrication of Valve Operating Mechanism*

It is also possible to replace a push rod, push rod spring, the spring seats or a cam follower without removing the cylinder head. However, these parts are more easily changed from the lower side when the cylinder head is off the engine. Both methods are covered in this SM.

To replace the exhaust valves, valve guides and valve seat inserts, the cylinder head must be removed (refer to SM1-63-7.0).

6.3 Remove Rocker Arms and Shaft

(1) Clean and remove the valve rocker cover.
(2) Remove the fuel pipes from the injector and the fuel connectors.

Note: Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

(3) Turn the crankshaft, or crank the engine with the starting motor, to bring the injector and valve rocker arms in line horizontally.

Note: Do not bar the crankshaft in a left hand direction of rotation with a wrench or barring tool on the crankshaft bolt, or the bolt may loosen.

(4) Remove the two bolts which secure the rocker arm shaft brackets to the cylinder head. Remove the brackets and shaft. Note: When removing the rocker arm shaft, fold the three rocker arms back just far enough so the shaft can be removed. Do not force the rocker arms all the way back with the shaft in place, as this may impose a load that could bend the push rods.

(5) Loosen the lock nuts at the upper ends of the push rods, next to the clevises, and unscrew the rocker arms from the push rods.

Note: If the rocker arms and shafts from two or more cylinders are to be removed, tag them so they may be reinstalled in their original positions.

6.4 Inspection

**WARNING**

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Wash the rocker arms, shaft, brackets, and bolts with clean fuel oil. Use a small wire to clean out the drilled oil passages in the rocker arms and rocker shaft bolts. Dry the parts with compressed air.

Inspect the rocker arm shaft and rocker arm bushings for wear. A maximum shaft to bushing clearance of .004" is allowable with used parts (refer to SM1-63-70.0). Service replacement bushings must be reamed to size after installation.

Inspect the rocker arms for galling or wear on the pallets (valve or injector contact surfaces).

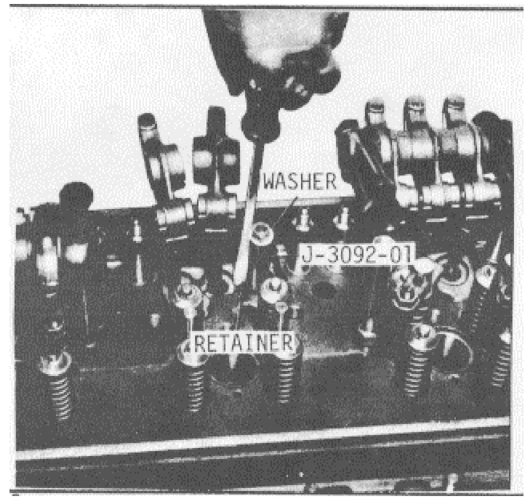


*Fig. 3*
*Removing Push Rod from Upper Side of Cylinder Head*

If worn, the surface may be refaced up to a maximum of .010". However, proceed with caution when surface grinding to avoid over- heating the rocker arm. Maintain the radius and finish as close to the original surface as possible. Also inspect the valve bridges for wear.
Inspect the rocker arm shaft brackets for cracks.

6.5 Remove Cam Follower and Push Rod (with Cylinder Head On Engine)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

To remove a push rod, spring, spring seats, and cam follower from the top of the cylinder head, proceed as follows:
(1) Remove the rocker arm shaft and brackets as outlined under 6.3 "Remove Rocker Arms and Shaft."
(2) Loosen the lock nut and unscrew the rocker arm from the push rod to be removed. Remove the lock nut.
(3) Install remover J 3092-01, a flat washer and the lock nut on the push rod, with the lower end of the tool resting on the upper spring seat.
(4) Thread the nut down to compress the spring.
(5) Remove the spring seat retainer from groove in the cylinder head (Fig. 3).
(6) Unscrew the lock nut to release the spring. Then remove the nut, flat washer and tool from the push rod.

(7) Pull the push rod, spring, spring seats and cam follower out of the cylinder head.

6.6 Remove Cam Follower and Push Rod (Cylinder Head Removed) When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location. (1) Rest the cylinder head on its side (Fig. 4)and remove the cam follower guide.

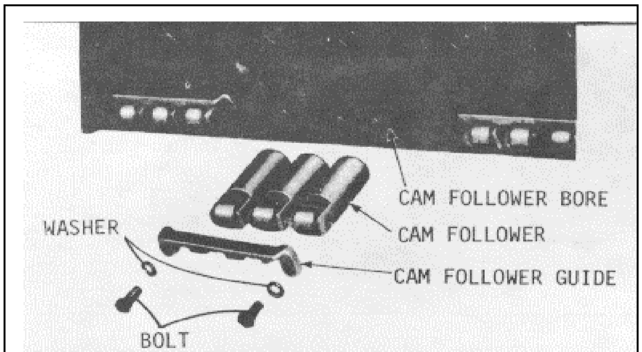


*Fig. 4*
*Cam Followers and Guide*

(2) Pull the cam follower out of the cylinder head.
(3) Remove the fuel pipes from the injector and the fuel connectors.

Note: Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

(4) Loosen the push rod lock nut and unscrew the push rod from the rocker arm clevis.
(5) Pull the push rod and spring assembly from the bottom of the cylinder head.
(6) Remove the push rod lock nut, spring and spring seats from the push rod. If the cylinder head is to be replaced, remove the spring retainers and install them in the new head.

6.7 Inspection

Proper inspection and service of the cam follower is very necessary to obtain continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, remove the cam followers and their related parts and inspect them for excessive wear. This change in injector timing or valve clearance can usually be detected by excessive noise at idle speed.

**WARNING**

Use Fuel Oil In Well Ventilated Area, Away From Flames.

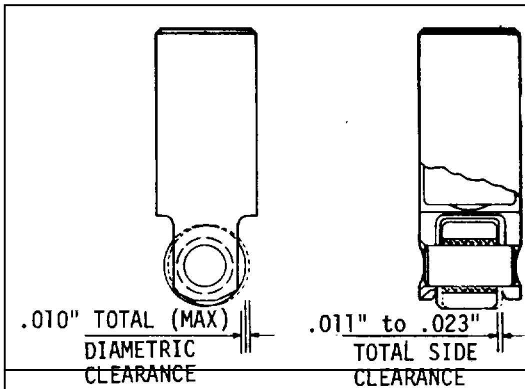


*Fig. 6*
*Cam Roller Clearances*

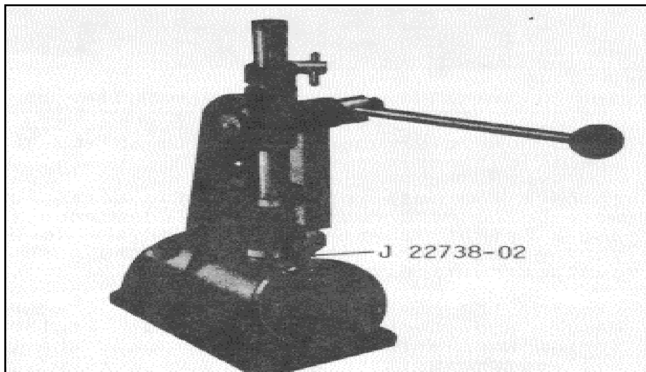


*Fig. 6*
*Testing Cam Follower Spring*

Wash the cam followers with lubricating oil or Cindol 1705 and wipe dry. Do not use fuel oil. Fuel oil working its way in between the cam roller bushing and pin may cause scoring on initial start-up of the engine since fuel oil does not provide adequate lubrication. The push rods, springs and spring seats may be washed with clean fuel oil and dried with compressed air.

Examine the cam follower rollers for scoring, pitting or flat spots. The rollers must turn freely on their pins. Measure the total diametric clearance and side clearance. Install a new roller and pin if the clearances exceed those specified in Fig. 5.

Examine the camshaft lobes for scoring, pitting-or flat spots. Replace the camshaft if necessary.

Measure the cam follower bores in the cylinder head with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record the readings and compare the readings of the

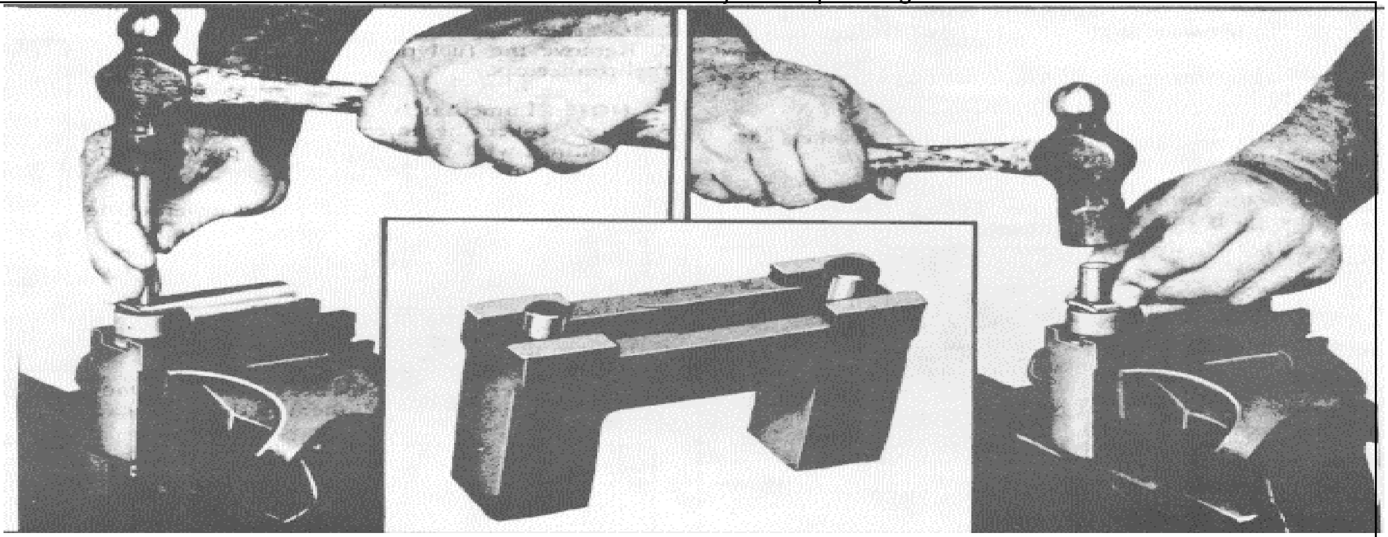

*Fig. 7*
*Removing or Installing Cam Follower Roller and Pin*

followers and bores to determine the cam follower-to-bore clearances (refer to SM1-63-70.0 for specifications).

Inspect the push rods and spring seats for wear. The push rods have milled wrench flats and a bright "turned" finish and the lower spring seats are serrated along the push rod contact surfaces.

Examine the cam follower springs for wear or damage and check the spring load. Replace a spring when a load of less than 250 lbs (1112 N) will compress it to a length of 2.1406". Use spring tester J 22738-02 to check the spring load (Fig. 6).

6.8 Replace Cam Roller and Pin

To replace cam roller & pin, proceed as follows:

(1) Clamp fixture J 5840-01 securely in a vise as shown in Fig. 7. Then place the cam follower in the groove in the top of the fixture, with the follower pin resting on top of the corresponding size plunger in the fixture.

(2) Drive the pin from the roller with a suitable drift. Exercise caution in removing the cam follower body and roller from the fixture as the roller pin is seated on a spring-loaded plunger in the fixture.

(3) Before installing the new roller and pin, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705 and wipe dry. Do not use fuel oil. After washing the parts, lubricate the roller and pin with Cindol 1705.

(4) Position the cam follower body in the groove of the fixture, with the small plunger extending through the roller pin hole in the lower leg of the follower body.

(5) Position the new cam roller in the cam follower body. When released, the plunger will extend into the roller bushing and align the roller with the cam follower body.

(6) Start the new pin in the cam follower body, then carefully tap it in until it is centered in the cam follower body.

(7) Remove the cam follower from the fixture and check the side clearance (Fig. 5). The clearance must be .011" to .023".

6.9 Install Cam Follower and Push Rod

If new cam follower assemblies are to be installed, remove the preservative by washing with Cindol 1605 and wipe dry. DO NOT USE FUEL OIL.

Before cam followers are installed, immerse them in clean Cindol 1705 (heated to 100-125°F or 38-520C) for at least one hour to ensure initial lubrication of the cam roller pins and bushings. Rotate the dam rollers during the soaking period to purge any air from the bushing-roller area. The heated Cindol oil results in better penetration as it is less viscous than engine oil and flows more easily between the cam roller bushing and pin. After the cam followers are removed from the heated Cindol 1705, the cooling action of any air trapped in the bushing and pin area will tend to pull the lubricant into the cavity.

Note: <u>Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent 'M the cam followers from touching the bottom of the pail and avoid the possibility of contamination.</u>

Install used cam followers and push rods in their original locations. Refer to Fig. 8 and proceed as follows:

Cylinder Head On Engine:

(1) Note the oil hole in the bottom of the cam

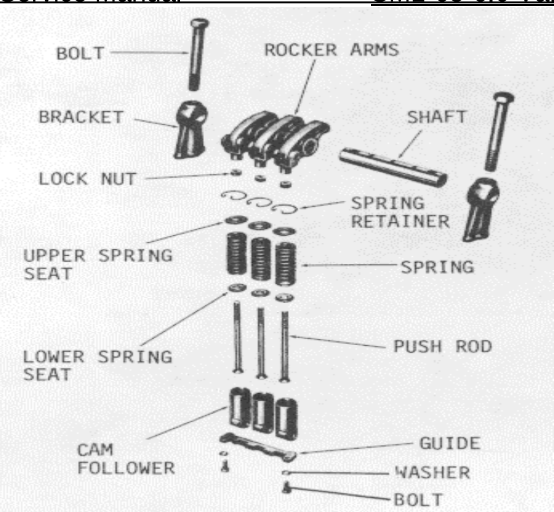


*Fig. 8*
*Valve and Injector Operating Mechanism and Relative Location of Parts*

follower. With the oil hole directed away from the exhaust valves (Fig. 9), slide the cam follower in position in the cylinder head.

(2) Assemble the serrated lower spring seat, spring and upper spring seat on the push rod.

(3) Place a flat washer over the upper spring seat and start the lock nut on the push rod. Place tool J 3092-01 on the push rod between the washer and the upper spring seat and place the push rod assembly in the cam follower. Then thread the lock nut on the push rod until the spring is compressed sufficiently to permit the spring retainer to be installed. Install the retainer with the tangs facing the notch in the cylinder head.

(4) Remove the nut, flat washer and tool. Then reinstall the lock nut and thread it as far as possible on the push rod.

Cylinder Head Removed from Engine:

Refer to Fig. 8 and install the cam follower and push rod as follows:

(1) Assemble the serrated lower spring seat, spring, upper spring seat and lock nut on the push rod.

(2) With the spring retainer-in place in the cylinder head, slide the push rod assembly in position from the bottom of the head.

(3) Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves (Fig. 9), slide the cam follower in position from the bottom of the head.

(4) Attach the follower guide to the cylinder head to hold the group of three cam followers in place. Check to make sure there is clearance between the cam followers and the cam follower guide. Tighten the guide bolts to 12-15 ft/lb (16-20 N.m) torque.

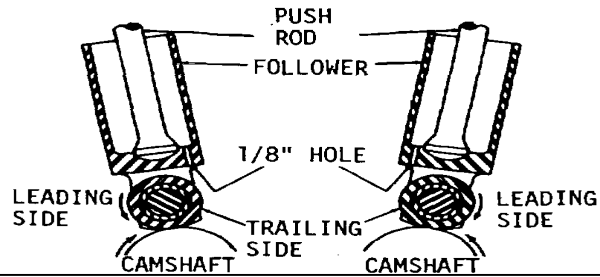


*Fig. 9*
*Installation of Cam Followers*

Note: <u>It is important to use the correct bolt as specified in the Parts Book. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation</u>.

6.10 Install Rocker Arms and Shaft

Note that the injector rocker arm (center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the shaft on the left and right-hand valve rocker arms is longer on one side. The extended boss of each valve rocker arm must face toward the injector rocker arm. The exhaust valve rocker arms also have a flat spot beneath the rocker shaft hole to ensure clearance with the valve bridge.

(1) Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. This will provide sufficient initial clearance between the exhaust valve and the piston when the crankshaft is turned during the valve clearance adjustment procedure.

(2) If removed, install the cylinder head on the engine (refer to SM1-63-5.0).

(3) Lubricate the valve bridge guides with sulphurized oil (E.P. type) and position the valve bridges in place on the guides. Refer to "Exhaust Valve Bridge Adjustment" in SM1-63-7.0 and adjust the valve bridges.

(4) If removed, install the fuel injectors.

(5) Apply clean engine oil to the rocker arm shaft and slide the shaft through the rocker arms. Then place a bracket over each end of the shaft, with the finished face of the bracket next to the rocker arm.

(6) Insert the rocker arm bracket bolts through the brackets and the shaft. Tighten the bolts to the specified torque (refer to SM1-63-70.0).

(7) Align the fuel pipes and connect them to the injectors and fuel connectors. Tighten the fuel pipe nuts to 12-15 ft/lb. (16-20N-m) torque using socket J 8932-01.

SM1-63-6.0 Valve and Injector Operating Mechanism

**Service Manual**

Note: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

(8) Fill the cooling system.

(9) Adjust the exhaust valve clearance and time the injectors (refer to SM1-63-68.0).

(10) If necessary, perform an engine tune-up.

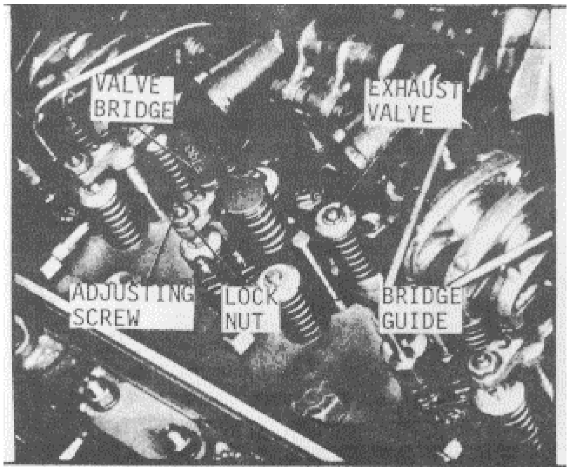


*Fig. 1*
*Location of Exhaust Valves*

Four exhaust valves are provided for each cylinder (Fig. 1). The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the exhaust valve bridge.
The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head (Fig. 2).

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head (Fig. 2).

The exhaust valve springs are held in place by the valve spring caps and tapered two-piece valve locks (Fig. 2).

Excess oil from the rocker arms lubricates the exhaust valve stems. The valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

7.1 Exhaust Valve Maintenance

Efficient combustion in the engine requires that the exhaust valves be maintained in good operating condition. Valve seats must be true and unpitted to assure leakproof seating, valve stems must work freely and smoothly within the valve guides, and the correct valve clearance, SM1-63-68.0, must be maintained.

Proper maintenance and operation of the engine is important to long valve life. Engine operating temperature should be maintained between 160-1850F (71-850C). Low operating temperatures (usually due to extended periods of idling or light engine loads) result in incomplete combustion, formation of excessive carbon deposits and fuel lacquers on valves and related parts, and a greater tendency for lubricating oil to sludge.

Unsuitable fuels may also cause formation of deposits on the valves, especially when operating at low temperatures.

When carbon deposits, due to partially burned fuel, build up around the valve stems and extend to that portion of the stem which operates in the valve guide, sticking valves will result. Thus, the valves cannot seat properly and pitted and burned valves and valve seats and loss of compression will result.

Lubricating oil and oil filters should be changed periodically to avoid the accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of antifreeze (glycol) into the lubricating oil which forms a soft, sticky carbon and gums the valve stems, and bent or worn valve guides. Sticking valves may eventually be struck by the piston and become bent or broken.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically, Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion.

7.2 Remove Exhaust Valve Spring (Cylinder Head Installed)

An exhaust valve spring may be removed, without removing the cylinder head from the engine, as follows:
(1) Clean and remove the valve rocker cover.
(2) Crank the engine over to bring the valve and injector rocker arms in line horizontally.
Note: <u>When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt will loosen.</u>

Note: <u>Tool J 22582 bolts to the flywheel housing in the same position as the engine starter. Gear teeth on one end of the tool mesh with the flywheel ring gear. The engine can then be rotated by hand with the aid of a 3/4" drive and ratchet.</u>
(3) Disconnect and remove the fuel pipes from the injector and the fuel connectors.

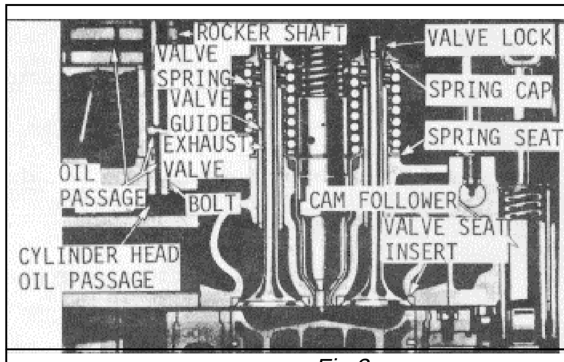


*Fig.2*
*Assembly of Exhaust and Guides*

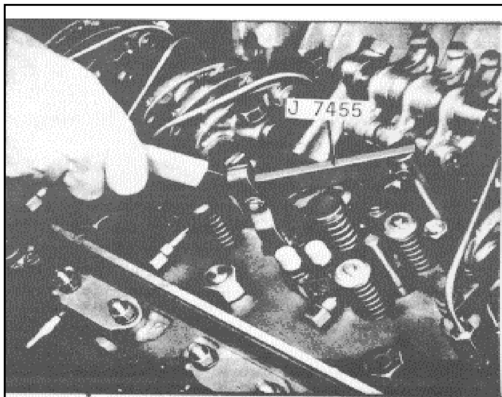


*Fig.3*
*Removing Exhaust Valve Spring with Tool J 7455*

Note: Immediately after removing the fuel pipes cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

(4) Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and shaft.
(5) Remove the exhaust valve bridge.
(6) Remove the cylinder block air box cover so that piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.
(7) Thread the valve spring compressor adaptor J 7455-7 into the rocker arm bracket bolt hole in the cylinder head (Fig. 3). Then compress the valve spring and remove the two-piece tapered valve lock.
(8) Release the tool and remove the spring cap, valve spring and spring seat.

7.3 Remove Exhaust Valves and Valve Springs (Cylinder Head Removed)

With the cylinder head removed from the engine, remove the exhaust valves and springs as follows

(1) Support the cylinder head on 2 inch thick wood blocks to keep the cam followers clear of the bench.

Note: Be careful not to damage or scratch the critical sealing area around the intermediate water nozzles.

(2) Remove the fuel pipes from the injector and the fuel connectors. Note: Immediately after removing the fuel pipes cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

(3) Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and the shaft.

(4) Remove the fuel injectors.
(5) Remove the exhaust valve bridges.
(6) Place a block of wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in Steps 7 and 8 in paragraph 7.2.
(7) Turn the cylinder head over, using care to keep the valves from falling out of the head. If the valves are to be re-used, number each valve to facilitate reinstallation in the same location. Then withdraw the valves from the cylinder head.
(8) Remove the cam followers and push rod assemblies as outlined in SMl-63-6.0 under "Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed From Engine)".

7.4 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean the springs with fuel oil, dry them with compressed air and inspect them. Replace a pitted or fractured spring.

Use spring tester J 22738-02 to check the spring I load (Fig. 4). The exhaust valve spring has an outside diameter of approximately .9531". Replace the spring when a load of less than 25 pounds (111 N) will compress it to 1.80" (installed length),

Inspect the valve spring seats and caps for wear. If worn, replace with new parts.

Examine the contact surfaces of the exhaust valve bridge guides, bridges and adjusting screws for wear and galling. Replace excessively worn parts.

Carbon on the face of a valve could indicate blow-by due to a faulty seat. Black carbon deposits extending from the valve seats to the valve guides may result from cold operation due to light loads or the use of too heavy a grade of fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the valve guides is evidence of high operating temperatures normally due to overloads, inadequate cooling, or imporper timing which results in carbonization of the lubricating oil.; '

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges, cracks or pitting. If necessary, reface the valves or install new valves. If the valve heads are warped, replace the valves.

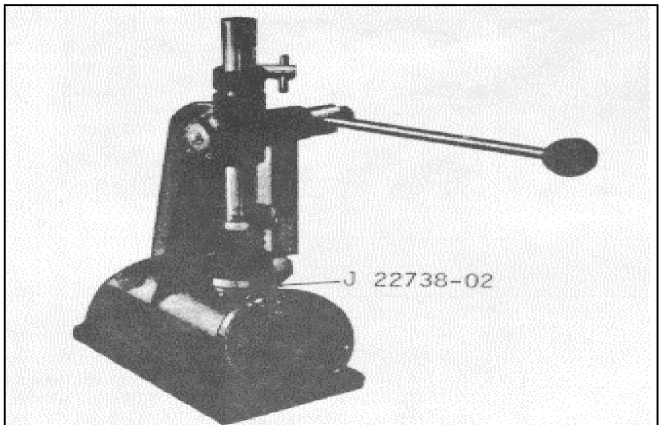


*Fig. 4*
*Testing Exhaust Valve Spring*

If there is evidence of engine oil running down the exhaust valve stem into the exhaust chamber, creating a high oil consumption condition because of excessive idling and resultant low engine exhaust back pressure, replace the valve guide oil seals or, if not previously used, install valve guide oil seals.

Clean the inside diameter of the valve guides with brush J 5437 (Figs 5). This brush will remove all gum or carbon deposits from the guides, including the spiral grooves.

Inspect the valve guides for fractures, chipping, scoring or excessive wear. Measure the valve guide inside diameter with a pin gage or inside micrometer and record the readings. After inspecting and cleaning the exhaust valves measure the outside diameter of the valve stems with a micrometer and record the readings.

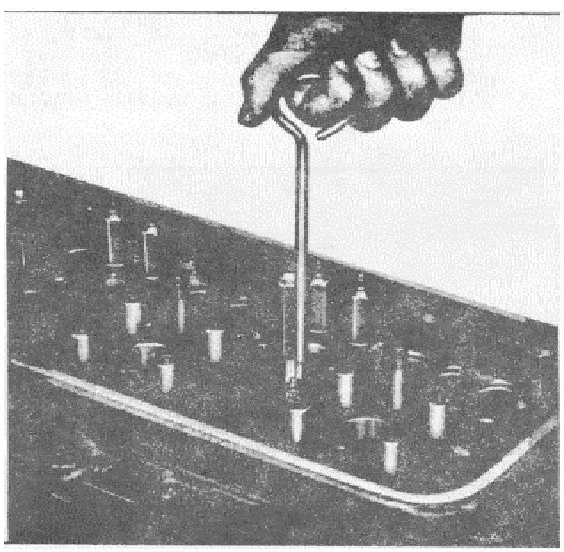

*Fig. 5*
*Cleaning Exhaust Valve Guide*

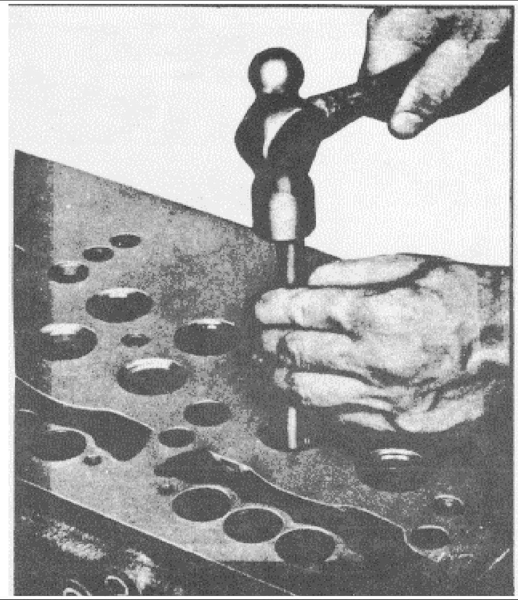

Fig. 6
Removing Exhaust Valve Guide

Compare the readings to obtain the valve-to- guide clearance. If the clearance exceeds .005" replace the valve guides. The valve guides are machined at the upper end.

7.5 Replace Exhaust Valve Guide

Remove an exhaust valve guide as follows:
(1) Support the cylinder head, bottom side up, on 2 inch thick wood blocks.
(2) Drive the valve guide out of the cylinder head with tool J 6569 (Fig. 6).

Place the cylinder head right side up on an arbor press and install the valve guide (Fig. 7) as follows:
(1) Insert the internally threaded end of the

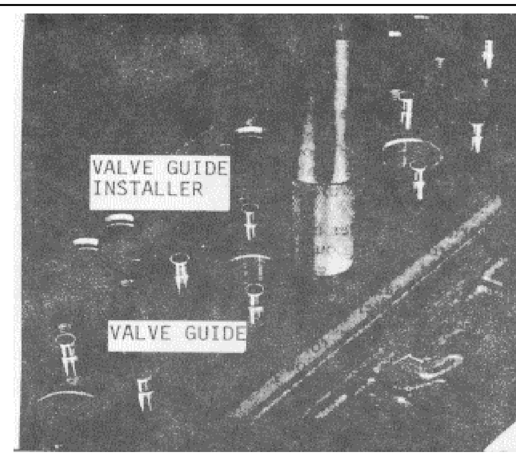


*Fig. 7*
*Installing Valve Guide*

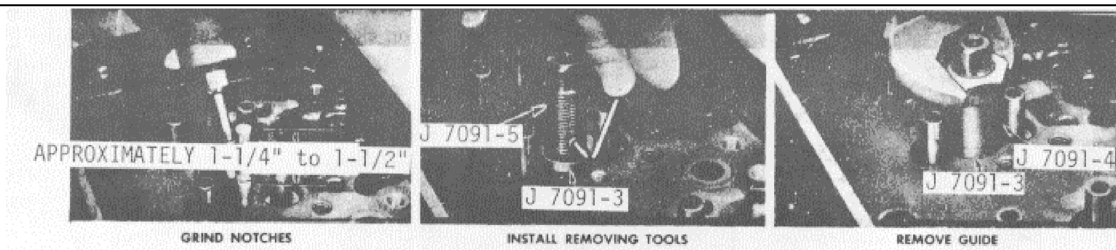


*Fig. 8*
*Removing Press-Fit Exhaust Valve Bridge Guide*

valve guide in the valve guide installing tool J 21520.

(2) Position the valve guide squarely in the bore in the cylinder head and press the installing tool J21520 gently to start the guide in place (Fig. 7). Then press the guide in until the tool contacts the cylinder head. The tool installs the guide to .670" - .710" above the top of the cylinder head.

Note: Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

Service replacement valve guides are completely finish reamed during manufacture and, therefore do not require reaming after installation.

(3) Install a new valve guide oil seal (refer to item 5 under 7.13 'Install Exhaust Valves and Springs').

7.6 Inspect Exhaust Valve Bridge and Guide

Inspect the valve bridge guide, valve bridge, and adjusting screw for wear. Replace excessively worn parts.

The press-fit valve bridge guide is hardened steel while the valve bridge is relatively soft steel.

7.7 Remove Exhaust Valve Bridge Guide Remove the valve bridge guide from the cylinder head as outlined below:

(1) Remove the press-fit guide (Fig. 8) with tool set J 7091-01 as follows:

(a) File or grind two diametrically opposite notches 1/16" deep in the side of the guide, approximately 1-1/4" to 1-1/2" from the upper end.

(b) Place spacer J 7091-3 over the guide. Then slide the guide remover J 7091-5 over the guide and align the set screws with the notches in the guide. Tighten the set screws to hold the tool securely.

(c) Place spacer J 7091-4 over the guide remover. Thread the nut on the guide remover and turn it clockwise to with- draw the guide from the cylinder head.

To remove a broken valve bridge guide, drill a hole approximately 1/2" deep in the end of the guide with a 1/4"-28 bottoming tap. Thread remover J 7453 into the guide and attach slide hammer J 2619-01 to the remover tool. One or two sharp blows with the puller weight will remove the broken guide (Fig. 9).

7.8 Install Exhaust Valve Bridge Guide
Install the press-fit bridge guide as follows:

(1) Start the guide (undercut end first) straight into the cylinder head.

(2) Place the installer J 7482 over the guide and drive it into place. The installer will properly position the guide to the correct height in the cylinder head.

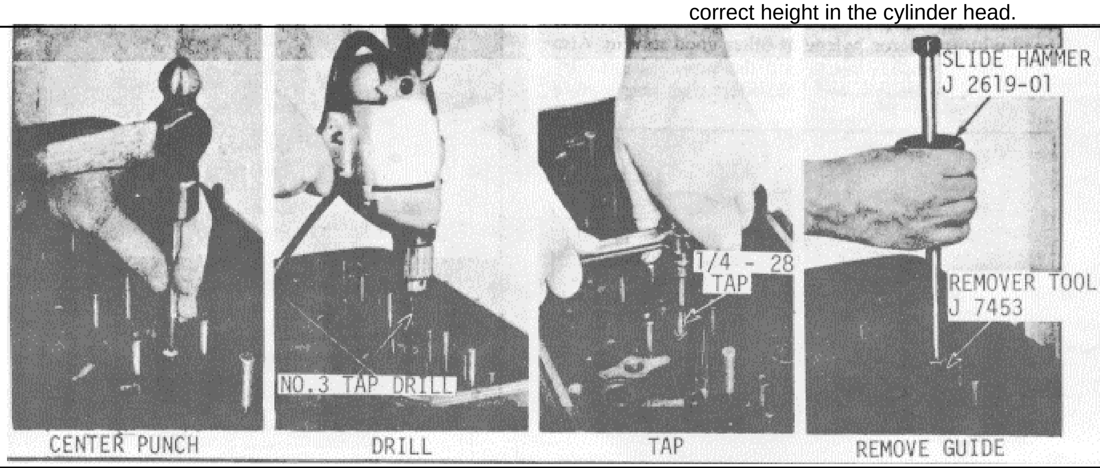


*Fig. 9*
*Removing Broken exhaust Valve Bridge Guide*

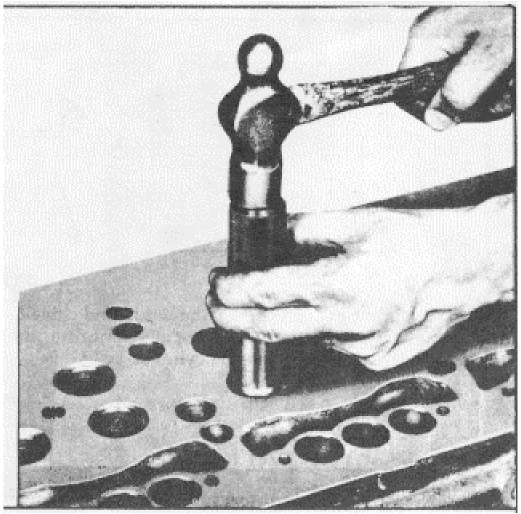

*Fig. 10*
*Installing Valve Seat Insert*

7.9 Inspect Exhaust Valve Seat Insert A new exhaust valve seat insert is pre-ground and only needs to be checked for concentricity after installation. Do not grind a new valve seat insert unless the runout exceeds .002".

Inspect the valve seat inserts for excessive wear, pitting, cracking or an imporper seat angle. The proper angle for the seating face of the valve is 300 and the angle for the insert is 310. When a valve seat insert has been ground to such an extend that the grinding wheel will contact the cylinder, install a new insert.

7.10 Remove Exhaust Valve Seat Insert Use the cam operated exhaust valve seat insert puller J 23479-13 to remove the insert from the cylinder head.

7.11 Install Exhaust Valve Seat Insert

**WARNING**

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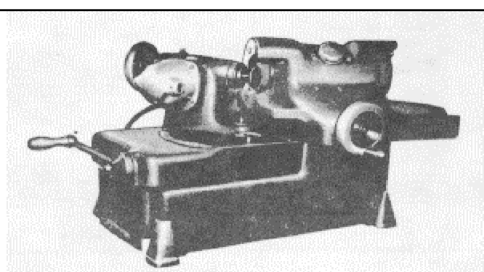

*Fig. 11*
*Refacing Exhaust Valve*

(1) Clean the valve insert counterbore in the cylinder head with trichloroethylene or other good solvent. Also wash the valve seat insert with the same solvent. Dry both the counterbore and the insert with compressed air.

(2) Inspect the valve seat insert counterbore in the cylinder head for cleanliness, concentricity, flatness and cracks. The counterbores have a diameter of 1.440" to 1.441" and a depth of .3395" to .3505". The counterbores must be concentric with the valve guides within .002" total indicator reading. If required, use a valve seat insert which is .010" oversize on the outside diameter.

(3) Immerse the cylinder head for at least 30 minutes in water heated to a temperature of 180-2000F (92-930C).

(4) Rest the cylinder head, bottom side up, on a bench and place an insert in the counter bore valve seat side up. Install the insert in the cylinder head while the head is still hot and the insert is at room temperature, otherwise installation will be difficult and the parts may be damaged.

(5) Drive the insert in place with installer J 24357 as shown in Fig. 10 until it seats solidly in the cylinder head.

(6) Grind the valve seat insert and check it for concentricity in relation to the valve guide as outlined below.

7.12 Recondition Exhaust Valve and Valve Seat An exhaust valve which is to be reused may be refaced, if necessary (Fig. 11). To provide sufficient valve strength and spring tension, the edge of the valve at the valve head must not be less than .031" in thickness after refacing.

When a new valve seat insert is installed or an old insert is reconditioned, the work must be done with a grinding wheel (Fig. 12).

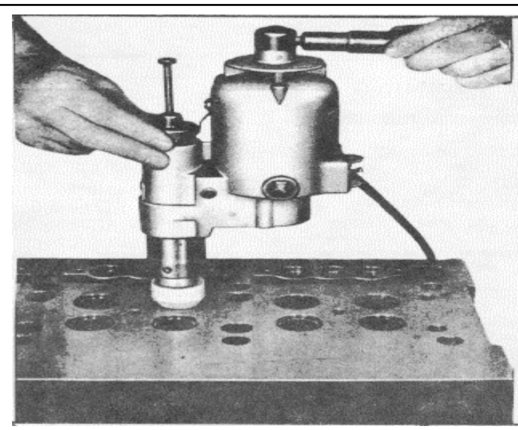

*Fig. 12*
*Grinding Valve Seat Insert*

The eccentric grinding method for reconditioning a valve seat insert is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits the operator to feed the grinding wheel into the work .001" at a time.

Eccentric valve seat grinder set J 7040, which includes the grinder, dress stand and pilot, and dial gage, is used to grind the inserts. An adaptor set J 24566 is used with the grinder set and includes the following:

(a) Pilot J 24566-1.
(b) Grinding wheel (150°) J 24566-2.
(c) Grinding wheel (310) J 24566-3.
(d) Grinding wheel (600) J 24566-4.

Grind the inserts as follows:

(1) Apply the 310 grinding wheel on the valve seat insert.
(2) Use the 600 grinding wheel to open the throat of the insert.
(3) Grind the top surface of the insert with the 150 wheel to narrow the width of the seat. The 310 face of the insert may be adjusted relative to the center of the valve face with the 150 and 600 grinding wheels.

Note: Do not permit the grinding wheel to contact the cylinder head when grinding the inserts. When an insert has been ground to the extent that the grinding wheel contacts the cylinder head, install a new insert.

(4) When occasion requires, the grinding wheel may be dressed to maintain the correct seat angle with the dressing tool provided with the grinder set (Fig. 13). Grinding will reduce the thickness of the valve seat insert and cause the valve to recede into the cylinder head. If, after several grinding operations, the valve recedes beyond these limits, replace the valve seat insert.

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(5) After the grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165-2 in position as shown in Fig. 14 and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. Total runout should not exceed .002". -If a runout of more than .002" is indicated, check for a bent or worn valve guide before regrinding the insert.

After the valve seat insert has been ground

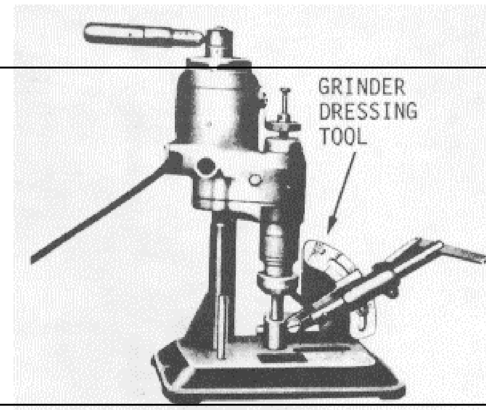


*Fig. 13*
*Grinding Wheel Dressing Tool of Set J 24566*

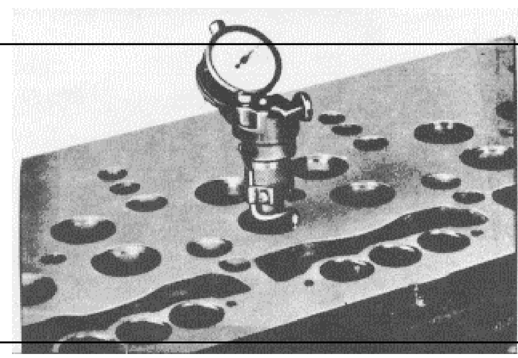

*Fig. 14*
*Checking Relative Concentricity of Valve Seat Insert with Relation to Valve Guide*

determine the position of the contact area between the valve and the valve seat insert as follows:

(1) Apply a light coat of Prussian blue, or a similar paste, to the valve seat insert.
(2) Lower the stem of the valve in the valve guide and "bounce" but do not rotate the valve on the insert. This procedure will indicate the area of contact on the valve face. The most desirable area of contact

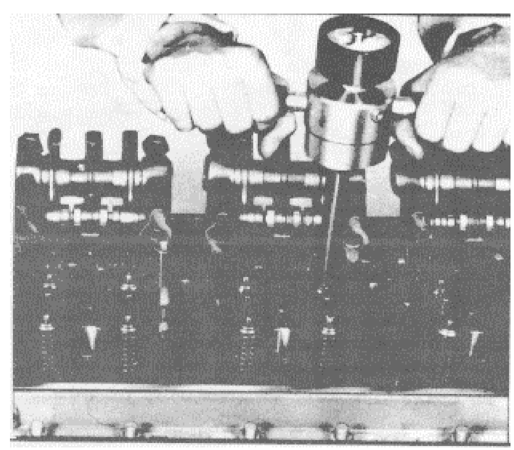

*Fig. 15*
*Checking Pressure Required to Open Exhaust Valve in Cylinder Head*

is at the center of the valve face.

Note: The use of valve lapping compounds is not recommended.

After the valve seat inserts have been ground and checked, thoroughly clean the cylinder head before installing the valves.

7.13 Install Exhaust Valves and Springs

Install the exhaust valves as follows:

(1) Clean the valve guides.

(2) Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides.

Note: If reconditioned valves are used, instal them in the same relative location from which they were removed.

(3) Hold the valves in place with a strip of masking tape and turn the cylinder head right side up on the bench. Place a board under the head to support the valves and to provide clearance between the cam follow ers and the bench.

(4) Install the valve spring seats.

(5) Install the valve springs and valve spring caps.

(6) Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig. 3).

(7) Apply pressure to the free end of the tool to compress the valve spring and install the two-piece tapered valve lock. Exercise car to avoid scoring the valve stem with the valve cap when compressing the spring. Give the end of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.

Note: Compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the valve guide oil seal.

(8) Release the tool and install the valve locks on the remaining exhaust valves in the same manner.

(9) Check the position of the exhaust valve.

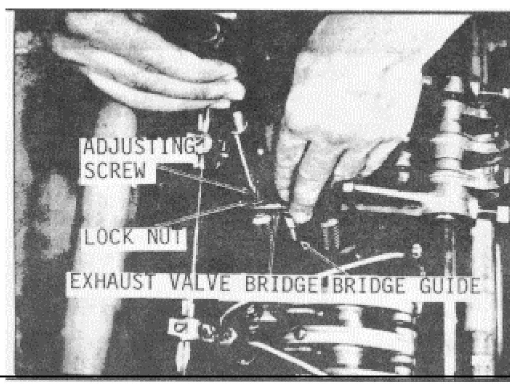


*Fig. 16*
*Valve Bridge Adjustment*

(10) With the exhaust valves installed in the cylinder head, use spring checking gage J 25076-01 and note the gage reading the moment the exhaust valve starts to open (Fig. 15). The minimum allowable pressure required to start to open the exhaust valve must not be less than 20 pounds (89 N.m).

(11) Install the injectors, rocker arms, shafts, brackets and any other parts previously removed from the cylinder head.

(12) Install the cylinder head (see "Pre-Installation Inspection" and "Install Cylinder Head" in SM1-63-5.0). Adjust the exhaust valve bridges as outlined below.

7.14 Exhaust Valve Bridge Adjustment

A complete valve bridge adjustment is performed as follows:

(1) Place the valve bridge in a vise or bridge holding fixture J 21772 and loosen the lock nut on the bridge adjusting screw.

Note: Loosening or tightening the lock nut with the bridge in place may result in a bent bridge guide or bent rear valve stem.

(2) Install the valve bridge on the valve bridge guide.

(3) While firmly pressing straight down on the pallet surface of the valve bridge, turn the adjusting screw clockwise until it just touches the valve stem. Then turn the screw an additional 1/8 to ¼ turn clockwise and tighten the lock nut finger tight (Fig. 16).

(4) Remove the valve bridge and place it in a vise. Use a screw driver to hold the adjustment screw from turning and tighten the lock nut to 20-25 ft/lb. (27-34 N.m) torque.

(5) Lubricate the valve bridge guide and the valve bridge with engine oil.

(6) Reinstall the valve bridge in its original position.

(7) Place a .0015" feeler gage (J 23185) under each end of the valve bridge or use a narrow strip cut from .0015" feeler stock to fit in the bridge locating groove over the inner exhaust valve. While pressing down on the pallet surface of the valve bridge, both feeler gages must be tight. If both of the feeler gages are not tight, readjust the adjusting screw as outlined in steps 3 and 4.

(8) Remove the valve bridge and reinstall it in its original position.

(9) Adjust the remaining valve bridges in the same manner.

(10) Swing the rocker arm assembly into position, making sure the valve bridges are properly positioned on the rear valve stems. This precaution is necessary to prevent valve damage due to mislocated valve bridges.

Tighten the rocker arm shaft bracket bolts to the torque specified in SM1-63-70.0. After the cylinder head is installed and the valve bridges adjusted, proceed as follows:

(1) Refer to SM1-63-32.0 under "Install Injector" and install the fuel pipes.

(2) Fill the cooling system.

(3) Adjust the exhaust valve clearance and time the injectors (SM1-63-68.0).

(4) Start the engine and check for leaks in the fuel, cooling and lubrication systems.

(5) Perform a complete engine tune-up as out-lined in SM1-63-68.0.

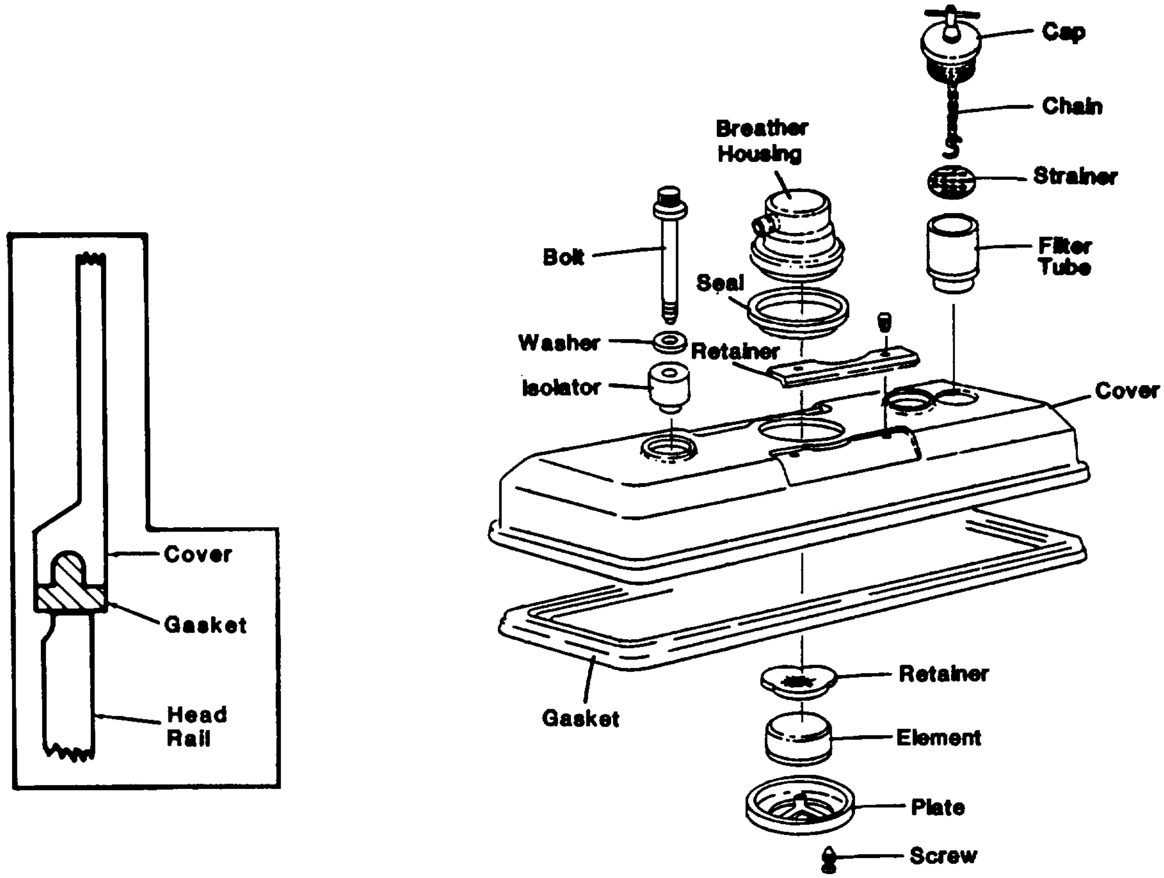


*Fig. 1*
*Typical Current Valve Rocker Cover Assembly*

The valve rocker cover assembly (Fig. 1) completely encloses the valve and injector rocker arm compartment at the top of the cylinder head. The top of the cylinder head is sealed against oil leakage by a gasket located in the groove of the lower rail of the die cast rocker cover.

An option plate is inserted in a retainer attached to one of the covers.

The die cast rocker cover (Fig. 1) is held in place by 3/8"-16 twelve-point head shoulder bolts with a steel washer and silicone isolator. The bolts have a shoulder which bottoms out against the cylinder head or throttle delay bracket. The isolators and gasket use low compression-set materials which provide long sealing life and minimize engine noise levels. Tighten the bolts to 15-20 ft/lb. (20-27 N.m) torque.

Note: The rocker cover bolt, which threads into the throttle delay bracket, can crack if the bracket is overtightened.

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Important: The rocker cover bolt is especially designed for this purpose and must not be replaced by an ordinary bolt.

The valve rocker cover assembly includes a breather assembly and an oil filler.

Clean the valve rocker covers and around the covers before removing them from the engine to avoid dust or dirt from entering the valve mechanism. Then loosen the bolts and lift each cover straight up from the cylinder head. Use new gaskets when reinstalling the covers.

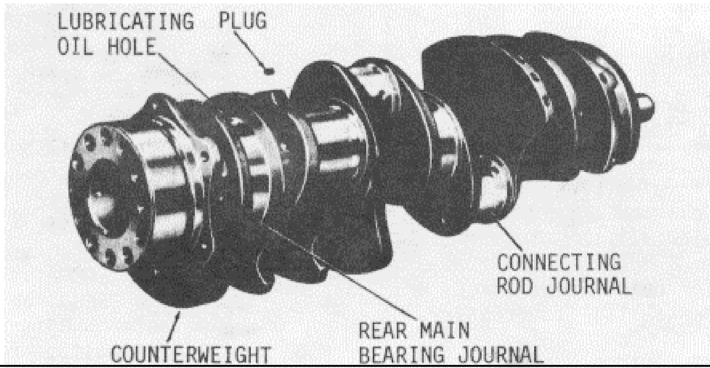



*Fig.1*
*Typical Crankshaft*

The crankshaft (Fig. 1) is a one-piece steel forging, heat-treated to ensure strength and durability. The main and connecting rod bearing journal surfaces and fillets on all crankshafts are induction hardened.

Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft.

The crankshaft end play is controlled by thrust washers located at the rear main bearing cap of the engine. Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block.

Twelve tapped holes equally spaced are provided for attaching the flywheel. No dowel pins are provided for locating the flywheel.

Each main bearing journal is 4-1/2" in diameter and each connecting rod journal is 3" in diameter.

9.1 Remove Crankshaft

When removal of the crankshaft becomes neces- sary, first remove the transmission, then proceed as follows:

(1) Clean the exterior of the engine.
(2) Drain the cooling system.
(3) Drain the engine crankcase.
(4) Remove all engine to base attaching bolts. Then, with a chain hoist and sling attached to the lifter brackets or eye bolts at each end of the engine, remove the engine from its base.
(5) Remove all of the accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an over-haul stand.
(6) Mount the engine on an overhaul stand and fasten it securely to the mounting plate.

**CAUTION**

Be Absolutely Sure The Engine Is Securely Attached To The Stand Before Releasing The Lifting Sling. Severe Injury To Personnel And Destruction Of Engine Parts Will Result If The Engine Breaks Away From The Stand.

(7) Remove the oil pan.
(8) Remove the lubricating oil pump.
(9) Remove the flywheel and flywheel housing.
(10) Remove the crankshaft pulley retaining bolt and washer at the front end of the crankshaft. Then remove the pulley.
(11) Remove the front engine support. Remove the crankshaft front cover and oil pump assembly.
(13) Remove the oil seal spacer.
(14) Remove the cylinder heads.
(15) Remove the connecting rod bearing caps.
(16) Remove the main bearing caps and stabilizers.
(17) Remove the thrust washers from each side of the rear main bearing cap.
(18) Remove the pistons, connecting rods and liners.
(19) Remove the crankshaft (Fig. 2), including the timing gear and oil pump drive gear.
(20) Refer to SM1-63-26.0 for removal of the crankshaft timing gear.
(21) Remove the oil pump drive gear and Woodruff keys from the crankshaft.

9.2 Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

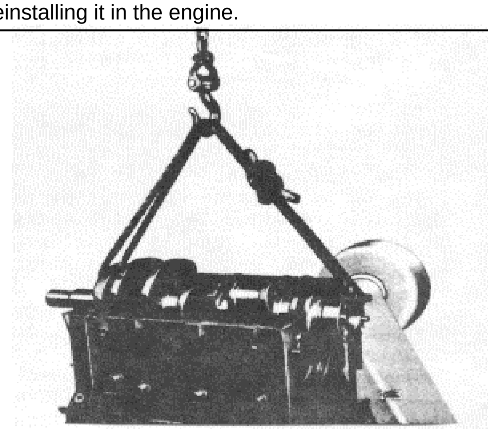


*Fig .2*
*Removing or installing Crankshaft*

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then reinstall the plugs.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary.

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.

Check the crankshaft journal surfaces for score marks and other imperfections. If excessively scored, the journal surfaces must be reground.

Carefully inspect the rear end of the crank- shaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

If the crankshaft oil seal contact surface is excessively worn and grooved, the oil seal may be repositioned in the flywheel housing as out-lined in SM1-63-10.0.

Check the crankshaft thrust surfaces for excessive wear or grooving. If excessively worn, the thrust surfaces must be reground. Do not exceed .018" countershaft end play.

Check the oil pump drive gear and the crank- shaft timing gear for worn or chipped teeth. Replace the gears, if necessary.

Inspect the crankshaft for cracks as outlined under 9.4 "Inspection for Cracks".

9.3 Crankshaft Measurements

Support the crankshaft on its front and rear journals on V-blocks or in a lathe and check the alignment at the adjacent intermediate main journals with a dial indicator.

When the runout on the adjacent journals is in opposite directions, the sum must not exceed .003" total indicator reading. When the runout on the adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. When high spots of runout on the adjacent journals are at right angles to each other, the sum must not exceed .004" total indicator reading, or .002" on each journal. If the runout limit is greater than given in Table 1, the crankshaft must be replaced.

Measure all of the main and connecting rod bearing journals (Fig. 5). Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn 2 of 5

| Engine | Journals | Max. Run-Out (Total indicator reading) |
|---|---|---|
| 6V | On No.2 and No. 3 | .002" |

Table 1

so that the maximum connecting rod or main bearing journal-to-bearing shell clearance (with new shells) exceeds .0040" or .0050" respectively, the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002". Also, if the journal taper of a used crankshaft exceeds .0015" or the out-of-round is greater than .001", the crankshaft must be reground.

Also measure the crankshaft thrust washer surfaces (Fig. 7).

9.4 Inspection for Cracks

Carefully check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of $45^\circ$ to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

Magnetic Particle Method: The part is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be de-magnetized after the test.

Flourescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are flourescent and glow under "black light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "black light."

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of the indications is but a first step in the procedure. Interpretation of the indications is the most important step.

All Detroit Diesel crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crank shaft in service -- a bending force and a twisting force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load (Fig. 3).

Bending Fatigue: Failures result from bending of the crankshaft which takes place once per revolution.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight will impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional Fatigue: Failures result from torsional vibration which takes place at high frequency.

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 3.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

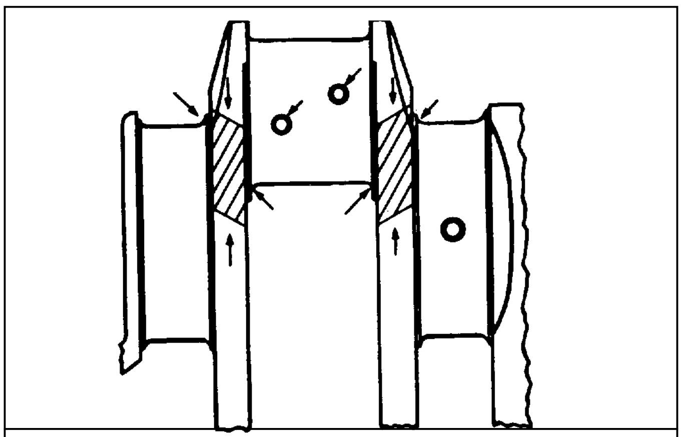


*Fig. 3*
*Critical Crankshaft Loading Zones*

A loose, damaged or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are the usual causes of this type of failure. Also, overspeeding of the engine or resetting the governor at a different speed than intended for - the engine application may be contributory factors.

As previously mentioned, most of the indications found during inspection of the crank-shaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks(45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes as shown in Fig. 4. Replace the crankshaft when cracks of this nature are found.

9.5 Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002", .010", .020" and .030" undersize bearings are available.

Note: <u>The .002" undersize bearings are used only to compensate for slight wear on crank-shafts on which regrinding is unnecessary.</u>

| Bearing Sizes | Conn. Rod Journal Dia. 'A' | Conn. Rod Journal Dia. 'B' |
|---|---|---|
| Standard | 3.000 | 4.500 |
| .002" Undersize | 3.000 | 4.500 |
| .010" Undersize | 2.990 | 4.490 |
| .020" Undersize | 2.980 | 4.480 |
| .030" Undersize | 2.970 | 4.470 |

Table 2

If the crankshaft is to be reground, proceed as follows:

(1) Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 2 and Fig. 5 and determine the

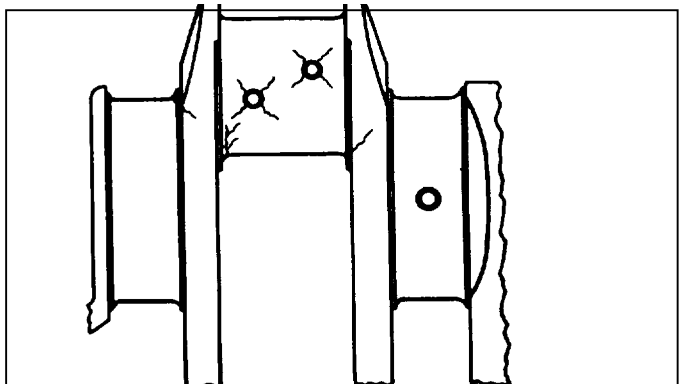


*Fig. 4*
*Crankshaft Fatigue Cracks*

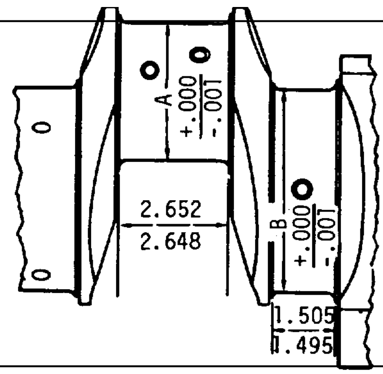



*Fig. 5*
*Dimensions of Crankshaft Journals*

size to which the journals are to be re-ground.

(2) If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.

(3) All journal fillets must have a .100" to .130" radius between the crank cheek and the journal and must not have any sharp grind marks (Fig. 6). The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.

Note: The journals and fillets are induction hardened and the fillets do not require rolling after regrinding.

(4) Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding using coolant generously. Do not crowd the grinding wheel into the work.

(5) Polish the ground surfaces to an 8-12 RMS finish. The reground journals will be subject to excessive wear unless polished smooth.

(6) If the thrust surfaces of the crankshaft (Fig. 7) are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .100" to .130" radius between each thrust surface and the bearing journal.

(7) Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32".

(8) After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

(9) De-maqnetize the crankshaft.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

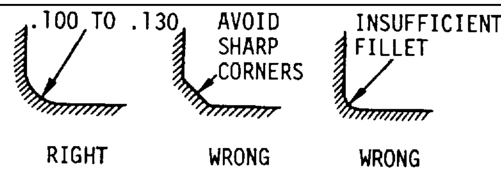



*Fig. 6*
*Crankshaft Journal Fillets*

(10) Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and re-install the plugs.

9.6 Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the plugs. Then install the crank-shaft as follows:

(1) Install or assemble the crankshaft.

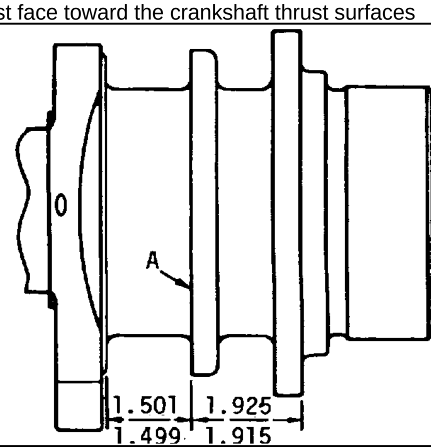
(a) Assemble the crankshaft timing gear (SM1-63-26.0) and the oil pump drive gear (SM1-63-47.0) on the crankshaft.

(b) Refer to SMl-63-11.0 for main bearing details and install the upper slotted main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed.

Note: When a new or reground crankshaft is installed, ALL new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

(c) Apply clean engine oil to all crank-shaft journals and install the crank-shaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to SM1-63-22.0 for the correct method of timing the gear train.

(d) Install the upper halves of the crank-shaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. The grooved side of the thrust washers must face toward the crankshaft thrust surfaces




(e)

*Fig. 7*
*Std. Dimension at Rear Main Bearing Thrust Washers*

Note: If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 7 and Table 3.

| Nominal Size | Thrust Washer Thickness | |
|---|---|---|
| | Min. | Max. |
| Standard | .1190 | .1220 |
| .005" Oversize | .1240 | .1270 |
| .010" Oversize | .1290 | .1320 |

Table 3

(e) Install the lower bearing shells (no oil slot) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

(f) Install the bearing caps and lower bearing shells as outlined under "Install Main Bearing Shells" in SM1-63-11.0.

Note: If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts draw, to the specified torque.

(2) Check the crankshaft end play by moving the crankshaft toward the gage (Fig. 8) with a pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then remove and insert the pry bar on the other side of the bearing cap Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .004" to .014" with new parts, or a maximum of .018" with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers.

(3) Install the cylinder liner, piston and connecting rod assemblies (SM1-63-20.0).

(4) Install the cylinder heads (SM1-63-5.0).

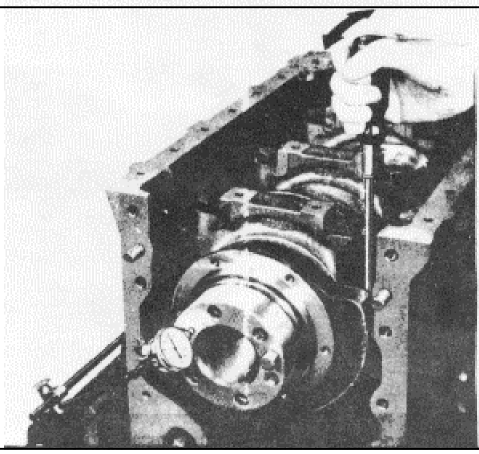


*Fig. 8*
*Checking Crankshaft End Play*

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(5) Install the flywheel housing (SM1-63-16.0), then install the flywheel (SM1-63-14.0).

(6) Install the crankshaft front cover and oil pump assembly.

Note: Install the oil seal spacer or inner cone AFTER the crankshaft front cover is in place to avoid damage to the oil seal lip.

(7) Install the engine front support.

(8) Install the oil seal spacer.

(9) Install the crankshaft pulley.

(10) Affix a new gasket to the oil pan flange and install the oil pan.

(11) Use a chain hoist and sling attached to the lifting bracket at each end of the engine and remove the engine from the overhaul stand.

(12) Install all of the accessories that were removed.

(13) After the engine has been completely re-assembled, refer to the "Lubricating Oil Specifications" in the Operators Manual and refill the crankcase to the proper level on the dipstick.

(14) Close all of the drains and fill the cooling system.

(15) After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the run-in schedule (SM1-63-67.0).

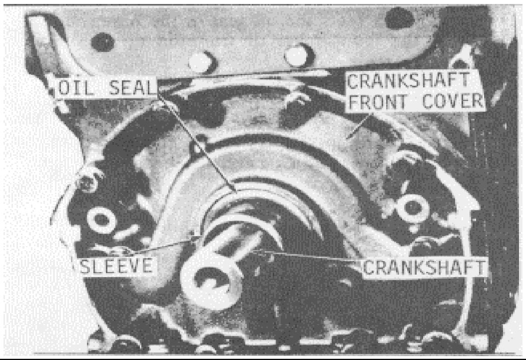



*Fig. 1*
*Typical Crankshaft Front Oil Seal Mounting*

An oil seal is used at each end of the crankcase to retain the lubricating oil in the crankcase. The sealing lips of the crankshaft oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring, thus preventing oil from escaping from the engine crankcase.

The front oil seal is pressed into the oil pump body assembly (crankshaft front cover) (Fig. 1). The lip of the seal bears against a removable spacer or vibration damper inner cone on the end of the crank-shaft.

A double-lip oil seal is used at the rear end of the crankshaft. The rear oil seal is pressed into the flywheel housing (Fig. 2).

10.1 Remove Crankshaft Oil Seals

(1) Remove the crankshaft front cover (SM1-63-12.0). Then remove the flywheel housing (SM1-63-16.0) and examine the crankshaft oil seals.
(2) Support the outer face of the cover housing on wood blocks.
(3) Drive the oil seal out and clean the seal bore in the cover or housing.

When necessary, the crankshaft oil seals may be taken out without removing the front cover flywheel housing. This may be done by drilling holes directly opposite each other in the seal casing and installing metal screws with flat washers. Remove the seals by prying against the flat washers with suitable pry bars.

10.2 Inspection

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout, grooved sealing surfaces on the crank-shaft or oil seal spacers and out of square installation. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

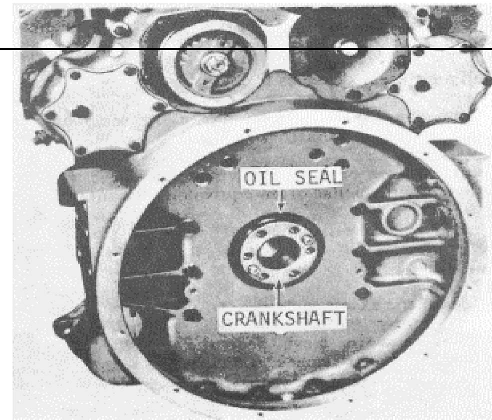



*Fig. 2*
*Crankshaft Rear Oil Seal Mounting*

Inspect the rear end of the crankshaft for wear caused by the tubbing action of the oil seal, dirt buildup or fretting by the action of the flywheel. The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed.

Slight ridges may be removed from the crank-shaft as outlined under "Inspection" in SM1-63-9.0.

An oil seal sleeve may be pressed on the crank-shaft to provide a replaceable wear surface at the point of contact with the rear oil seal. The oil seal sleeve 'may be used with either the single-lip or double-lip oil seal. However, an oversize oil seal must be used with the sleeve.

Install an oil sleeve as follows:

(1) Stone the high spots from the oil seal contact surface of the crankshaft.
(2) Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.
(3) Press the sleeve on the shaft. Use oil seal sleeve installer J 4194-01 to position the sleeve on the crankshaft.
(4) Wipe off the excess sealant. To remove a worn sleeve, peen the outside diameter until the sleeve stretches sufficiently so it can be slipped off the end of the crankshaft.

The maximum run out of the oil seal bore in the front cover or the flywheel housing is .008". The bore may be checked with a dial indicator mounted on the end of the crankshaft in a manner similar to the procedure for checking the fly-wheel housing concentricity as outlined in SM1-63-16.0. This check must be made with the flywheel housing or front cover in place on the engine and the oil seal removed.

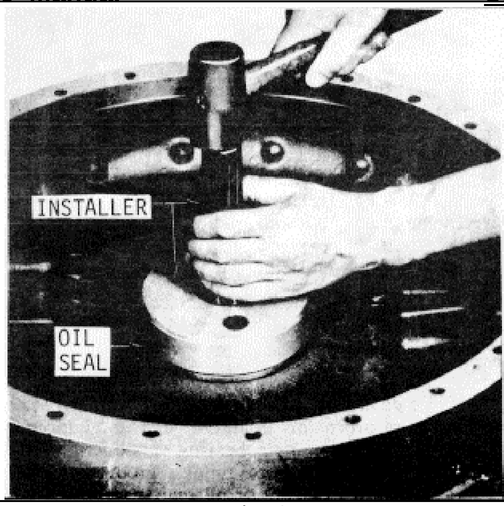



*Fig. 3*
*Installing Oil Seal in Flywheel Housing*

10.3 Oil Seals
Oil seals are made of an oil resistant synthetic . rubber which is pre-lubricated with a special lubricant. Do not remove this lubricant. Keep the sealing lip clean and free from scratches. In addition, the outer surface of the casing has a plastic coating which acts as a sealant. Do not remove this coating.

10.4 Install Crankshaft Front Oil Seal

(1) Apply grease or vegetable shortening to the sealing lip, then position the seal in the front cover or trunnion with the lip of the seal pointed toward the inner face of the cover.

Note: The oil seal spacer must be removed from the engine before installing the oil seal.

(2) Drive a new oil seal into the crankshaft' front cover with tool J 9783, which seats the oil seal in the bore. The tool is designed to drive only on the outer edge of the seal casing to prevent damage to the seal.
(3) Remove any excess sealant from the cover and the seal.
(4) Install the crankshaft front cover as out-lined in SM1-63-12. O.
(5) Install the oil seal spacer after the front cover and seal assembly is in place.

10.5 Install Crankshaft Rear Oil Seal

(1) Support the inner face of the flywheel housing on a flat surface.
(2) Position the seal with the lip pointed toward the inner face of the housing.
(3) Drive or press the seal into the housing with installer J 21112 and handle J 3154-1 until it is flush with the inside surface of the housing (Fig. 3).

Note: The flywheel housing has a machined counterbore adjacent to the rear oil seal. After the oil seal is installed, check the rear face of the seal case to be sure it is parallel to the counterbored surfaces. Also, for an effective outer diameter seal, be sure to push the rear oil seal past the chamfer at the rear face of the flywheel housing.

If it is necessary to install a standard size oil seal with the flywheel housing on the engine place the oil seal expander J 4239 against the end of the crankshaft. Use expander J 8682 with handle J 8092 for an oversize seal. Then, with the lip of the seal pointed toward the engine, slide the seal over the tool and on the crankshaft. Remove the seal expander and drive the seal in place with installer J 21112 and handle J 3154-1.

(4) Remove any excess sealant from the fly- wheel housing and the seal.
(5) Install the flywheel housing as outlined in SM1-63-16. 0.

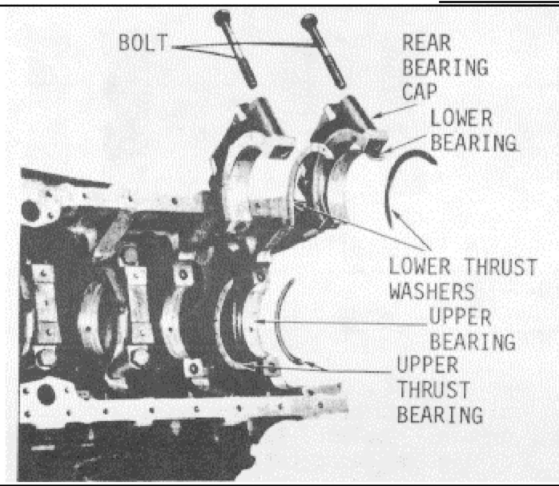



*Fig. 1*
*Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers*

The crankshaft main bearing shells (Fig. 1) are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

A through slot in each upper bearing shell registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings.

The lower main bearing shells have no oil grooves. Therefore, the upper and lower bearing shells must not be interchanged.

Thrust washers (Fig. 1), on each side of the rear main bearing, absorb the crankshaft thrust. The lower halves of the two-piece washers are doweled to the bearing cap; the upper halves are not doweled.

Main bearing trouble is ordinarily indicated by low or no oil pressure. All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time, as outlined below and examine the bearing shells.

11.1 Remove Main Bearing Shells (Crankshaft in Place)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position

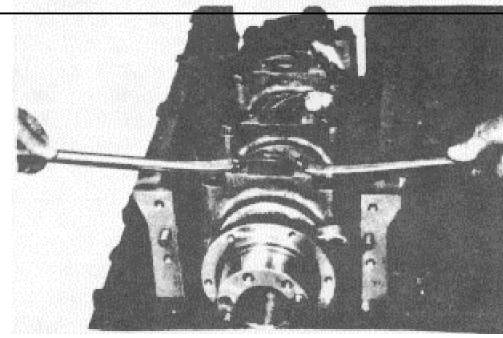


*Fig. 2*
*Removing Main Bearing Cap*

All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bearing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove the main bearing shells as follows:

(1) Drain and remove the oil pan to expose the main bearing caps.

(2) Remove the oil pump and the oil inlet and outlet pipe assemblies.

Note: <u>If shims are used between the oil pump and the main bearing caps, save the shims so that they may be reinstalled in exactly the same location.</u>

(3) Remove one main bearing cap stabilizer at a time, place washers (equal to the thickness of the stabilizer) on the bearing cap bolts and reinstall the bolts.

(4) Remove one main bearing cap at a time (Fig. 2) and inspect the bearing shells as out-lined under "Inspection". Reinstall each bearing shell and bearing cap before removing another bearing cap.

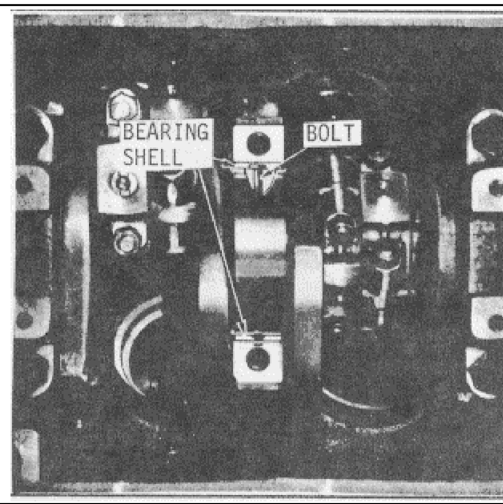



*Fig. 3*
*Removing Upper Main Bearing Shell (Except Rear Main)*

(a) To remove all except the rear main bearing shell, insert a 5/16" x 1" bolt with a 1/2" diameter and a 1/16" thick head (made from a standard bolt) into the crankshaft journal oil hole. Then revolve the shaft to the right (clock- wise) and roll the bearing shell out of position as shown in Fig. 3. The head of the bolt must not extend beyond the outside diameter of the bearing shell.

(b) Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out as shown in Fig. 4.

(c) The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

11.2 Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

Check the oil filter elements and replace them if necessary. Also check the oil bypass valve to make sure it is operating freely.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt or signs of overheating (Fig. 5). The lower bearing shells, which carry the load, will normally show-signs of distress

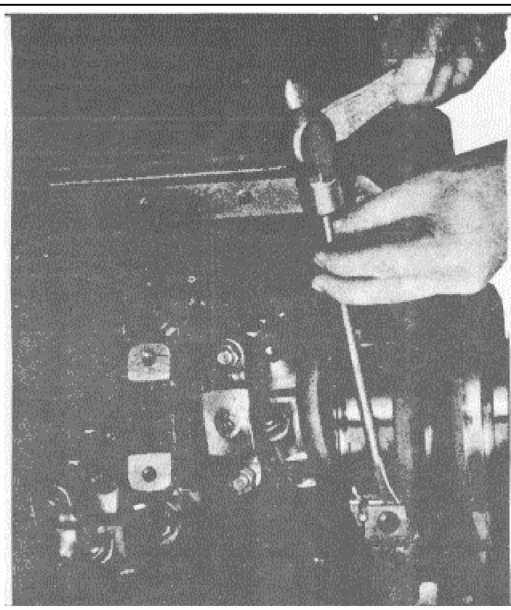


*Fig. 4*
*Removing Upper Rear Main Bearing Shell*

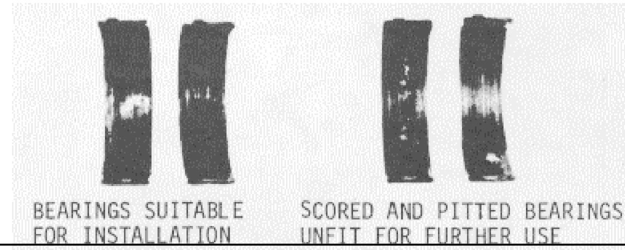



*Fig. 5*
*Comparison of Lower Main Bearing Shells*

before the upper bearing shells. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are not detrimental to this type of bearing. They should not be replaced for these minor surface imperfections since function of the bearings is in no way impaired and they will give many additional hours of trouble-free operation.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells at point 'C', **900** from the parting line, as shown in Fig. 6 and Fig. 7. Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness if the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is 1540" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has thickness of .1545" to .1552". Refer to
Table 1.

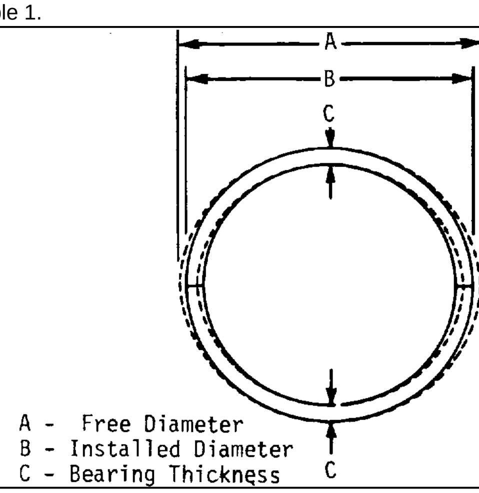



*Fig. 6*
*Main Bearing Measurements*

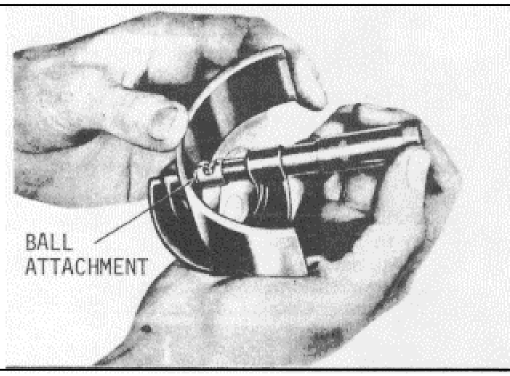



*Fig. 7*
*Measuring Thickness of Bearing Shell*

In addition to the thickness measurement, check the clearance between the main bearings and the crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to "Shop Notes" in SMl-63-30.0). With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque on the bearing cap bolts. When installed the bearing shells are .001" larger in diameter at the parting line than 900 from the parting line.

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This crush assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds .0060", all of the bearing shells must be discarded and replaced. This clearance is .0016" to .0050" with new parts.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to SM1-63-9.0 under "Crankshaft Inspection" for inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, in- stall all new upper and lower shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .010", .020", and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to "Crankshaft Grinding" in SM1-63-9.0. Bearings which are .002" undersize are available to compensate for slight journal

| Bearing Size | Bearing Thickness | Minimum Thickness |
|---|---|---|
| Standard .154" | . | .1545"/.1552" |
| .002" Undersize | .1555"/.1562" | .155" |
| .010" Undersize | .1595"/.1602" | .159" |
| .020" Undersize | .1645"/.1652" | .164" |
| .030" Undersize | .1695"/.1702" | .169" |

Table 1

wear where it is unnecessary to regrind the crankshaft. Make sure the correct clearances are maintained when using these parts.

Note: Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Inspect the crankshaft thrust washers. If the washers are scored or worn excessively or the crankshaft end play is excessive, they must be replaced. Improper clutch adjustment can contribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to "Install Crankshaft" in SM1-63-9.0. If, after dressing or regrinding the thrust surfaces new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is .1190" to .1220" thick. Thrust washers are available in .005" and .010" oversize.

Bearing cap stabilizers (Fig. 8) are used at all main bearing cap positions on the engine cylinder block.

11.3 Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then apply clean engine oil to each crankshaft journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

The upper and lower main bearing shells are not alike. The upper shell has a through slot for lubrication, the lower shell does not. Be sure to install the grooved slot shells in the cylin-

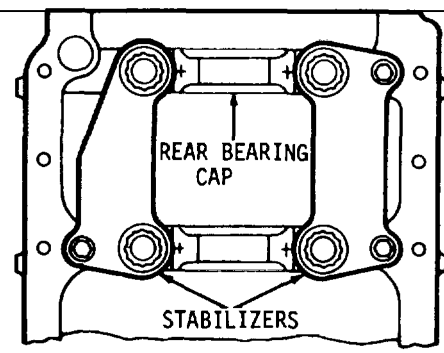



*Fig. 8*
*Stabilizers Mounted on Block*

der block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

(1) When installing an upper main bearing shell with the crankshaft in place, start the plain end of the shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.

(2) Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.

(3) Assemble the crankshaft thrust washers before installing the rear main bearing cap. Clean both halves of the thrust washer carefully and remove any burrs from the washer seats -- the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then, assemble the lower halves over the dowel pins in the bearing cap.

Note: The main bearing caps are bored in position and marked 2 3, etc. They must be installed in their original positions in the cylinder block.

(4) With the lower bearing shells installed in the bearing caps, apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolt head contact area. Install the bearing caps and bearing cap stabilizers and draw the bolts up snug. Then rap the caps sharply with a soft hammer to seat them properly. Tighten all bolts (except the rear main bearing bolts) to 250-260 ft/lb. (339-352 N.m) torque starting with the center bearing cap bolts and working alternately towards both ends of the block. Tighten the rear main bearing bolts to 40-50 ft/lb. (54-68 N.m) torque. Strike both ends of the crankshaft two or three sharp blows with a soft hammer to insure proper positioning of the rear main bearing cap in the block saddle. Re-torque all bearing bolts to 250-260 ft/lb. (339-352 N.m). Tighten the 7/16"-14 stabilizer bolts to 70-75 ft/lb. (95-102 N-m) torque.

Note: If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

(5) Check the crankshaft end play as outlined under "Install Crankshaft" in SM1-63-9.0.

(6) Install the lubricating oil pump and the oil inlet and outlet pipe assemblies.

Note: If shims were used between the pump and the bearing caps, install them in their original positions. Then check the oil pump gear clear-
ance (SM1-63-47.0).

(7) Install the oil pan, using a new gasket.

(8) Fill the crankcase to the proper level on the dipstick with heavy-duty lubricating oil of the recommended grade and viscosity (refer to "Lubricating Oil Specifications" in the Operators Manual).

(9) After installing new bearing shells, operate the engine on a run-in schedule as outlined in SM1-63-67.0.

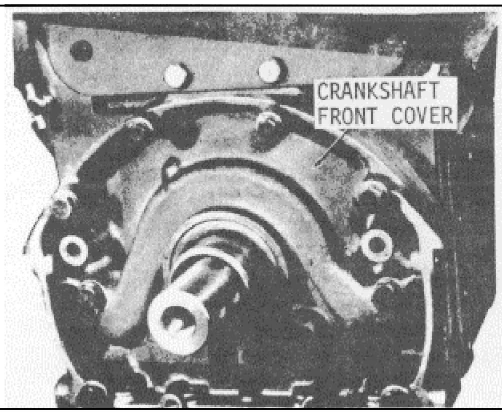



*Fig. 1*
*Engine Cover Mounting*

The engine frontcover is mounted against the cylinder block at the lower front end of the engine (Fig. 1). It serves as a retainer for the crankshaft front oil seal and serves as the lubricating oil pump housing. The engine is supported at the front end by engine supports attached to the front cover.

It will be necessary to remove the engine front cover to remove and install the crankshaft or when the engine is overhauled. Also, the front cover must be removed to service the lubricating oil pump. In addition, the front cover used with trunnion mounts must be removed to replace the crankshaft front oil seal.

12.1 Remove Engine Front Cover

(1) Drain the oil. Then remove the four oil pan-to-front cover attaching bolts and lock washers. Loosen all of the remaining oil pan bolts so the oil pan and gasket can be lowered approximately 1/4" at the front end of the engine.

**CAUTION**

Be Careful Not To Damage The Gasket. Otherwise, It Will Be Necessary To Remove The Oil Pan And Replace The Gasket.

(2) Remove the crankshaft pulley(SM1l-63-13.O)and any other accessories that may be mounted on the front end of the crankshaft.
(3) Remove the oil seal spacer.
(4) Disconnect the lubricating oil pump inlet tube at the bottom of the front cover.
(5) Remove the cover to cylinder block attaching bolts.
(6) Strike the edges of the cover alternately on each side with a soft hammer to free it from the dowels. Then pull the cover straight off the end of the crankshaft.
(7) Remove the gasket from the cover or the cylinder block.
(8) Replace the oil seal (SMl-63-10.0).

12.2 Install Engine Front Cover

With the oil pump installed and the oil seal installed, refer to Fig. 2 and install the front cover as follows:

(1) Affix a new gasket to the inner face of the cover.
(2) Coat the lip of the oil seal lightly with cup grease or vegetable shortening.
(3) Install the front cover using oil seal expander J 22425 (standard size seal) or J4195 and J 8092 (oversize seal) to pilot the oil seal over the crankshaft. Position the cover over the crankshaft and up against the cylinder block. Remove the oil seal expander.
(4) Install the cover attaching bolts and lock washers and tighten the 3/8"-16 bolts to 25- 30 ft/lb. (34-41 N.m) torque and the 1/2"-13 bolts to 80-90 ft/lb. (108-122 N-m) torque.

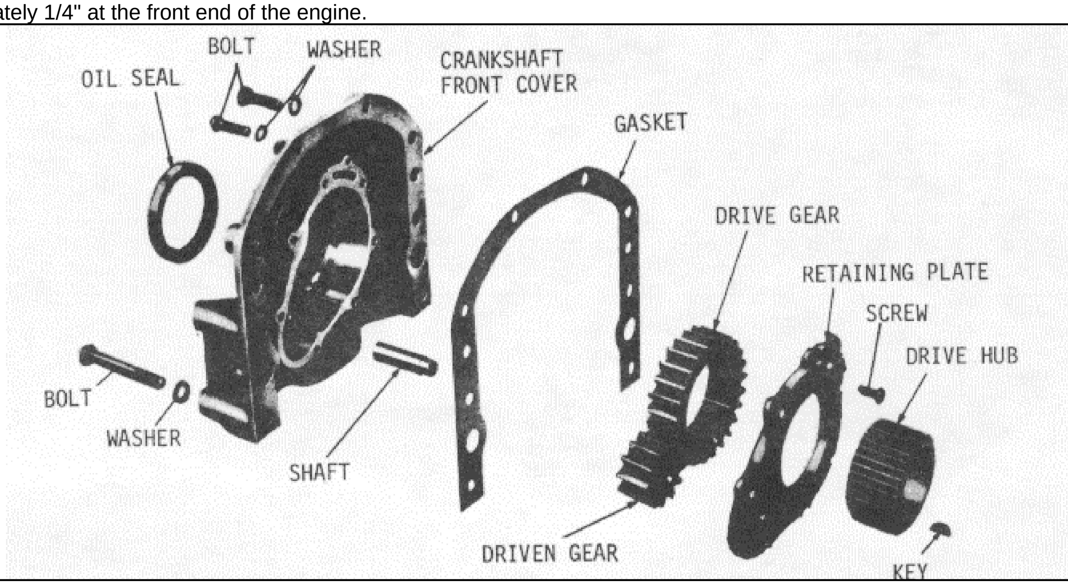



*Fig. 2*
*Front Cover Details and Relative Location of Parts*

HC238A

Note: Studs are provided on certain engines to allow for installation of front support and idler pulley mounting brackets.

(5) Apply engine oil to the oil seal spacer and slide it in place on the crankshaft.
(6) Affix a new gasket to the flange on the oil pump inlet tube and attach the tube to the bottom of the engine cover.
(7) Install the four oil pan-to-front cover attaching bolts and lock washers. Tighten all of the oil pan attaching bolts to 15-20 ft/lb. (20-27 N-m) torque.
(8) Install crankshaft pulley (SM1-63-13.0) and any other accessories that were removed.
(9) Refer to "Lubricating Oil Specifications" in the Operators Manual and fill the crank-case with oil to the proper level on the dipstick.

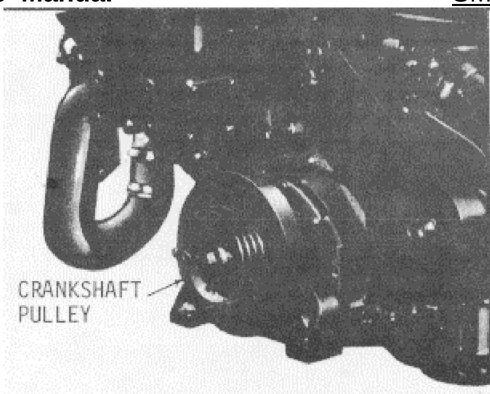



*Fig. 1*
*Crankshaft Pulley Mounting*

The crankshaft pulley is keyed to the crankshaft and secured with a special washer and bolt. The crankshaft bolts are lubrite coated to prevent possible damage (galling) to the bolt threads and to increase the clamp load to the front end stack up. Also, the washer (retainer) is case hardened.

13.1 Inspection

The appearance of the rubber bushed crankshaft pulley cannot be determined by the appearance of the rubber. The only reliable method of checking for failure of the rubber bushing is to hold the crankshaft stationary and apply pres- sure to the pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. If necessary, replace the bushing.

13.2 Remove Crankshaft Pulley

(1) Remove the pulley retaining bolt and washer and static clip, if used.
(2) Remove the pulley using a suitable puller or thread the pulley retaining bolt halfway into the crankshaft and strike the bolt with a 2 to 3 pound lead hammer while prying behind the pulley with two pry bars. Keep the ends of the pry bars as close to the crankshaft as possible.

If tapped holes are provided, install the pulley bolt in the end of the crankshaft then, using puller J 24420, remove the pulley from the crankshaft.

13.3 Install Crankshaft Pulley

(1) Place the Woodruff key slots in the front end of the crankshaft, if they were removed.
(2) Lubricate the end of the crankshaft with engine oil to facilitate pulley installation.
(3) Slide the pulley on the end of the crank-shaft.
(4) Place the washer on the bolt and thread the bolt into the end of the crankshaft.
(5) Tighten the crankshaft end bolt as follows:
   (b) Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.
   (c) Tighten to 300 ft/lb. (407 N.m) torque and strike the bolt again.
   (d) Retighten the bolt to 290-310 ft/lb. (393-421 N-m) torque.

Note: Do not strike the bolt after final torque has been applied.

The hex head of the crankshaft bolt may be use( to bar, or turn, the crankshaft. However, the barring operation should always be performed ii a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Other- wise, serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

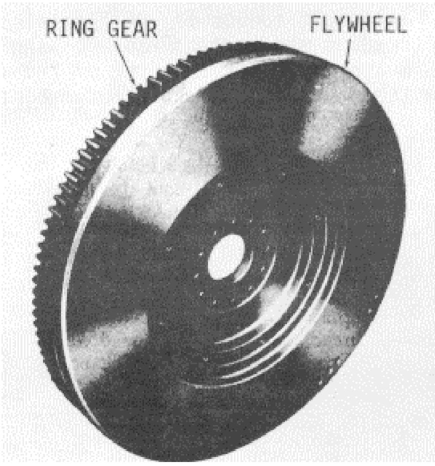



*Fig. 1*
*Typical Flywheel Assembly*

The flywheel (Fig. 1) is attached to the rear end of the crankshaft with six self-locking bolts. A scuff plate is used between the flywheel and the bolt head! to prevent the bolt heads from scoring the flywheel surface.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing.

14.1 Remove Flywheel (Transmission Removed)

(1) Remove two flywheel bolts. Install two suitable guide pins in these holes to support the flywheel.
(2) Remove the remaining flywheel attaching bolts and scuff plate.
(3) Attach flywheel lifting tool J 25026, or some other suitable safe lifting device, to the flywheel.
(4) Attach a chain hoist to the lifting tool to support the flywheel.
(5) Remove the flywheel from the crankshaft and the flywheel housing.
(6) Remove the clutch pilot bearing as outlined in SM1-63-15. O.

14.2 Inspection

Check the clutch contact surface of the fly- wheel or wear plate for cracks or wear. If the flywheel is cracked or worn, it may be refaced. Do not remove more than .020" of metal from the flywheel. Maintain all of the radii when refacing the flywheel. If cavities (porosity) of any size appear, fill them so no damage can result to the clutch.

Replace the ring gear if the gear teeth are excessively worn or damaged.

Check the butt end of the crankshaft and fly-wheel contact surface. If necessary, lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinelling.

On crankshafts with dowels, be sure and check the dowel extension. Dowels must not extend more than 1/2" from the crankshaft.

Make sure that the crankshaft and flywheel contact surfaces and the bolt threads in the crankshaft end are clean and dry, to ensure proper metal-to-metal contact and maximum friction, before attaching the flywheel.

New bolts should be used to mount or remount the flywheel. However, if the original bolts are determined to be serviceable and are to be reused, clean them thoroughly before starting the assembly procedure.

14.3 Remove Ring Gear

Note whether the ring gear teeth are chamfered. The replacement gear must be installed so that the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that is to be removed. Then remove the ring gear as follows:

(1) Support the flywheel, crankshaft side down, on a solid flat surface or hardwood block which is slightly smaller than the inside diameter of the ring gear.
(2) Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.

14.4 Install Ring Gear

(1) Support the flywheel, ring gear side up, on a solid flat surface.
(2) Rest the ring gear on a flat metal surface and heat the gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.

**CAUTION**

Do Not, Under Any Circumstances, Heat The Gear Over 4000 F (2040 C); Excessive Heat May Destroy The Original Heat Treatment.

Note: Heat indicating "crayons", which are placed on the ring gear and melt at a predetermined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

(3) Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.
(4) Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it and apply additional heat, noting the above caution.

**Service Manual** SM1-63-14.0 Flywheel

14.5 Install Flywheel

(1) Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs). Align the flywheel bolt holes with the crankshaft bolt holes.
(2) Install the clutch pilot bearing.
(3) Install two bolts through the scuff plate 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide studs.
(4) Remove the flywheel lifting tool.
(5) Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2 and any excess wiped off.

Note: International Compound must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

(6) Install the remaining bolts and run them in snug.
(7) Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.
(8) Use an accurately calibrated torque wrench and tighten the bolts to 50 ft/lb. (68 N.m) torque.
(9) Turn the bolts an additional 90° to 120° (Fig. 2) to obtain the required clamping.

Note: Since the torque-turn method provides more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

Important: When a clutch pilot bearing is installed, index the flywheel bolts so that the corners of the bolt heads do not overlap the pilot bearing bore in the flywheel. Thus, one of the flats of each bolt head will be in line with the bearing bore. Always rotate bolts in the increased clamp direction to prevent under- clamping.

(10) Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. The maximum allowable runout is .001" total indicator reading per inch of radius. The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

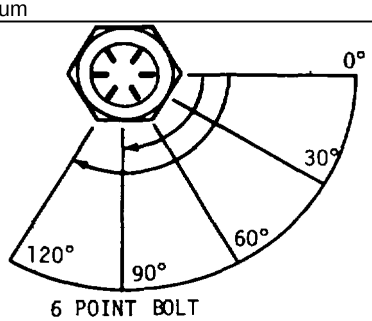



*Fig. 2*
*Torque-Turn Limits*

The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft.

The clutch pilot bearing is held in place by a scuff plate, secured in place by the flywheel attaching bolts.

15.1 Lubrication

A single-shielded ball type clutch pilot bearing should be packed with an all purpose grease such as Shell Alvania No. 2, or equivalent, if not previously packed by the manufacturer. A double sealed ball type clutch pilot bearing is pre-packed with grease and requires no further lubrication.

15.2 Remove Clutch Pilot Bearing (Transmission Removed)

With the flywheel attached to the engine, remove the ball type clutch pilot bearing as follows:

(1) Remove the bolts attaching the flywheel to the crankshaft. Install two 9/16"-18 studs to prevent the flywheel from dropping off the end of the crankshaft.
(2) With the clutch pilot bearing remover adaptor J 5901-2 attached to slide hammer J 5901-1, insert the fingers of the adaptor through the pilot bearing and tighten the thumb screw to expand the fingers against the inner race of the bearing.
(3) Tap the slide hammer against the shoulder on the shaft and pull the bearing out of the flywheel.

With the flywheel removed from the engine, the clutch pilot bearing may be removed as follows:

(1) Place the flywheel on wood supports to provide clearance for the bearing.
(2) Use bearing remover J 5901-2 as outlined above, or tool J 3154-04 with suitable adaptor plates, to tap the bearing from the flywheel.

15.3 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wipe the prepacked double-sealed bearing clean on the outside and inspect it. Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Clean the other types of bearing thoroughly with clean fuel oil and dry them with compressed air.

Check the bearing for free rolling by holding the inner race and revolving the outer race slowly by hand. Rough spots in the bearing are sufficient cause for rejecting it.

5.4 Install Clutch Pilot Bearing

(1) Lubricate the outside diameter of the bearing with clean engine oil.
(2) Start the bearing in the bore of the fly-wheel, with the numbered side of the bearing facing away from the engine, and drive the bearing in place with bearing installer J 3154-04 and suitable adaptor plates.
(3) Install the flywheel on the crankshaft (refer to SM1-63-14.0).
(4)

The flywheel housing is a one-piece casting mounted against the rear end plate which is attached to the cylinder block. The flywheel housing provides a cover for the gear train and flywheel. It also serves as a support for the starting motor and transmission.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing (SM1-63-10.0).

## 16.1 Remove Flywheel Housing

(1) Mount the engine on an overhaul stand as outlined in SM1-63-2.0.
(2) Remove the flywheel housing support brackets attached to the housing and the cylinder heads.
(3) Remove the accessories attached to the flywheel housing.
(4) Remove the starting motor (SM1-63-62.0).
(5) Remove the flywheel (SM1-63-14.0).
(6) Remove the oil pan (SM1-63-52.0).
(7) Remove the twelve attaching bolts located in the bell of the housing. Remove one attaching bolt located behind the small hole cover on the right-hand side of the flywheel housing. Then remove the remaining bolts around the upper portion of the housing and the two bolts which go through the rear end plate from the front and thread into the housing. Install aligning studs J 1927-01 (Fig. 1) to guide the housing until it clears the crankshaft during removal.

Note: When removing the flywheel housing bolts, note the location of the various size bolts, lock washers, flat washers and copper washers so they may be reinstalled in their proper location.

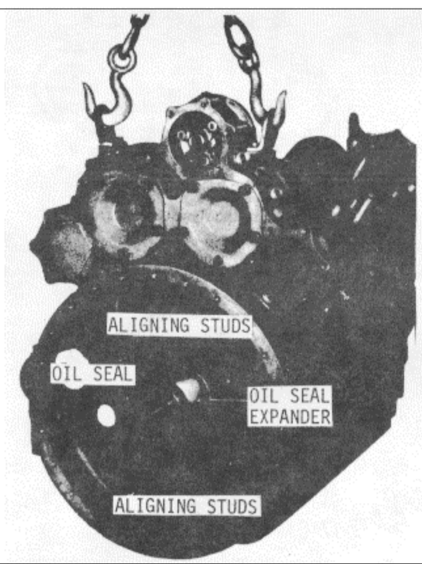



*Fig. 1*
*Installing Flywheel Housing, Using Oil Seal Expander Aligning Studs*

(8) With the flywheel housing supported by a chain hoist attached to the lifter brackets, strike the front face of the housing alternately on each side of the engine with a soft hammer to work it off the dowels and away from the cylinder block rear end plate.
(9) Remove all traces of the old gasket from the cylinder block rear end plate and the flywheel housing.

## 16.2 Inspection

Clean the flywheel housing and inspect it for cracks or other damage. Replace the housing if it is damaged.

Replace the crankshaft rear oil seal as outlined in SM1-63-10.0.

Inspect the rear end of the crankshaft for wear due to the rubbing action of the oil seal, dirt buildup, or fretting caused by the action of the flywheel. The crankshaft must be clean and smooth, otherwise the oil seal lip will be damaged when the flywheel housing is reinstalled.

If necessary, the crankshaft may be smoothed up with emery cloth and polished with crocus cloth wet with fuel oil. Rotate the crankshaft at intervals to clean up the circumference of the shaft without disturbing the concentricity.

Note: The polishing motion should be parallel to the sealing area and in the opposite direction of crankshaft rotation.

## 16.3 Install Flywheel Housing

(1) Lubricate the gear train teeth with clean engine oil.
(2) Affix a new gasket to the flywheel housing.

Note: On the flywheel housing, the idler gear hole spacer is cast integrally in the housing, opposite the idler gear (Fig. 2). As a result

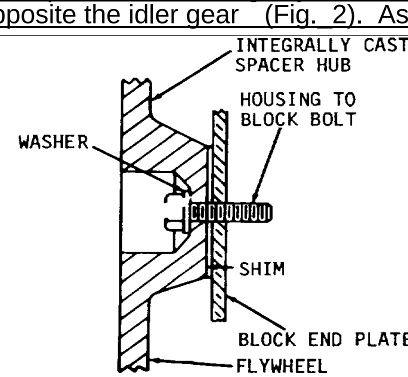



*Fig. 2*
*Idler Gear Hole Spacer Shim*

of this integral cast design, a shim must be installed between the flywheel housing and the cylinder block end plate. Use grease to hold the shim on the spacer during installation of the flywheel housing.

(3) Coat the lip of the crankshaft oil seal lightly with vegetable shortening (double lip seal). Do not scratch or nick the sealing edge of the oil seal.

(4) To pilot the oil seal on the crankshaft successfully, use expander stud set J 25002 and oil seal expander J 4239 (standard size seal) or expander J 8682 and handle J 8092 (oversize seal). Thread two aligning studs J 1927-01 into the cylinder block to guide the housing in place (Fig. 1).

(5) With the housing suitable supported, position the housing over the crankshaft and up against the cylinder block rear end plate an gasket. Remove the oil seal expander.

Note: Before installing the flywheel housing, be sure the 5/8"-11 x 1" rear end plate to cylinder block bolt is installed and tightened as noted in SM1-63-3.0.

(6) Install three flywheel housing bolts with a nylon patch and flat washers at the right bank camshaft gear area (positions 13, 14, and 15 in Fig. 4).

(7) Refer to Fig. 3 for the bolt tightening sequence and, starting at number 4, draw the flywheel housing bolts up snug.

Important: If the idler gear hole spacer is integrally cast into the housing, be sure the shim is in place.

Note: When tightening the flywheel housing bolts, the idler gear hub bolts should always be tightened first. Also turn the crankshaft by hand while tightening the idler gear hub bolts to prevent any bind or brinelling of the rollers and cups of the tapered roller bearing.

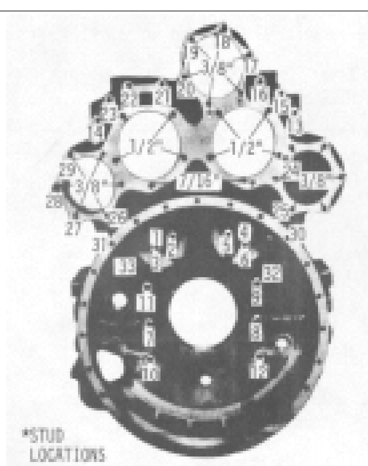


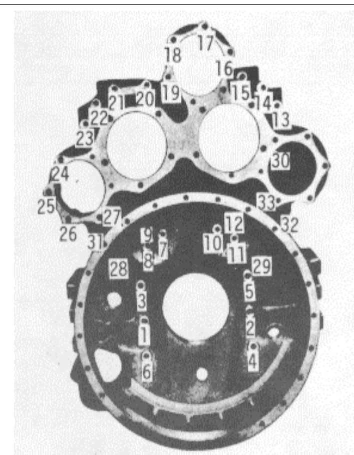

*Fig. 3*
*Flywheel Housing Bolt Tightening Sequence (Operation 1)*

(8) Refer to Fig. 4 for the final bolt tightening sequence and, starting at number 1, tighten the flywheel housing bolts to the specified torque. Tighten the 3/8"-24 bolts to 25-30 ft/lb (34-41 N•m); the 3/8"-16 self-locking idler gear hub and idler gear hole spacer bolts to 40-45 ft/lb. (54-61 N•m) torque; the remaining 3/8"-16 bolts, number 30 with nylon patch to 30-35 ft/lb. (41-47 N•m) torque; and the 1/2"-13 bolts to 90-100 ft/lb. (122-136 N•m) torque. Tighten the two 5/8"-11 outboard flywheel housing bolts on the left and right side to 137-147 ft/lb. (186-200 N•m) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts.

(9) Check the flywheel housing concentricity and bolting flange face with tool set J 9737-01 as follows:

(a) Refer to Fig. 5 and thread the base post J 9737-3 tightly into one of the tapped holes in the flywheel. Then assemble the dial indicators on the base post with the attaching parts provided in the tool set.

(b) Position the dial indicators straight and square with the flywheel housing and make sure each indicator has adequate travel in each direction.



| Bolt Size | Location | Final Torque |
|---|---|---|
| 3/8"-16 x 1" | 7-8-9-10-11-12,28,29 | 40-45(54-61N•m) |
| 3/8"-16 x 1-1/4" | 30 | 30-35(41-47N•m) |
| 3/8"-24 x 3-7/8" | 13,14,15,20,21,22,23 | 25-30 (34-41N•m) |
| 1/2"-13 x 3-1/4" | 1,2,3,4,5,6 | 90-100 (122-136) |
| 5/8"-11 x 4" | 31,32 | 137-l47(186-200) |

*Fig. 4*
*Flywheel Housing Bolt Tightening Sequence (Operation 2)*

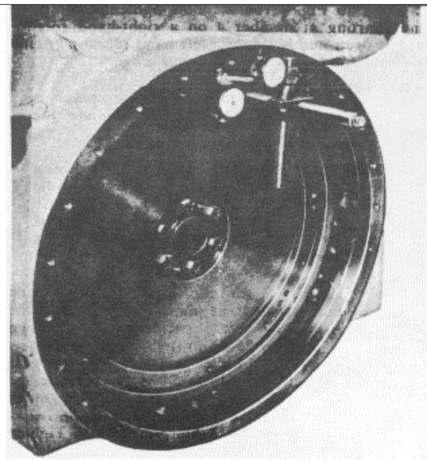


*Fig. 5*
*Checking Flywheel Housing Concentricity*

Note: If the flywheel extends beyond the flywheel housing bell, the housing bore and face must be checked separately. Use the special adapter in the tool set to check the housing bore.

(c) Pry and hold the crankshaft in one direction to ensure end play is in one direction only.
(d) Adjust each dial indicator to read zero at the twelve o'clock position. Then rotate the crankshaft one full revolution, taking readings at 45 intervals (8 readings each of the flywheel housing bore and bolting flange face). Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed .013" for either the bore or the face.
(e) If the runout exceeds the maximum limits, remove the flywheel and the flywheel housing and check for dirt or foreign material, such as old gasket material, between the end plate, fly-wheel housing and new gasket (and between the end plate and the cylinder block), which may result in warpage.
(f) Reinstall the flywheel housing and secure the attaching bolts in the proper sequence and to the specified torque. Then recheck the runout. If necessary, replace the flywheel housing.

(10) Install the flywheel (SM1-63-14.0).
(11) Install the oil pan.
(12) Install the starting motor (SM1-63-62.0).
(13) Install any accessories previously removed.
(14) Install the small and large hole covers on the flywheel housing. Refer to Fig. 3 and tighten the 3/8"-24 stud nuts to 20-25 ft/lb. (27-34 N•m) torque. The 3/8"-24 bolts, 7/16"-14 bolts. and 1/2"-13 bolts should be tightened to 30-35 ft/lb. (41-47 N•m) torque.

Note: The engine includes thread inserts at the small and large hole cover stud hole positions.

(15) Remove the engine from the overhaul stand and complete assembly of the engine.

The cross-head piston (Fig. 1 and 2) is a two-piece piston consisting of a crown and skirt. A metal oil seal ring is used between the crown and skirt which are held together by the piston pin. Ring grooves are machined in the piston crown for a fire ring and two compression rings. The crown is also machined to accept a 1500 slipper type bushing (bearing). The piston skirt incorporates two oil control ring grooves, piston pin holes and piston pin retainer counter-bores. Equally spaced drain holes are located in the oil ring groove area to permit excess oil, scraped from the cylinder walls, to return to the crankcase.

Two bolts and spacers are used to attach the connecting rod (SM1-63-18.0) to the piston pin. The solid core piston pin has a radial drilled oil hole through the center. A threaded hole on each side of the oil hole receives the connecting rod attaching bolts.

Internal parts of the piston are lubricated and cooled by the engine lubricating oil. Oil is pressure-fed up the drilled passage in the connecting rod, through the oil tube or drilled hole in the piston pin, then through the center hole in the bushing to the underside of the piston crown. A portion of the oil flows along the grooves in the bushing to lubricate the piston pin.

During engine operation, gas loads pushing down on the piston crown are taken directly by the piston pin and bushing. The piston skirt, being separate, is free from vertical load distortion; thermal distortion is also reduced as the piston crown expands. As the connecting rod swings to one side during downward travel of the piston, the major portion of the side load is taken by the piston skirt.

The turbo-charger engines use 17:1 compression ratio pistons. To aid identification of a piston, refer to Fig. 3. Fit the proper side of the gage in the bowl of the piston crown. When the gage rests on the rim of the crown, it is a "GO" check for a piston used in a turbocharged engine. When there is a space of approximately .040", it identifies a piston not used with this engine.

### 17.1 Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

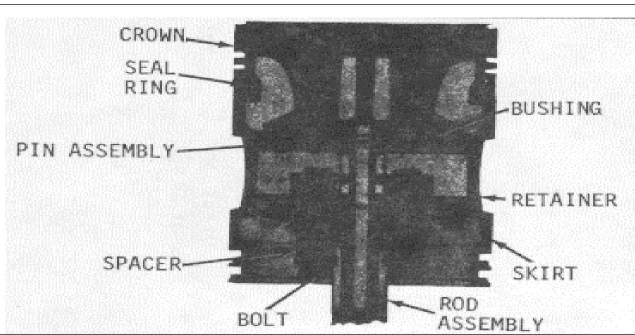



*Fig. 1*
*Cross-Head Piston and Connecting Rod Assembly*

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to SM1-63-69.0 for the procedure for checking compression pressure.

### 17.2 Remove Piston and Connecting Rod

(1) Drain the cooling system.
(2) Drain the oil and remove the oil pan.
(3) Remove the oil pump and inlet and outlet pipes, if necessary (SM1-63-47.0).
(4) Remove the cylinder head (SM1-63-5.0).
(5) Remove the carbon deposits from the upper inner surface of the cylinder liner.
(6) Remove the bearing cap and the lower bearing shell from the connecting rod. Then push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
(7) Reassemble the bearing cap and lower bearing shell to the connecting rod.

### 17.3 Disassemble Piston and Connecting Rod

Note the condition-of the piston and rings. Then remove the rings and disassemble the piston as follows:

(1) Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 as shown in Fig. 4.
(2) Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushing. Remove the opposite retainer in the same manner.
(3) Loosen the two bolts which secure the connecting rod to the piston pin. Then remove the rod and piston assembly from the vise and place the assembly on the bench. Remove the two bolts and spacers and remove the connecting rod.
(4) Withdraw the piston pin.

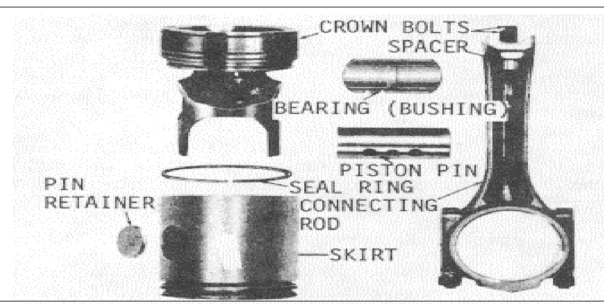



*Fig. 2*
*Cross-Head Piston and Connecting Rod Components*

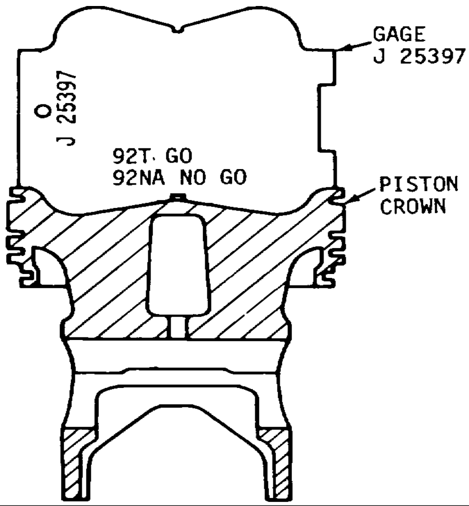



*Fig. 3*
*Identification of Piston Using Gage J 25397*

(5) Separate the piston skirt from the piston crown .
(6) Remove the metal seal ring from the piston crown.
(7) Remove the piston pin bushing (bearing).

### 17.4 Cleaning

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean the piston components with fuel oil and dry them with compressed air. If the fuel oil does not remove the carbon deposits, use a chemical solvent that will not harm the tinplate on the piston.

The piston crown, including the compression ring grooves, is not tin-plated and may be wire brushed to remove any hard carbon. Do not wire brush the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston crown and skirt and the oil drain holes in the lower half of the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

### 17.5 Inspection

If the tin-plate on the piston skirt and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored piston skirts, rings, or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston skirt and crown for score marks, cracks, damaged ring groove lands or indications of overheating. Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots may be the result of an obstruction in the connecting rod oil passage.

Check the tapered fire ring groove width in the piston crown with tool J 24599 as shown in Fig. 5. Slide the "NO GO" wire (.106" diameter) of the tool completely around the fire ring groove. Should the wire be below flush at any one area, the piston crown must be replaced. The "GO" wire (.100" diameter) should be flush or protrude slightly from the fire ring groove.

Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston (refer to SM1-63-70.0 for specifications).

The current piston skirt used in turbocharged engines has only one row of oil drain holes (Fig. 16).


*Fig. 4*
*Removing or Installing Piston Rings*

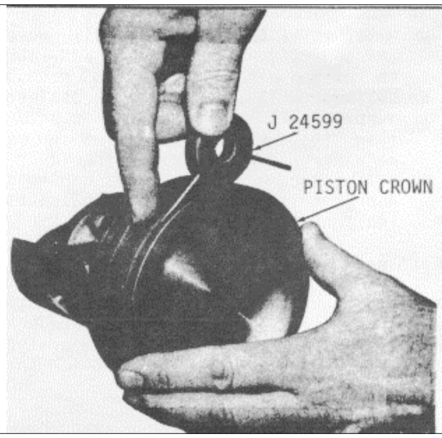



*Fig. 5*
*Checking Fire Ring Groove in Piston Crown*

Inspection of the connecting rod, piston pin, and piston pin bushing are covered in SM1-63-18.0. Other factors that may contribute to piston failure include oil leakage into the air box, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

### 17.6 Assemble Piston

(1) Install the bearing (bushing) in the piston crown. It should slide into the piston crown without force. With new parts, there is .0005" to .0105" clearance between the edge of the bushing and the groove in the piston crown.

*Fig. 6*
*Installing Seal Ring*

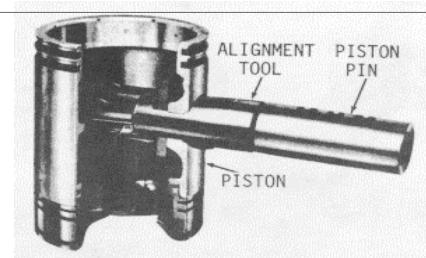



*Fig. 7*
*Installing Piston Pin*

Note: <u>The bearing must be installed before assembling the piston skirt and crown.</u>

(2) Lubricate the metal seal ring (Fig. 6) with engine oil and install it with the chamfer directed toward the bottom of the piston.

(3) Compress the seal ring with ring compressor J 24226 and push the skirt into position on the piston crown.

Important:<u>Before completely assembling the piston, check to make sure the seal ring does not stick in the ring groove. It is imperative for satisfactory engine operation that the seal ring is free in the piston crown groove. Check it full 3600 circumference of the groove to be sure there are no tight spots. When the piston crown, seal ring and piston skirt are assembled, the skirt should spin freely on the crown (crown top down on the bench). If the seal ring sticks remove high spots or nicks with a flat file. If this does not relieve sticking, replace the piston crown.</u>

(4) Lubricate the piston pin with clean engine oil and install it as shown in Fig. 7.

Note: <u>Line up the piston pin opening in the piston skirt with the bearing(bushing)opening in the piston crown with tool J 24285 to prevent damage to the pin or bushing. (5) Install the spacers on the two 7/16"-20 x 2" connecting rod to piston pin attaching bolts.</u>

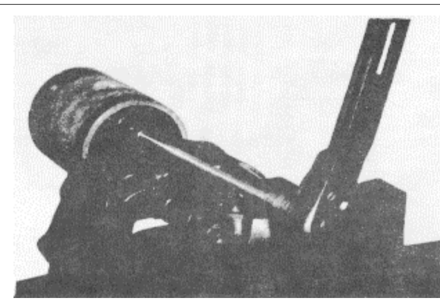


*Fig. 8*
*Tightening Connecting Rod to Piston Pin Bolts*

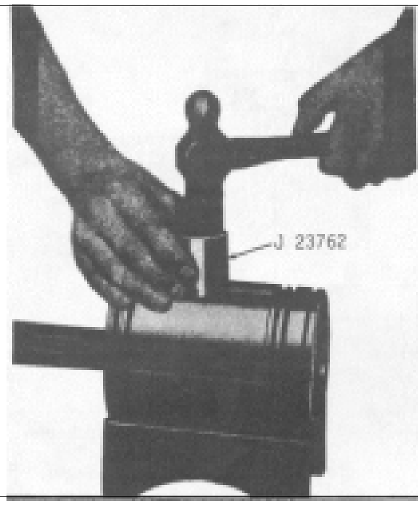



*Fig. 9*
*Installing Piston Pin Retainer*

(6) Apply a small amount of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact surfaces.
(7) Install and tighten the bolts finger tight. Then clamp the connecting rod in a vise and tighten the bolts to 55-60 ft/lb. (75-8 N•m) torque (Fig. 8). Do not exceed this torque.
(8) Place a new piston pin retainer in position Place the crowned end of installer J 23762 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston (Fig. 9)
(9) Install the second piston pin retainer in the same manner.

Note: <u>Due to the size of the counter-bore in the piston skirt, be careful when installing the piston pin retainers and inspect them to be sure they are not buckled and that they are fully seated in the counter-bore. The width of the land should be even around the retainer.</u>

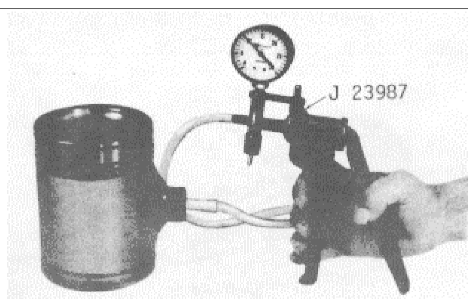



*Fig. 10*
*Checking Piston Pin Retainer for Proper Sealing*

(10) One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushing, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987 (Fig. 10). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

**17.7 Fitting Piston**

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (700 F or 210 C). Refer to SM1-63-70.0 for specifications.

The piston-to-liner clearance, with new parts, will vary with the particular piston diameter (refer to SM1-63-70.0). A maximum clearance of .012" is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston skirt upside down in the liner and check the clearance in four places 900 apart (Fig. 11).

Use feeler gage set J 5438-01 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

Select a feeler gage with a thickness that will require a pull of six pounds (26.7 N) to remove. The clearance will be .001" greater than the thickness of the feeler gage used; i.e., a .004" feeler gage will indicate a clearance of .005" when it is withdrawn with a pull of six pounds (26.7 N). The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs.

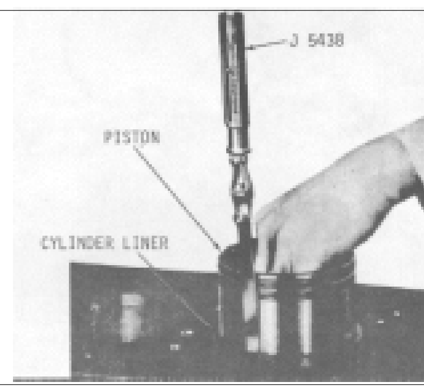



*Fig. 11*
*Measuring Piston-to-Liner Clearance*

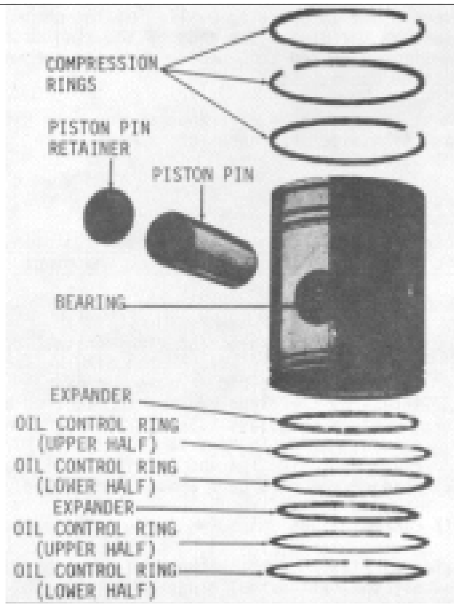



*Fig. 12*
*Typical Piston Assembly, Piston Rings, Pin and Relative Location of Parts*

Remove burrs with a fine hone (a flat one is preferable)' and recheck the clearance.

### 17.8 Fitting Piston Rings

Each piston is fitted with a fire ring, two compression rings and two oil control rings (Fig. 12).

The top (fire) ring and the upper compression ring (second groove) are pre-stressed (Fig. 13). Both are identified by an oval mark on the top side. In addition, the fire ring is chrome- plated on the lower side.

A two-piece oil control ring is used in both

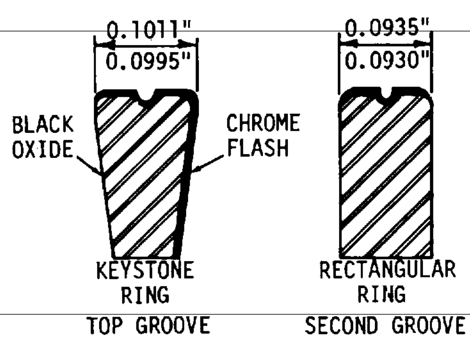



*Fig. 13*
*Compression of Pre-Stressed Compression Rings*


*Fig. 14*
*Measuring Piston Ring Gap*

oil ring grooves in the pistons for all current engines.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new of used piston or cylinder liner is installed.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston skirt to push the ring down to be sure it is parallel with the top of the liner. Then measure the ring gap with a feeler gage as shown in Fig. 14. Refer to SM1-63-70.0 for ring gap specifications.

If the gap on a compression ring is insufficient it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will

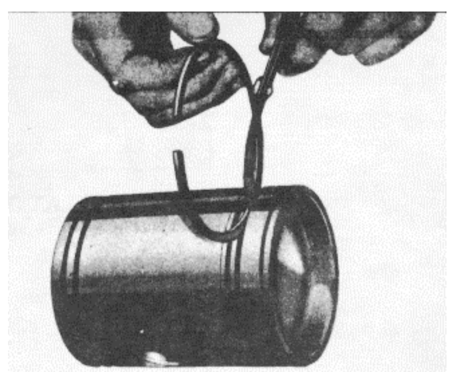


*Fig. 15*
*Measuring Piston Ring Side Clearance*

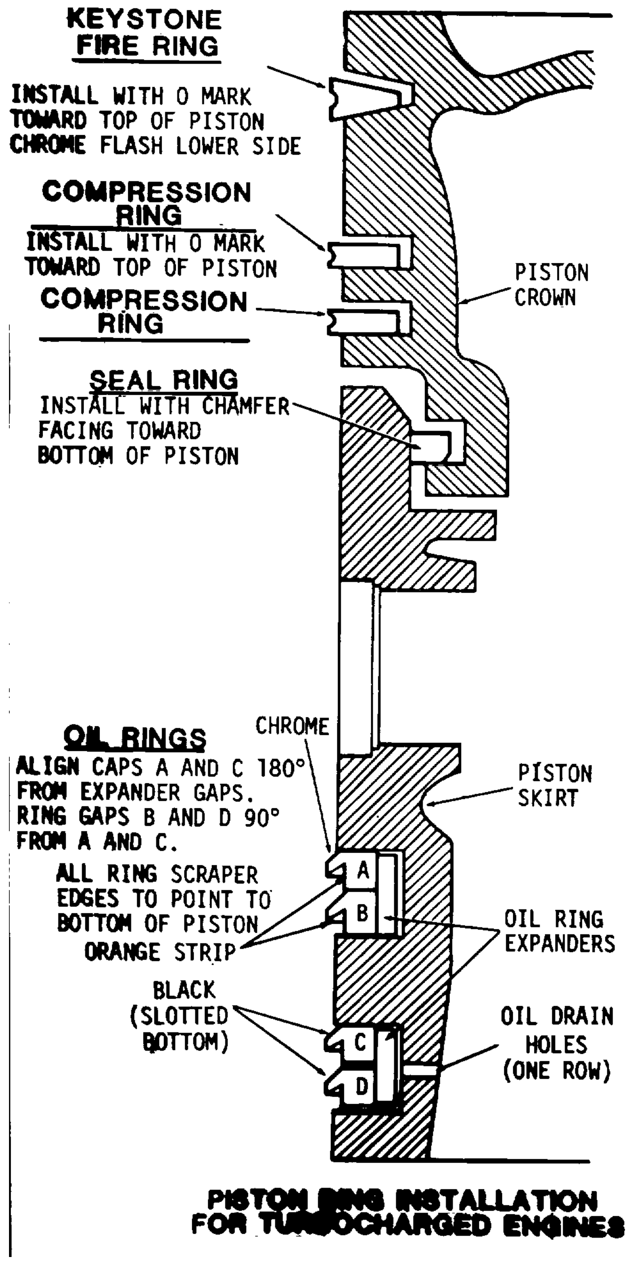



*Fig. 16*
*Piston Ring Installation Instructions*

prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015". Check the ring side clearance as shown in Fig. 15. Ring side clearances are specified in SM1-63-70. 0.

### 17.9 Install Piston Rings

Note: Lubricate the piston rings and piston with engine oil before installing the rings.

Compression Rings:

(1) Starting with the bottom ring, install the compression rings with tool J 8128 as shown in Fig. 4. To avoid breaking or over-stressing the rings, do not spread them any more than necessary to slip them over the piston. Refer to Fig. 12 and Fig. 16 for ring identification and location.

(2) Stagger the ring gaps around the piston.

Oil Control Rings:

Refer to Fig. 16 for the type and location and install the oil control rings as follows:

(1) Install the ring expanders in the oil control ring grooves in the piston skirt.

Note: When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

Important: Install the peripheral abutment type ring expanders with -the legs of the free ends toward the top of the piston (Fig. 17). With the free ends pointing up, noticeable resistance will be encountered during installation of the piston if the ends of the expander are overlapped and corrective action can be taken before ring breakage occurs.

(2) Install the oil control rings by hand. Start with the upper half of the top oil ring and align the gaps as indicated in Fig. 16.

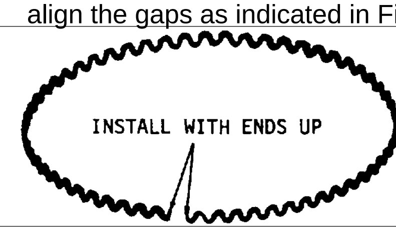



*Fig. 17*
*Peripheral Abutment Type Oil Control Ring Expander*

Note: The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

Install the piston and connecting rod assembly as outlined in SM1-63-20.0.

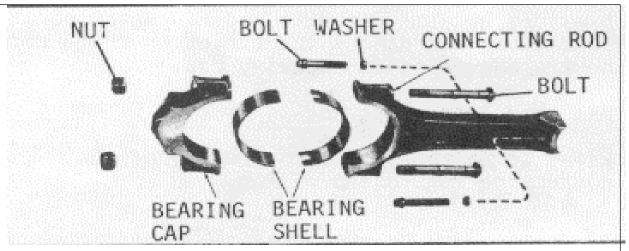



*Fig. 1*
*Connecting Rod Details*

The connecting rod (Fig. 1) is forged to an "I" section with an open or saddle type contour at the upper end and a bearing cap at the lower end. The bearing cap and connecting rod are forged in one piece and bored prior to separation.

The upper end of the connecting rod is machined to match the contour of the piston pin. The piston pin is secured to the connecting rod with two self-locking bolts and spacers. The lower bearing cap is secured to the connecting rod by two specially machined bolts and nuts.

Lubricating oil is forced through a "Y" drilled oil passage in the connecting rod to the piston pin and bushing.

A service connecting rod Includes the bearing cap and the attaching bolts and nuts.

The replaceable connecting rod bearing shells are covered in SM1-63-19.0.

18.1 Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined in SM1-63-17.0.

18.2 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean the connecting rod and piston with fuel oil and dry them with compressed air. Blow compressed air through the oil passage in the connecting rod to be sure it is clear of obstructions. Use crocus cloth, wet with fuel oil, to remove any trace of fretting and/or

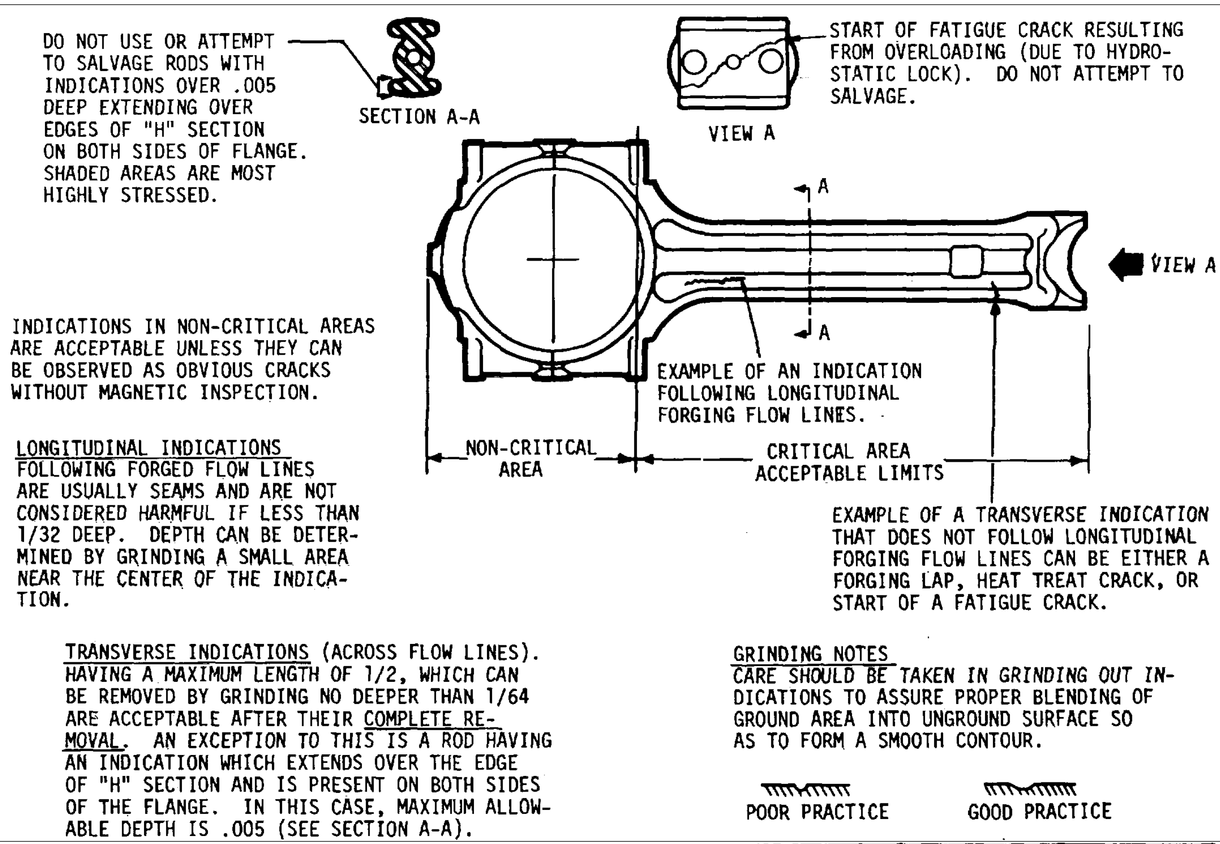



*Fig. 2*
*Magnetic Particle Inspection Limits for Connecting Rod*

corrosion on the connecting rod saddle and piston pin contact surface before reassembly.

Visually check the connecting rod for twist or bending.

Check for cracks (Fig. 2) by the magnetic particle method outlined in SMl-63-9.0 under "Crankshaft Inspection".

Remove any nicks or burrs from the connecting rod bolt holes with reamer J 28460. The reamer includes a 60° angle to clean up the chamfer at the bolt hole to ensure proper seating of the underside of the bolt head.

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to SM1-63-20.0).

Important: <u>Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clear of obstructions. Also make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".</u>

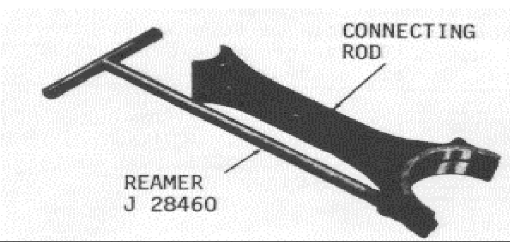



*Fig. 3*
*Connecting Rod Bolt Hole Reamer*

Inspect the bearing (bushing) for indications of scoring, overheating, or other damage. Measure the thickness of the bushing along the center. Replace the bushing if it is damaged or worn to a thickness of .086" or less. A new bushing is .087" to .088" thick.

Inspect the piston pin for signs of fretting. When re-using a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear. A new piston pin has a diameter of 1.4996" to 1.5000". Replace the piston pin if it is worn to a diameter of 1.4980" or less.

A solid core piston pin is used in the turbo-charged engines. The piston pin has a drilled oil hole at the center and a tapped hole on each side of the oil hole is provided to receive the connecting rod attaching bolts. The connecting rod has a 1.470" wide column and provides greater strength under severe operating conditions and can be identified by white paint on the bottom of the bearing cap.

## 18.3 Assemble Connecting Rod to Piston

Refer to SM1-63-17.0 for assembly of the connecting rod to the piston.

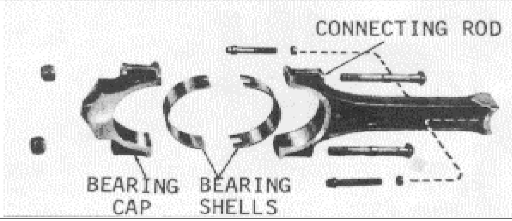



*Fig. 1*
*Connecting Rod and Bearing Shells*

The connecting rod bearing shells (Fig. 1) are precision made and are of the replaceable type without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell.

The multiple layer copper-lead coplated bearings have an inner surface, called the matrix, of copper-lead. A thin deposit of lead-tin is then plated onto the matrix. The lead-tin overlay has excellent resistance to friction, corrosion and scoring tendencies which, combined with the material of the matrix, provides improved load carrying characteristics. These bearings are identified by the satin silver sheen of the overlay when new and a dull gray after being in service.

The upper and lower connecting rod bearing shells are different and are not interchangeable. Both shells are notched midway between the bearing edges for approximately 3/4 of an inch in from each parting line for bolt clearance and oil flow. In addition, the lower bearing shell has a circumferential oil groove that terminates at the notched ends. These notches maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings and piston pin bushing through the oil passage in the connecting rod.

## 19.1 Remove Bearing Shells

The connecting rod bearing caps are numbered 1L, 1R, 2L, 2R, etc., with matching numbers and letters stamped on the connecting rod. When removed, the bearing cap and the bearing shell should always be reinstalled on the original connecting rod.

Remove the connecting rod bearings as follows:

(1) Drain the oil and remove the oil pan.
(2) Disconnect and remove the lubricating oil pump inlet pipe and screen assembly. If the engine is equipped with an oil pump which is mounted on the main bearing caps, remove the oil pump as outlined in SM1-63-47.0.
(3) Remove one connecting rod bearing cap. Push the connecting rod and piston assembly. Up into the cylinder liner far enough to permit removal of the upper bearing shell. Do not pound on the edge of the bearing shell with a sharp tool.
(4) Inspect the upper and lower bearing shells as outlined under "Inspection."
(5) Install the bearing shells and bearing cap before another connecting rod bearing cap is removed .

## 19.2 Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no lubricating oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, chipping, cracking, loss of overlay or signs of over-heating. If any of these defects are present, the bearings must be discarded. However, over-lay plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of, and are NOT detrimental to, this type of bearing. The bearings should not be replaced for these minor surface imperfections (Fig. 2). The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been shifting in their supports. If such spots are present, discard the bearing shells. Also inspect the connecting rod bearing bore for burrs, foreign particles, etc.

Examine the backs of the bearing shells for areas of no contact. Determine the amount of wear and replace, if necessary, the bearings and/or the connecting rod.

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under "Inspection" in SM1-63-11.0. The minimum thickness of a worn standard connecting rod bearing shell should not be less than .1230" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1240" to .1245". Refer to Table 1.

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic

*Table 1*

| Bearing Size | *New Bearing Thickness | Minimum Worn Thickness |
|---|---|---|
| Standard | .1240"/.1245" | .1230" |
| .002" Undersize | .1250"/.1255" | .1240" |
| .010" Undersize | .1290"/.1295" | .1280" |
| .020" Undersize | .1340"/.1345" | .1230" |
| .030" Undersize | .1390"/.1395" | .1380" |

*Thickness 900 from parting line o- bearing.

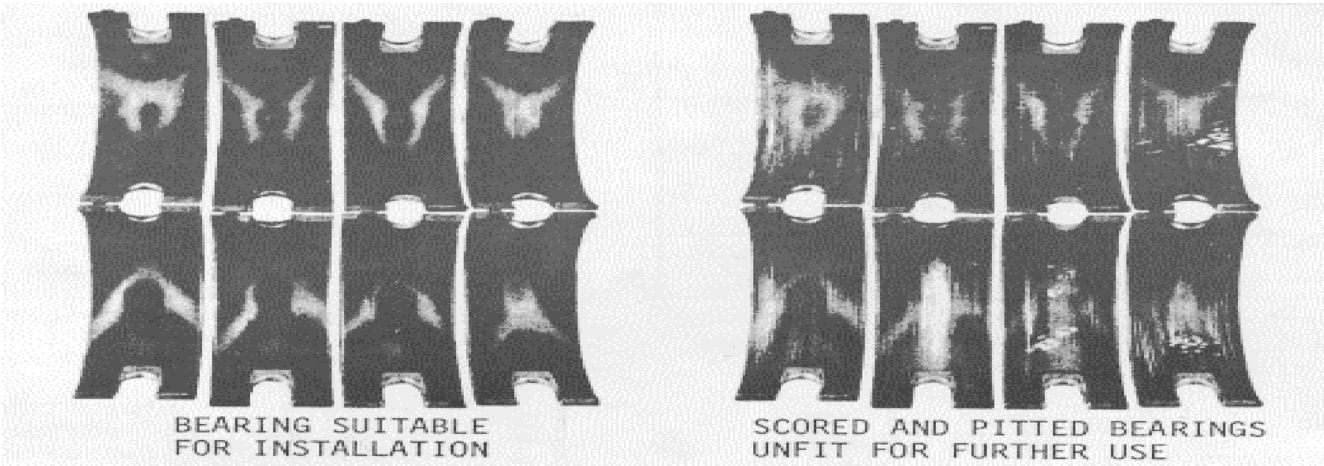



*Fig. 2*
*Comparison of Connecting Rod Bearing Shells*

measuring strip which is squeezed between the journal and the bearing (refer to "Shop Notes" in SM1-63-30.0). The maximum connecting rod bearing-to-journal clearance with used parts is .0056".

Before installing the bearings, inspect the crankshaft journals (refer to "Inspection" in SMl-63-9.0).

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells. Bearing shells are available in .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to "Crankshaft Grinding" in SM1-63-9.0. Bearings which are .002" under- size are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

**CAUTION**

Bearing Shells Are Not Reworkable From One Under Size To Another Under Any Circumstances.

### 19.3 Install Connecting Rod Bearing Shells

(1) Wipe the journal clean and lubricate it with clean engine oil.

(2) Install the upper bearing shell -- the one without the continuous oil groove. Be sure the tang on the shell fits in the groove in the rod.

If there is a visible difference in the color of new upper and lower bearing shells, it is due to a change in the manufacturing process and they should not be rejected on the basis of dissimilar appearance.

(3) Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.

(4) Note the number and letter stamped on the bearing cap and install the lower bearing shell -- the one with the continuous oil groove -- into the bearing cap. Install the cap and shell in place.

(5) Lock the bearing caps securely in place with bolts and nuts. Tighten the connecting rod bolt nuts to 60-70 ft/lb. (81-95 N•m) torque (lubrite nut).

Note: Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut.

(6) Install the lubricating oil pump inlet pipe and screen assembly. If the engine is equipped with an oil pump which is mounted on the main bearing caps, install the oil pump as outlined in SM1-63-47.0.

(7) Install the oil pan.

(8) Refer to "Lubricating Oil Specifications" in the Operators Manual and refill the crankcase to the proper level on the dipstick.

(9) If new bearings were installed, operate the engine on the run-in schedule as outlined in SM1-63-67.0.

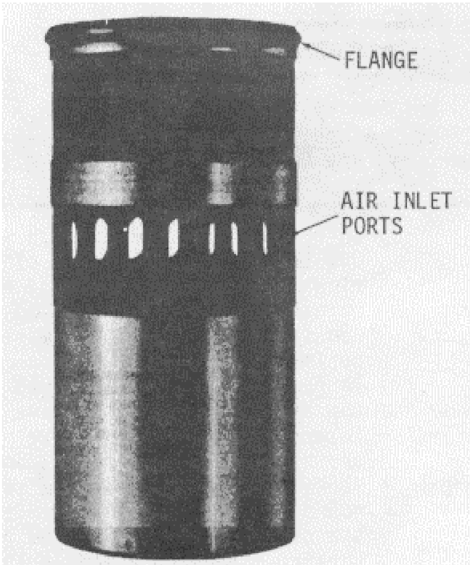



*Fig. 1 Typical Cylinder Liner*

The cylinder liner (Fig. 1) is of the replaceable wet type (water above ports) made of hardened alloy cast iron, and is a slip fit in the cylinder block. The liner is inserted in the cylinder bore from the top of the cylinder block. The flange at the top of the liner fits into a counterbore in the cylinder block and rests on a replaceable cast iron insert which permits accurate alignment of the cylinder liner.

Two seal rings, recessed in the cylinder bore, are used between the liner and the block to prevent water leakage.
The upper half of the liner is directly cooled by water surrounding the liner. At the air inlet ports, the liner is cooled by the air introduced into the cylinder through equally spaced ports around the liner. The lower half of the liner is cooled by water inside the cylinder block water jacket surrounding the liner.
The air inlet ports in the liner are machined at an angle to create a uniform swirling motion to the air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

The wear on a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaners must be serviced regularly according to the surroundings in which the engine is operating.

20.1 Remove Cylinder Liner

It is very important that the proper method is followed when removing a cylinder liner. DO NOT attempt to push the liner out by inserting a bar in the liner ports and rotating the crank- shaft, otherwise the piston may be damaged or the upper ring groove may collapse. Refer to Fig. 2 and remove a cylinder liner as follows:

(1) Remove the piston and connecting rod assembly as outlined in SM1-63-17.0.

(2) Remove the cylinder liner with tool set J 24563 as follows:

(a) Ease the lower shoe and bolt assembly down into the liner. Place the shoe on the bottom edge of the liner with the flat on the shoe parallel with the crankshaft bore.

(b) Hold the lower shoe and bolt assembly in the pulling position. Place the upper shoe with the flat in the same position as the lower shoe over the threaded end of the bolt. Thread the nut down on the bolt assembly and be sure that the pilots on both of the shoes are seated properly.

(c) Place the bridge assembly (open end down) over the upper shoe and down against the block.

(d) With the thrust bearing on the bolt, install the bolt through the bridge assembly strap hole.

(e) Thread the bolt into the female threaded portion of the bolt assembly. (f) Turn the bolt in a clockwise direction and withdraw the liner from the block. Then remove the tool from the liner.

(g) Remove and tag the liner insert from the counterbore in the block.

(h) Remove and discard both cylinder liner seal rings from the grooves in the cylinder block bore.

If tool set J 24563 is unavailable, tap the liner out with a hardwood block and hammer.

20.2 Inspect Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for:

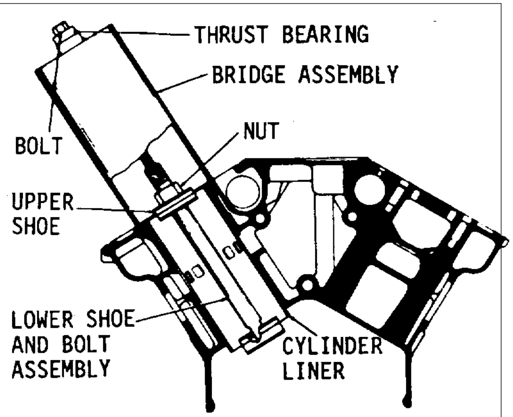



*Fig. 2 Removing Cylinder Liner*

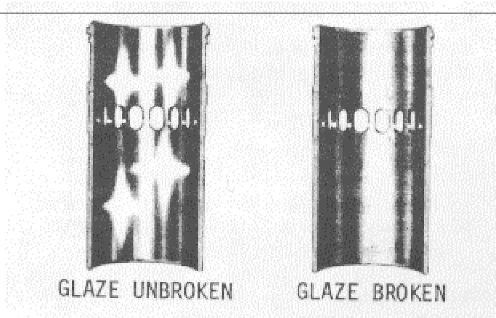



*Fig. 3 Glazed Surface of Cylinder Liner*

Cracks, scoring, poor contact on outer surface, flange irregularities, inside diameter, outside diameter, out-of-round, and taper.

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned up and reused.

Examine the outside diameter of the liner for fretting below the ports. Fretting is the result of a slight movement of the liner in the block bore during engine operation, which causes material from the block to adhere to the liner. These metal particles may be removed from the surface of the liner with a coarse, flat stone. Also examine the liner for cavitation erosion above the ports.

The liner flange must be smooth and flat on both the top and bottom surfaces. Check for cracks at the flange. The liner insert must also be smooth and flat on the top and bottom surfaces as it also acts as a water seal. Replace the insert if there is evidence of brinelling.

Measure the block bore and the outside diameter of the liner. Refer to SM1-63-70.0 for the liner-to-block specifications.

A used cylinder liner must be honed for the following reasons:

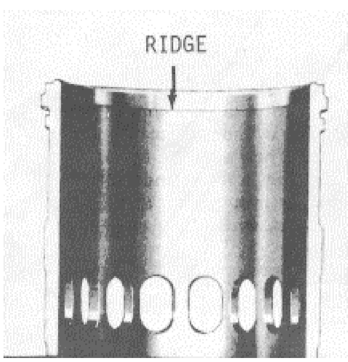



*Fig. 4 Cylinder Liner Ridge Due To Wear*

**CAUTION**

Do Not Modify The Surface Finish In A New Service Liner. Since The Liner Is Properly Finished At The Factory, Any Change Will Adversely Affect Seating Of The Piston Rings.

(1) To break the glaze (Fig. 3) which results due to the rubbing action of the piston rings after long periods of operation. Unless this glaze is removed, the time required to seat the new piston rings will be lengthened.

(2) To remove the ridge (Fig. 4) formed at the top by the piston ring travel. Otherwise, interference with the travel of the new compression rings may result in ring breakage. Therefore, even though the taper and out-of- round are within the specified limits, the glaze and ridge must be removed by working a hone up and down the full length of the liner a few times.

Place the liner in a fixture (a scrap cylinder block makes an excellent honing fixture). How- ever, if. it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

The hone J 5902-1, equipped with 120 grit stones J 5902-14, should be worked up and down (at 300- 400 rpm) the full length of the liner a few times in a criss-cross pattern that produces hone marks on a 450 axis.

After the liner has been honed, remove it from the fixture and clean it thoroughly. Then dry it with compressed air and check the entire surface for burrs.

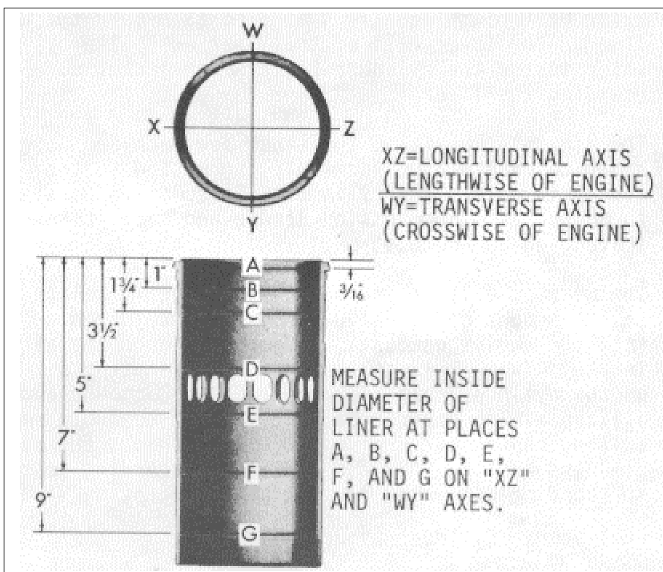



*Fig. 5 Cylinder Liner Measurement Diagram*

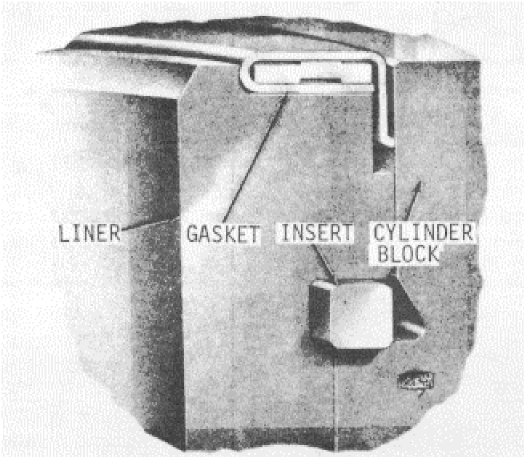



*Fig. 6 Cylinder Liner Mounting In Block*

After honing, the liner must conform to the same limits on taper and out-of-round as a new liner and the piston-to-liner clearance must be within the specified limits (SM1-63-70.0).

Install the liner (new or used) in the proper bore of the cylinder block and measure the inside diameter at the various points shown in Fig. 5. New service liners have an inside diameter of 4.8390" to 4.8415". Use cylinder bore gage J 5347-01, which has a dial indicator calibrated in .0001" increments. Set the cylinder bore gage on zero in master ring gage J 24564. Also check the liner for taper and out-of-round.

Note: Dial bore gage master setting fixture J 23059-01 may be used in place of the master ring gage.

The piston-liner clearance must be within the specified limits (SM1-63-70.0). Also, the taper and the out-of-round mist not exceed .0025" on a used liner. The taper must not exceed .0015" or the out-of-round must not exceed .002" on a new liner.

20.3 Fitting Cylinder Liner in Block Bore

(1) Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean, so the liner insert will seat properly. The block counterbore depth must be from either .4755" to .4770" or .4905" to .4920" and must not vary more than .0015" in depth around the circumference. Also, no two adjacent block counterbores may range in depth more than .001" when gaged along the longitudinal cylinder block centerline, with the possible exception of the .4905" to .4920" deep counterbores.

Note: The cylinder liner is classified ac- cording to the flange thickness to help control the distance from the top of the liner to the top of the cylinder block. A cylinder liner with a flange thickness of .3109" to .3100" (thin) has the part number etched on the lower portion of the bottom half of the liner. A liner with a flange thickness of .3120" to .3110" (thick) has the part number etched on the upper portion of the bottom half of the liner (below the air inlet orts). Install cylinder liners of the same flange thickness range on any one cylinder bank.

(2) Place the liner insert (previously tagged) in the counterbore of the block (Fig. 6). Refer to Table 1 for the dimensions and identification of the liner inserts avail- able, if a new liner insert is required. The .015" thicker inserts are used where the cylinder block counterbore is .015" or more below standard specifications.

(3) Push the cylinder liner into the cylinder block until the liner flange rests on the insert. Do not use excessive force to install the liner. The liner should slide smoothly in place with hand pressure.

(4) Clamp the liner in place with hold-down clamp J 24565 as illustrated in Fig. 7 and tighten the two bolts to 50 ft/lb. (68 N.m) torque.

Note: The cylinder head bolt hole counterbore has been increased in depth to .800" on current cylinder blocks. The depth was formerly .500". This necessitates the use of longer bolts (11/16"-11l x 3") for use with the hold-down clamps.

(5) Measure the distance from the top of the liner to the top of the block with a dial indicator (Fig. 7). The liner flange must be .0418" to .0482" below the surface of the block. However, even though all of the liners are within these specifications, there must not be over .0015" difference between any two adjacent liners when measured along the cylinder longitudinal centerline. If the above limits are not met, install a different thickness

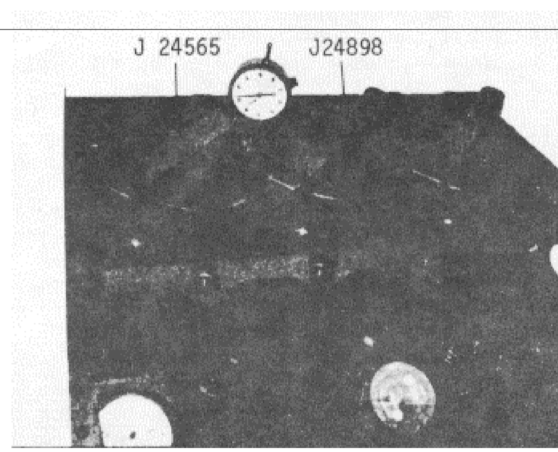



*Fig. 7 Checking Distance of Liner Flange Below Top Face of Block*

| Size | Thickness | Identification (New Inserts) |
|---|---|---|
| Std. | .1188"-.1193" | Black oxide or 2 purple stripes |
| Std. | .1200"-.1205" | No color |
| Std. | .1212"-.1217" | Copper or two orange stripes |
| +.015" | .1338"-.1343" | White and purple stripe |
| +.015" | .1350"-.1355" | White stripe |
| +.015" | .1362"-.1367" | White and orange stripe |

Table 1

insert (Table 1), install the liner in another cylinder bore and recheck, or use a new cylinder liner.

(6) Matchmark the liner and the cylinder block with a felt pen so the liner may be rein- stalled in the same position in the same block bore. Place the matchmarks on the side opposite the camshaft.

(7) Remove the hold-down clamp and the cylinder liner.

Note: Do not remove the liner insert.

20.4 Install Piston and Connecting Rod Assembly

(1) With the piston assembled to the connecting rod and the piston rings in place as out- lined in SM1-63-17.0 and 18.0, apply clean engine oil to the piston, rings and the inside surface of the piston ring compressor J 24227.

**CAUTION**

Inspect The Ring Compressor For Nicks Or Burrs, Especially At The Non-Tapered Inside Diameter End. Nicks Or Burrs On The Inside Diameter Of The Compressor Will Result In Damage To The Piston Rings.

(2) Place the piston ring compressor on a wood block, with the tapered end of the ring compressor facing up.

(3) Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of the oil control ring expanders are not overlapped.

(4) Start the top of the piston straight into the ring compressor. Then push the piston down until it contacts the wood block (Operation 1 of Fig. 8).

(5) Note the position of the matchmark and place the liner, with the flange end down, on the wood block.

(6) Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner (Operation 2 of Fig. 8).

Note: The numbers on the side of the connecting rod and cap identify the rod with the cap and indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification numbers must be stamped in the same location as on the connecting rod that was replaced.

**(7)** Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.

**CAUTION**

Do Not Force The Piston Into The Liner. The Peripheral Abutment Type Expanders Apply Considerable Force On The Oil Ring. Therefore, Extra Care Must Be Taken During The Loading Operation To Prevent Ring Breakage.

(8) Remove the connecting rod cap and the ring compressor. Then push the piston down until the compression rings pass the cylinder liner ports.

20.5 Install Cylinder Liner, Piston and Connecting Rod Assembly

After the piston and connecting rod assembly have been installed in the cylinder liner, install the entire assembly in the engine as follows:

(1) Make sure the seal ring grooves in the cylinder block bore are clean. Then in- stall a new seal ring in each groove.

(2) Apply hydrogenated vegetable type shortening or permanent antifreeze to the inner surface of each seal ring.

**CAUTION**

Do Not Use A Methoxy Propanol Base Antifreeze As It Will Damage The Seal Rings.

(3) **If** any of the pistons and liners are already in the engine, use hold-down

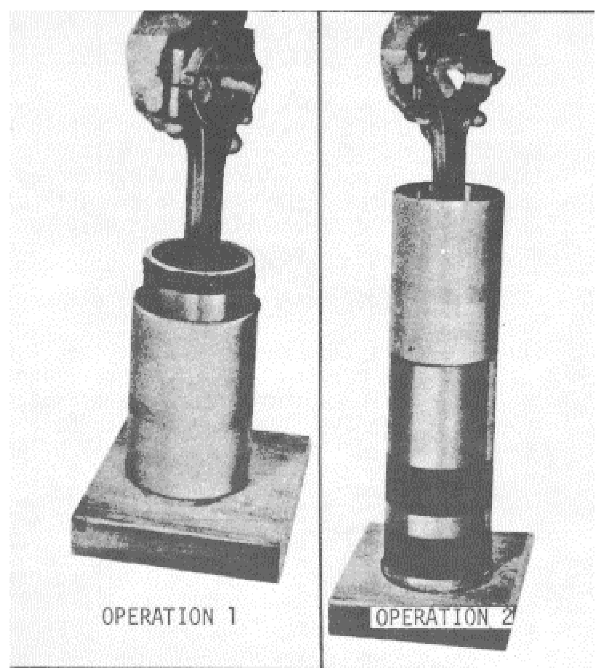



*Fig. 8 Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner*

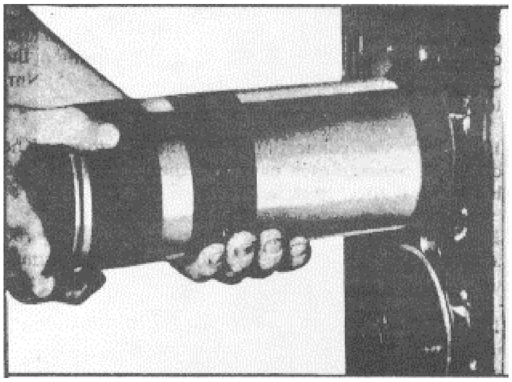


*Fig. 9 Installing Piston, Connecting Rod and Liner Assembly in Cylinder Block*

clamps to retain the liners in place when the crankshaft is rotated.

(4) Rotate the crankshaft until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel. Wipe the journal clean and lubricate it with clean engine oil.

(5) Install the upper bearing shell the one without the continuous oil groove in the connecting rod. Lubricate the bearing shell with clean engine oil.

(6) Position the piston, rod and liner assembly in front of the cylinder block bore so that the identification number and letter on the connecting rod face the outer edge of the cylinder block and the matchmarks on the liner and the block are in alignment. Guide the end of the connecting rod through the block bore carefully to avoid damaging or dislodging the bearing shell. Then slide the piston, rod and liner assembly straight into the block bore (Fig. 9) until the liner flange rests against the insert in the counterbore in the block.

(7) Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal. Note: Be sure the marks on the end of the connecting rod cap bolts are parallel with each other. This indicates proper alignment of the bolts in the connecting rod.

**CAUTION**

The Distance From The Vertical Center Line Of The Connecting Rod Bolts To The Edges Of The Rod Are Not Equal. Therefore, When Installing The Piston And Connecting Rod Assembly, Be Sure That The Narrow Side Of The Two Connecting Rods On The Crankshaft Journal Are Together To Avoid Cocking Of The Rod.

(8) Place the lower bearing shell the one with the continuous oil groove from one parting line to the other in the connecting rod cap. Lubricate the bearing shell with clean engine oil.

(9) Install the bearing cap and the bearing shell on the connecting rod with the identification numbers on the cap and the rod adjacent to each other. Tighten the connecting rod bolt nuts to 60-70 ft/lb. (81-95 N.m) torque.

(10) Check the connecting rod side clearance. The clearance between each pair of connecting rods should be .008" to .016" with new parts.

(11) Install the remaining liner, piston and rod assemblies in the same manner. Use hold-down clamps to hold each liner in place.

(12) After all of the liners and pistons have been installed, remove the hold-down clamps.

(13) Install new compression gaskets and water and oil seals as outlined in SM1-63-5.0. Then install the cylinder head and any other parts which were removed from the engine.

(14) After the engine has been completely reassembled, refer to the "Lubricating Oil Specifications" in the Operators Manual and refill the crankcase to the proper level on the dipstick.

(15) Close all of the drains and fill the cooling system.

(16) If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the run-in schedule given in SM1-63-67.O.

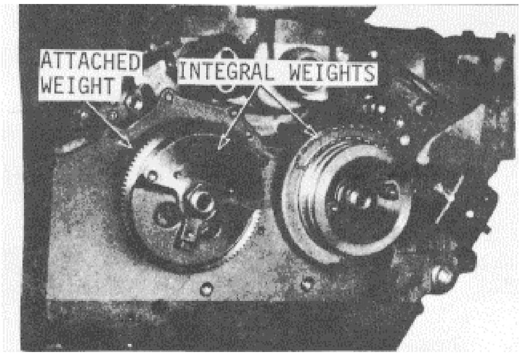



*Fig. 1 Typical Front Balance Weight Mounting*

In the balance of the two-cycle engine, it is important to consider disturbances due to the reciprocating action of the piston masses. These disturbances are of two kinds; unbalanced forces and unbalanced couples. These forces and couples are considered as primary or secondary according to whether their frequency is equal to engine speed or twice engine speed. Although it is possible to have unbalanced forces or couples at frequencies higher than the second order, they are of small consequence in comparison to the primary forces and couples. Even the secondary forces and couples are usually of little practical significance.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple due to their arrangement on the crankshaft. This unbalanced couple tends to move the ends of the engine in an elliptical path. This couple is cancelled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the camshafts. These camshaft balance weights are integral with the camshaft gears and the camshaft front pulley. An additional balance weight is bolted to the water pump drive gear. This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple.

On the camshafts, each set of weights (weights on the outer ends of one cylinder bank comprise a set) rotate in an opposite direction with respect to the other. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces of these balance weights oppose each other and are, therefore, cancelled. The front balance weights act in a direction opposite to the rear balance weights, therefore, rotation will result in a couple effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple which completely balances the primary couple.

Both the rotating and primary reciprocating forces and couples are completely balanced in the V-92 engine. There are no secondary forces present in the V-92 engine. Consequently, the engine will operate smoothly and in balance throughout its entire speed range.

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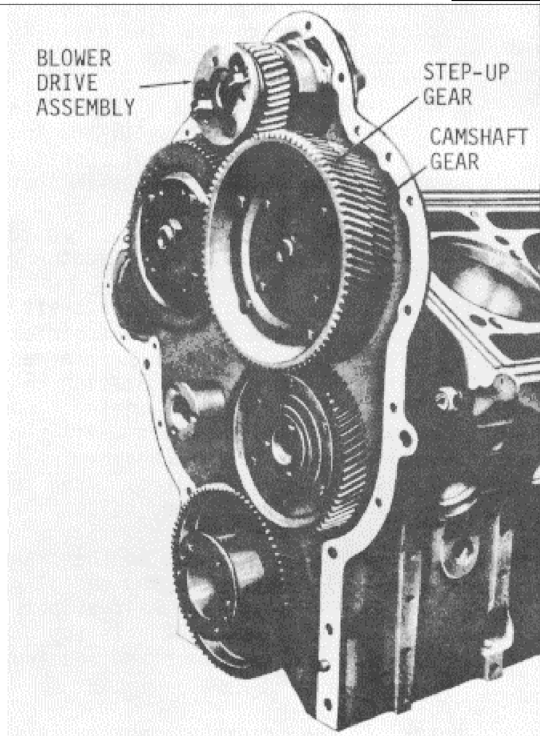


*Fig. 1 Gear Train*

22.1 Gear Train (6V Engines)

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the engine. The gear train consists of a crankshaft gear, an idler gear, two camshaft gears and a blower drive gear.

The crankshaft gear, bolted to the flange at the rear of the crankshaft, drives the camshaft gears as well as the blower drive gear through an idler gear mounted on a stationary hub.

The camshaft gears are pressed on and keyed to their respective shafts and each is secured by a nut and gear nut retainer.

The two camshaft gears mesh with each other and run at the same speed as the crankshaft gear. Since the camshaft gears must be in time with each other, and the two as a unit in time with the crankshaft gear, timing marks (Fig. 2) have been stamped on the face of the gears to facilitate correct gear train timing. The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, it is important to remember the engine rotation. Then, working from the crankshaft gear to the idler gear and to the cam- shaft gear in that order, line up the appropriate symbols on the gears as each gear assembly is installed on the engine.

Note: It is advisable to line up and make a sketch indicating the position of the timing marks before removing or replacing any of the gears in the gear train. There is no advance timing (A) on the V-92 engines.

There are no timing marks on the accessory drive gear or the blower drive gear. Therefore, it is not necessary to align these gears in any particular position during their installation.

However, as the blower drive gear and the accessory drive gear have only about half as many teeth as the camshaft gears, they turn at approximately twice the speed of the crankshaft.

The backlash between the various mating gears in the gear train should be .002" to .008", and should not exceed .010" backlash between worn gears.

ear train noise is usually an indication of excessive gear lash, shipped, pitted or burred gear teeth or excessive bearing wear. There- fore, when noise develops in a gear train, the flywheel housing should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash whereas a whining noise indicates too little gear lash.

22.2 Lubrication

The gear train is lubricated by the overflow of oil from the camshaft pockets spilling into the gear train compartment and by splash from the oil pan. A certain amount of oil also spills into the gear train compartment from both camshaft rear end bearings, the blower drive gear bearing and the idler gear bearing. The idler gear bearing is lubricated by oil directly from the cylinder block oil gallery to the idler gear bearing hub. The blower drive

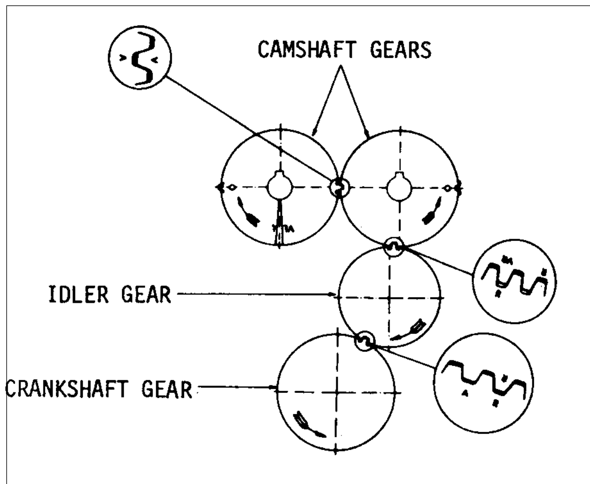


*Fig. 2 Gear Train And Timing Marks*

gear bearing is lubricated through an external pipe from the blower rear end plate to the blower drive support.

22.3 Engine Timing

The correct relationship between the crankshaft and the two camshafts must be maintained to properly control fuel injection, the opening and closing of the exhaust valves and engine balance.

The crankshaft timing gear can be mounted in only one position since one attaching bolt hole if offset. The two camshaft gears can also be mounted in only one position due to the location of the keyway in each camshaft relative to the cams. Therefore, when the engine is properly timed, the timing marks on the various gears will match as shown in Fig. 2.

An engine which is "out of time" may result in preignition, uneven running and a loss of power. When an engine is suspected of being out of time due to an improperly assembled gear train, a quick check can be made without having to remove the flywheel and flywheel housing by following the procedure outlined below.

22.4 Check Engine Timing

Access to the crankshaft pulley, to mark the top-dead center position of the selected piston and to the front end of the crankshaft or flywheel, for turning the crankshaft or flywheel, for turning the crankshaft, is necessary when performing the timing check. Then proceed as follows:

(1) Clean and remove one valve rocker cover. top-dead-center position of the selected piston, and to the front end of the crankshaft or fly- wheel, for turning the crankshaft, is necessary when performing the timing check. Then proceed

(2) Select any cylinder for the timing check it is suggested that a cylinder adjacent to one of the valve rocker cover bolt or stud holes be chosen since the stud or bolt may be used to mount a dial indicator.

(3) Remove the injector as outlined in SM1-63-32.0.

(4) Carefully slide a rod, approximately 12" long, through the injector tube until the end of the rod rests on top of the piston.

(5) Place the throttle in the no-fuel position. Then turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crank- shaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.

(6) Select a dial indicator with .001" graduations and a spindle movement of at least one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.

(7) Mount the indicator over the injector tube. The indicator mounting may be threaded into the rocker cover stud or the tapped hole in the cylinder head. Check to be sure the indicator spindle is free in the injector tube and is free to travel at least 1 inch.

(8) Attach a suitable pointer to the crank- shaft front cover. The outer end of the pointer should extend over the top of the crankshaft pulley.

(9) Turn the crankshaft slowly in the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

(10) Reset the dial to zero. Then turn the crankshaft until the indicator reading is .010".

(11) Scribe a line on the crankshaft pulley in line with the end of the pointer.

(12) Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

(13) Reset the dial to zero. Then turn the crankshaft until the indicator reading is .010".

(14) Scribe a second line on the crankshaft pulley in line with the end of the pointer.

(15) Scribe a third line halfway between the first two lines. This is top dead center. Remove the indicator and rod from the engine.

Note: If the crankshaft pulley retaining bolt has loosened, tighten it to the specified torque (SM1-63-13.0)

(16) Install the injector as outlined in SM1- 63-32.0. Then refer to SM1-63-68.0 and adjust the valve clearance and time the injector.

(17) Turn the crankshaft in the direction of engine rotation, until the exhaust valves in the cylinder selected are completely open. Reinstall the dial indicator so the indicator spindle rests of top of the injector follower. Then set the indicator on zero. Next, turn the crankshaft slowly in the direction of engine rotation, until the center mark on the pulley is in line with the pointer.

(18) Note the indicator reading and compare it with the dimensions listed in Table 1.

(19) After completing the timing check, remove the dial indicator. Also remove the pointer from the crankshaft front cover.

(20 Install the valve rocker cover.

*Table 1*

| Camshaft + Identification | Indicator Reading * | | |
|---|---|---|---|
| | Correct | Retarded 1-Tooth | Advanced 1-Tooth |
| 3J41 | .139 | .106 | .172 |

+ Camshaft Identification stamped on rear end of camshaft.
* Indicator Readings shown are nominal values. The allowable tolerance is * .005".

Table 1

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The contrarotating camshafts are located just below the top of the cylinder block. A left cylinder bank and a right cylinder bank camshaft is provided to actuate the exhaust valve and injector operating mechanism.

Both ends of each camshaft are supported by a bearing assembly which consists of a flanged housing and two bushings. In addition, intermediate two-piece bearings support the camshafts at uniform intervals throughout their length. The intermediate bearings are secured to the camshaft by lock rings, thus permitting them to be inserted in the cylinder block with the shafts. Each intermediate bearing is secured in place, after the camshafts are installed, with a lock screw threaded into a counterbored hole in the top of the cylinder block.

The camshaft gear thrust load is absorbed by two thrust washers, one on each end of the rear camshaft end bearing, on each shaft.
A camshaft front pulley (integral weight) is attached to the front end of the left bank camshaft and a water pump drive gear (bolt-on weight) is attached to the front end of the right bank camshaft. A camshaft gear is attached to the rear end of each camshaft. The pulley and the gears are retained on the camshafts with a retaining nut or a lock bolt and washer.

23.1 Lubrication

Lubricating oil is supplied under pressure to the bearings via drilled passages in the rear of the cylinder block, which lead from the main oil gallery to each rear end bearing. From the rear end bearings, the oil passes through the drilled oil passages in the camshafts to the intermediate bearings and to the front end bearings.

The lower halves of the camshaft intermediate bearings are grooved along the horizontal surface that mates with the upper halves of the bearings (Fig. 2). Oil from the passage in the camshaft is forced through the milled slots in the bearing and then out the grooves to furbish additional oil to the cam follower rollers. This permits the cam pocket to be filled rapid- ly to the operating oil level immediately after starting the engine.

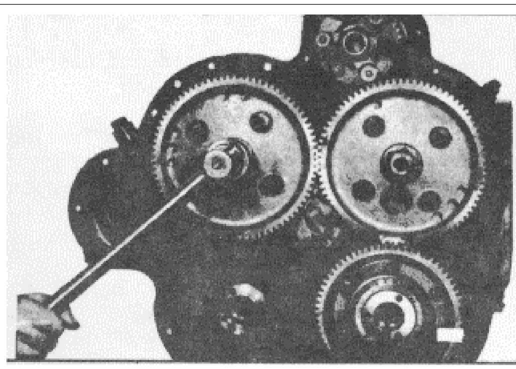

*Fig. 1 Loosening Camshaft Gear Retaining Nut*

23.2 Remove Camshafts

Whenever an engine is to be completely re- conditioned or the bearings, thrust washers, or gears need replacing, remove the camshafts from the engine as follows:

(1) Drain the engine cooling system.

(2) Remove all of the accessories and assemblies necessary so the engine may be mounted on an overhaul stand (see SM1-63-2.0).

(3) Mount the engine on the overhaul stand. Be sure the engine is securely mounted on the overhaul stand before releasing the lifting sling.
(4) Remove the cylinder heads as outlined in SM1-63-5.0.
(5) Remove the flywheel and flywheel housing as outlined in SM1-63-14.0.
(6) Remove the water pump.
(7) Remove the front balance weight cover.
(8) Remove the bolts and step-up gear, if used, from the rear right bank camshaft gear (Fig. 1, SM1-63-22.0).
(9) Remove the bolts which secure the nut retaining plates to the camshaft gears. Then remove the nut retaining plates.
(10) Wedge a clean rag between the gears (Fig. 1) and remove the gear retaining nut from both ends of each camshaft.
(11) Attach puller J 24420 to the camshaft pulley. Use adaptor J 7932 between the end of the camshaft and the pulley screw to protect the end of the camshaft (Fig. 3).
(12) Remove the water pump drive gear from the front end of the right bank camshaft, using puller J 24420 and adapter J 7932.
(13) Remove the Woodruff key and the spacer from the front end of each camshaft.
(14) Remove all of the camshaft intermediate bearing lock screws from the top of the cylinder block.
(15) Rotate the camshaft gears as required to reveal the camshaft end bearing retaining bolts. Then remove the bolts as shown in Fig. 4.
(16) Withdraw each camshaft, bearing and gear assembly from the cylinder block as shown in Fig. 5.
(17) Remove the camshaft front end bearings retaining bolts. Then withdraw the bearings.

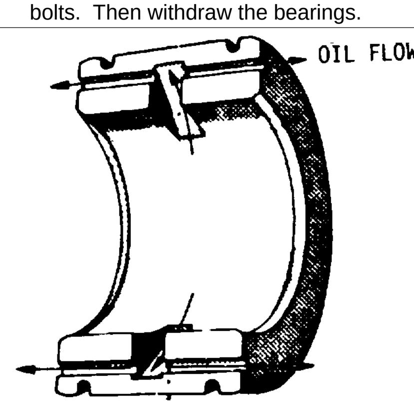


*Fig. 2 Camshaft Intermediate Bearing (Lower Half)*

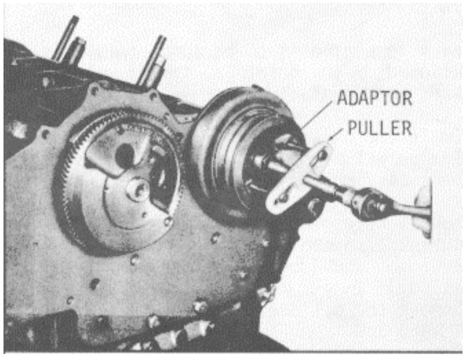


*Fig 3. Removing Camshaft Pulley*

from the cylinder block. If necessary, use a prybar under the bearing flange.

23.3 Remove Camshaft (Flywheel Housing and Transmission in Place)

The camshaft may be removed and replaced without removing the flywheel housing and disconnecting the transmission if there is space enough to slide the shaft out through the front of the engine and attach the camshaft gear puller tool J 1902-01 to the flywheel housing.

(1) Drain the engine cooling system and remove the radiator or heat exchanger and all attaching parts.
(2) Remove the parts, accessories and assemblies that are necessary to facilitate the removal of the flywheel housing hole cover over the camshaft and the front balance weight cover.
(3) Remove the cylinder head (SM1-63-5.0).
(4) Remove the front balance weight cover.
(5) Remove the camshaft gear nut retaining plate.
(6) Block the crankshaft, between the crankshaft throw and the cylinder block, and remove the gear retaining nut or lock bolt and washer from both ends of the camshaft.
(7) If a left bank camshaft is to be removed, attach puller J 24420 to the camshaft pulley. Use adapter J 7932 between the end of the camshaft and the pulley screw to protect the end of the camshaft (see Fig. 3).

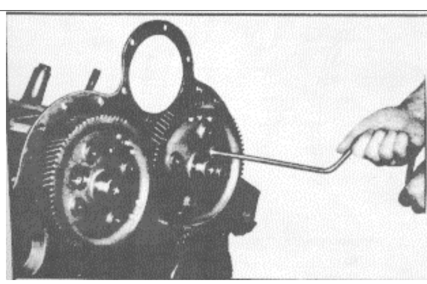

*Fig. 4 Removing or Installing Camshaft End Bearing Retaining Bolts*

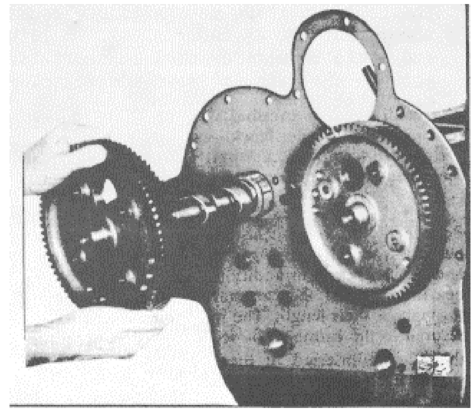

*Fig. 5 Removing or Installing Camshaft Assembly*

(8) Remove the water pump drive gear and spacer from the front end of the camshaft, using puller J 24420 and adapter J 7932.
(9) Remove the Woodruff key and the spacer from the front end of the camshaft.
(10) Remove all of the camshaft intermediate bearing lock screws from the top of the cylinder block.
(11) Remove the three bolts that secure the camshaft bearing to the front end plate.
(12) Install the camshaft gear puller J 1902-01, four spacers J 6202-2 and camshaft gear puller adapter plate J 6202-1 on the cam- shaft gear (Fig. 6 and Fig. 7).
(13) Turn the center screw of the puller clockwise to disengage the camshaft gear. Note: Do not remove the puller or the adapter plate until the camshaft is reinstalled. The adapter plate, secured to both the flywheel housing and the camshaft gear, will hold the gear, also the thrust washers securely in place anTin alignment which will aid in the re- installation of the camshaft.
(14) Remove the front bearing from the camshaft. Then pull the camshaft and intermediate bearings from the cylinder block.

23.4 Disassemble Camshafts

(1) Remove the gear from each camshaft (refer to SMl-63-24.0).
(2) Slide the camshaft rear end bearing and thrust washers off of each camshaft.
(3) Remove the lock rings from the camshaft intermediate bearings, thus freeing the two halves of each bearing.
(4) Remove the end plugs from each camshaft, to facilitate the removal of any foreign material lodged behind the plugs, as follows:
   (a) Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shaft.
   (b) Make an indentation in the center of

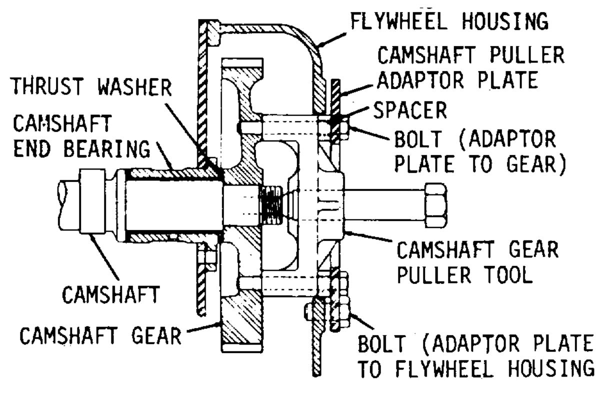


*Fig. 6 Removing Camshaft with Camshaft Gear Puller J 1902-01 and Adapter Plate Set J 6202*

drill (carboloy tip).

(c) Punch a hole as deeply as possible with a center punch, to aid in breaking through the hardened surface of the plug.

(d) Then drill a hole straight through the center of the plug with a 1/4" drill (carboloy tip).

(e) Use the 1/4" drilled hole as a guide and re-drill the plug with a 5/16" drill (carboloy tip).

(f) Tap the drilled hole with a 3/8"-16 tap.

(g) Thread a 3/8"-16 adapter J 6471-2 into the plug. Then attach a slide hammer J 2619-5 to the adapter and remove the plug by striking the weight against the handle.

(h) Insert a length of 3/8" steel rod in the camshaft oil gallery and drive the remaining plug out.

Note: <u>If a steel rod is not available, remove the remaining plug as outlined in steps (a) through (g).</u>

23.5 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Soak the camshaft in clean fuel oil. Then run a wire brush through the oil gallery to remove any foreign material or sludge. Clean the exterior of the camshaft and blow out the oil gallery and the oil holes with compressed air. Clean the camshaft bearings and related parts with fuel oil. and dry them with compressed air. Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam followers as outlined in SM1-63-6.0. Also inspect the camshaft keyways and threads for damage.

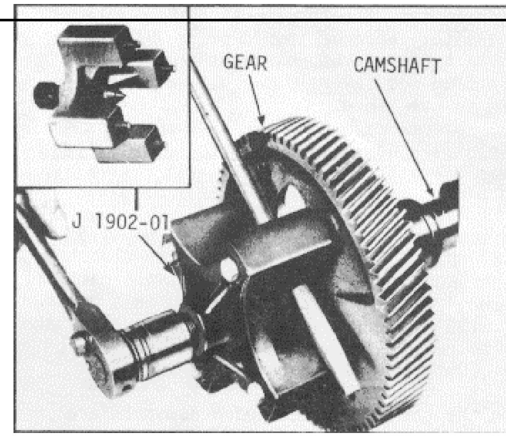


*Fig. 7*
*Removing Gear (Camshaft Gear Puller J 1902-01)*

If there is a doubt as to the acceptability of the camshaft for further service, determine the extent of cam lobe wear as follows.

Note: <u>The camshaft can be in or out of the engine during this inspection.</u>

(1) With a tapered leaf set of feeler gages (.0015" - .010") and a piece of square hard material (1/8" x 3/8" x 1"), measure the flat on the injector rise side of the cam lobes (Fig. 8)

(2) If the flats measure less than .003" in depth and there are no other defects, the camshaft is satisfactory for service.

(3) A slightly worn cam lobe, still within acceptable limits, may be stoned and smoothed over with a fine crocus cloth.

Check the runout at the center bearing with the camshaft mounted in the end bearing surfaces. Runout should not exceed .002".

Examine both faces of each camshaft rear end bearing and thrust washer. Also examine the

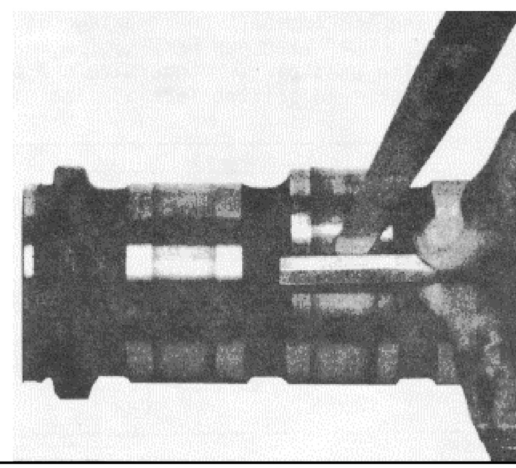

*Fig. 8 Checking Cam Lobe Wear*

surfaces of each camshaft and camshaft gear which contact the thrust washers. Replace excessively worn or scored parts. Camshaft or camshaft gear thrust surfaces that are not scratched too severely may be smoothed down with an oil stone.

Note: If a new camshaft is to be installed, steam clean it to remove the rust preventive and blow out oil passages with compressed air.

New standard size thrust washers are .119" to .122" thick. The clearance between the thrust washer and the thrust shoulder of the camshaft is .004" to .012" with new parts, or a maximum of .018" with used parts. Excessive clearance may be reduced by using thrust washers which are .005" or .010" oversize.

When the thrust surfaces of a camshaft are ground undersize, a radius of 1/32" to 3/32" must be maintained between the bearing surface of the thrust collar shoulder and the bearing surface of the camshaft (Fig. 9). A fillet radius gage may be used to measure the specified radii.

Inspect the bushings in the front and rear cam- shaft end bearings. Replace the bushings if they are worn excessively (maximum of .006" bushing to shaft clearance) or if the bushings have turned in the bearing. Rear camshaft end bearings are available in .010" or .020" under-size for use with shafts which have worn or been reground and the clearances exceed the specified limits.

New bushings must be finish bored to a 20 rms finish after installation and checked for the proper press fit, which is indicated if the bushings will not move when a 2000 pound (13.5 kN) end load is applied. Also, the inside diameter of the bushings must be square with the rear face of the bearing within .0015" total indicator reading. The bushings must project .045" to .055" from each end of the rear camshaft end bearings. The bushings in the front camshaft end bearings must be flush with the ends of the bushing bore.

The clearance between the camshaft end journals and the camshaft end bearing bushings is .0025" to .004" with new parts, or a maximum of .006" with used parts. Undersize and oversize cam- shaft end bearings are available for service.

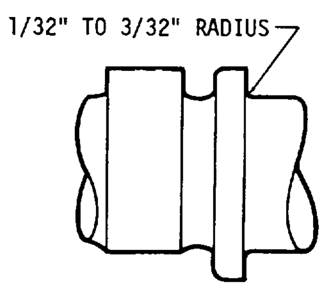


*Fig. 9 Camshaft Journal Fillet*

Inspect the oil seal in the left bank camshaft front end bearing for wear or damage. Replace the seal if necessary. Also examine the spacer used at the front end of each camshaft. The outside diameter of the spacer used in the left bank front end bearing must provide a smooth oil seal contact surface. The outside diameter is not ground and polished on the original spacer used on the right bank camshaft. Only the polished spacer is available for service and may be used in either position.

Replace excessively scored or worn camshaft intermediate bearings. The clearance between the camshaft journals and the intermediate bearings is .0025" to .005" with new parts, or a maximum of .009" with worn parts. Under- size and oversize camshaft intermediate bearings are available for service. Also examine the intermediate bearing lock screws and the tapped holes in the cylinder block for damaged threads.

Examine the teeth on the water pump drive gear and the camshaft gears for scoring, pitting or wear. Replace the gears if necessary. Also examine the keyways and tapped holes in the gears and the camshaft pulley for damage.

Inspect the rubber bushed torsion vibration damper, if used, for deterioration of rubber, slippage of the outer ring and alignment of the hub face to the rubber and outer ring.

23.6 Assemble Camshafts

Refer to Fig. 10 and assemble the camshafts.

(1) Install new end plugs in each camshaft.
(2) Apply grease to the steel face of each thrust washer against each end of the two camshaft rear end bearings. Be sure the steel face of each thrust washer is next to the bearing.
(3) Lubricate the rear camshaft bearing journal and slide a rear end bearing on each cam- shaft, with the bolting flange of the bearing toward the outer (camshaft gear) end of the shaft.
(4) Install the camshaft gear on each shaft as outlined in SM1-63-24.0.
(5) Lubricate the camshaft intermediate bearing journals. Then place the two halves of each intermediate bearing on a camshaft journal and lock the halves together with two lock rings. Assemble each lock ring with the gap over the upper bearing, and the ends an equal distance above the split line of the bearing.

3.7 Install Camshafts

(1) Insert the front end of the camshaft with the right-hand helix gear through the opening on the right bank side in the rear end plate until the first intermediate bearing enters the bore. Continue to work the camshaft and bearings into the cylinder block until the camshaft gear teeth are about to engage the teeth of the mating gear (refer to Fig. 5). Use care not to

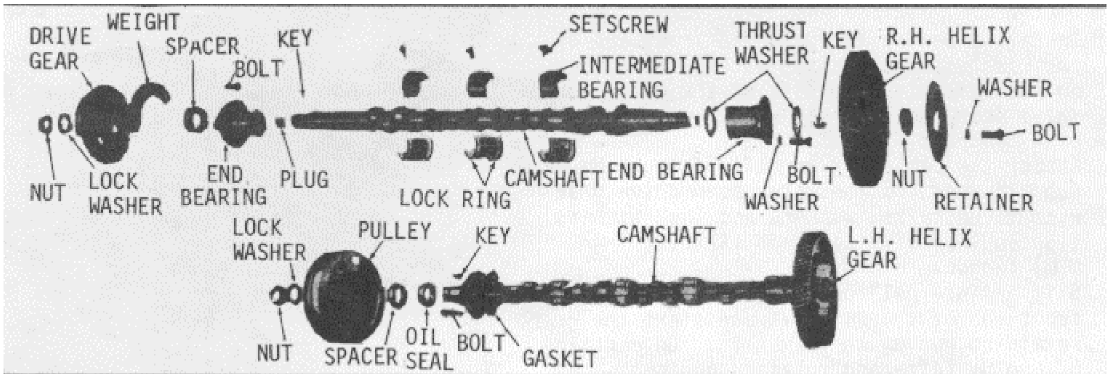


*Fig. 10*
*Camshaft Details and Relative Location of Parts*

damage the cam lobes when installing the camshaft.

(2) Align the timing marks on the mating gears as shown in Fig. 2 of SM1-63-22.0 and slide the camshaft gear in place.

(3) Secure the camshaft rear end bearing to the cylinder block with three lock washers and bolts. Rotate the camshaft gear as required to install the bolts through the hole in the web of the gear (Fig. 4). Tighten the bolts to 35-40 ft/lb. (47-54 Nm) torque.

(4) Turn the camshaft intermediate bearings until the holes in the bearings are in alignment with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15-20 ft/lb. (20-27 N-m) torque.

(5) Install the other camshaft in the same manner.

(6) Attach a new gasket to the camshaft front end bearing that includes the oil seal. Lubricate the bearing journal and slide the bearing on the left bank camshaft, with the bolting flange of the bearing toward the outer end of the shaft. Secure the bearing to the cylinder block with three bolts and lock washers. Tighten the bolts to 35-40 ft/lb. (47-54 N.m) torque.

(7) Install the right bank camshaft front end bearing -- the one without the oil seal. Secure the bearing to the cylinder block with three bolts and lock washers and tighten the bolts to 35-40 ft/lb. (47-54 N.m) torque.

(8) Select the spacer with the polished outside diameter. Lubricate the spacer and slide it in place on the left bank camshaft.

(9) Install the other spacer on the right bank camshaft.

(10) Install a Woodruff key in each camshaft.

(11) Install the pulley on the front end of the left bank camshaft and the water pump drive gear and external weight on the right bank camshaft.

(12) Attach the rubber bushed camshaft vibration damper and hub to water pump drive gear with three bolts, plain washers and lockwasher, if used. Tighten bolts to 30-35 ft/lb. (41-47 N.m) torque.

(13) Slip an internal tooth lock washer over the front end of each camshaft. Then start the gear and pulley retaining nuts on the camshafts

(14) Wedge a clean rag between the camshaft shafts to 300-325 ft/lb (407-441 N.m) torque.

(15) Install the camshaft gear nut retainers with bolts and lock washers. Tighten the bolts to 35-39 ft/lb. (47-53 N.m) torque.

(16) Check the clearance between the thrust washer and the thrust shoulder of each camshaft. The specified clearance is .004" to .012" with new parts, or a maximum of .018" with used parts.

(17) Check the backlash between the mating gears. The specified backlash between new gears is .002" to .008", or a maximum of .010" between worn gears.

(18) Install the parts, accessories or assemblies that were removed from the engine as outlined in their respective SMs in this manual.

23.8 Install Camshaft (Flywheel Housing and Transmission in Place)

(1) Install a Woodruff Key in the drive gear end of the camshaft and insert this end into position from the front end of the engine. Push the camshaft in until it slides into the rear end bearing. Use care not to damage the cam lobes when installing the camshaft.

(2) Align the key in the shaft with the keyway in the drive gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.

(3) Remove the camshaft gear puller, spacers, and adaptor plate. Finger tighten the gear retaining nut on the shaft.

(4) Attach a new gasket to the front end bearing that includes an oil seal and install the front end bearing (and spacer or spacer and oil seal) with the bolts and lock washers. Tighten the bolts to 35-40 ft/lb. (47-54 N.m) torque.

Note: Lubricate the spacer with the polished outside diameter and slide it in place on the left bank camshaft.

(5) Install a Woodruff key in the front end of the camshaft and install either the pulley on the left bank camshaft or the water pump drive gear and external weight on the right bank camshaft.
(6) Attach the camshaft vibration damper and hub, if used, to the water pump drive gear with three bolts, washers and lock washers. Tighten the bolts to 30-35 ft/lb. (41-47 N.m) torque.
(7) Slip an internal tooth lock washer over the front end of the camshaft and start the gear retaining nut on the camshaft. On certain 6V and 8V left-hand rotation engines, install a 9/16"-18 lock bolt and washer in the right bank camshaft.
(8) Block the crankshaft, between the crankshaft throw and the cylinder block, to prevent rotation of the engine. Tighten the retaining nuts at both ends of the camshaft to 300-325 ft/lb. (407-441 N.m) torque. Tighten the lock bolt to 180-190 ft/lb. (244-258 N.m) torque.
(9) Revolve the camshaft intermediate bearings to align the locking holes in the bearing with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15-20 ft/lb. (20-27 N.m) torque.
(10) Install the camshaft gear nut retainers with bolts and lock washers. Tighten the bolts to 35-39 ft/lb. (47-53 N.m) torque (retainers not used with lock bolts).
(11) Reinstall the parts, accessories and assemblies that were removed from the engine as outlined in their respective SMs in this manual. Refill the cooling system.

## SM1-63-24.0 Camshaft Gears



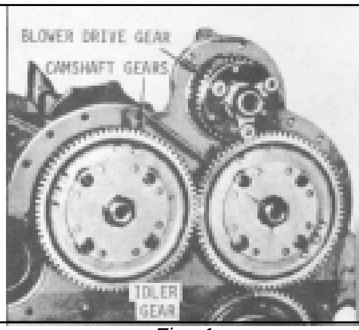


*Fig. 1*
*Camshaft Gears Mounted on Engine*

The camshaft gears (Fig. 1), located at the flywheel end of the engine, mesh with each other and run at the same speed as the crankshaft. Either one of the gears may be driven by the crankshaft timing gear through an idler gear, depending upon engine rotation. Viewing the engine from the gear train end, the right-hand camshaft gear has right-hand helical teeth. The idler gear mates with the right-hand camshaft gear as shown in Fig. 2 and Fig. 3 in SMI-63-22. O.

Since the two camshaft gears must be in time with each other, timing marks are stamped on the rim of both gears. Also, since these two gears as a unit must be in time with the crankshaft, timing marks are located on the idler gear and the crankshaft gear.

24.1 Remove Camshaft Gears

(1) Remove the camshafts from the engine as outlined in SM1-63-23.O.

(2) Place one of the camshaft and gear assem-

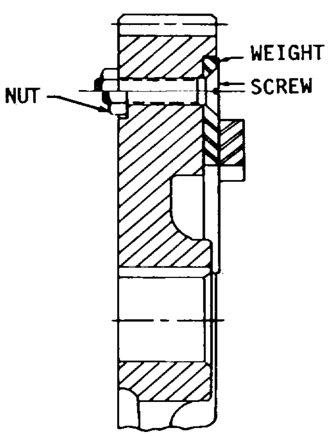


*Fig. 2*
*Camshaft Gear Weight*

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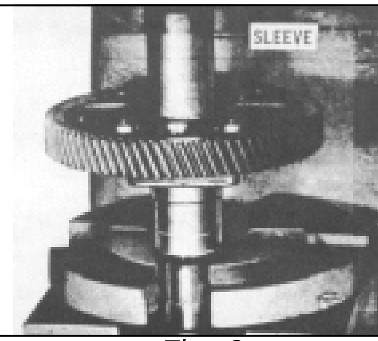


*Fig. 3*
*Removing Camshaft Gear*

blies in an arbor press as shown in Fig. 3.

(3) Place a wooden block under the lower end of the camshaft to protect the threads when the shaft is pressed from the gear.

(4) Place a short one-inch diameter brass rod on the end of the camshaft and press the shaft out of the gear.

(5) If necessary, remove the Woodruff key from the camshaft.

(6) Remove the gear from the other camshaft in a similar manner.

24.2 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Clean the gears with fuel oil and dry them with compressed air. Then examine the gear teeth for scoring, pitting or wear. Replace the gears if necessary. Also check the other gears in the gear train.

24.3 Install Camshaft Gears

(1) If previously removed, install the camshaft rear end bearing and thrust washers on the camshaft as follows:

  (a) Apply grease to the steel face of each thrust washer and place one washer at each end of the bearing. Be sure the steel face of each washer is next to the bearing.

  (b) Lubricate the bearing journal and slide the bearing and thrust washers on the camshaft, with the bolting flange of the bearing toward the outer (gear) end of the shaft.

(2) Install a Woodruff key in the camshaft.

(3) Start the gear over the end of the camshaft, with the key in the shaft aligned with the keyway in the gear.

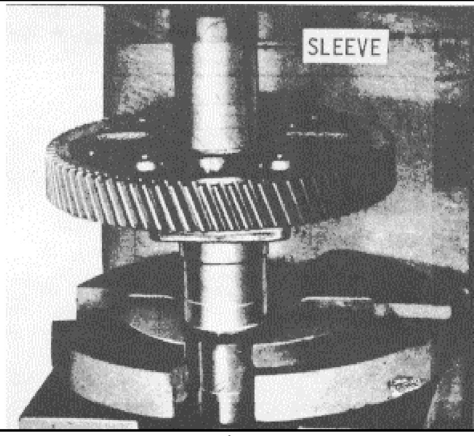


*Fig. 4*
*Installing Camshaft Gear*

(4) Then, with the camshaft supported in an arbor press, place a sleeve on top of the gear and press the gear tight against the shoulder on the shaft (Fig. 4).

Note: If an arbor press is not available, use tool J 1903 to install the gear on the camshaft.

(5) Thread the camshaft gear retaining nut on the camshaft. Tighten the nut after the camshaft is installed in the engine.

(6) Install the gear on the other camshaft in a similar manner.

(7) Install the camshaft and gear assemblies in the engine as outlined in SM1-63-23.0.

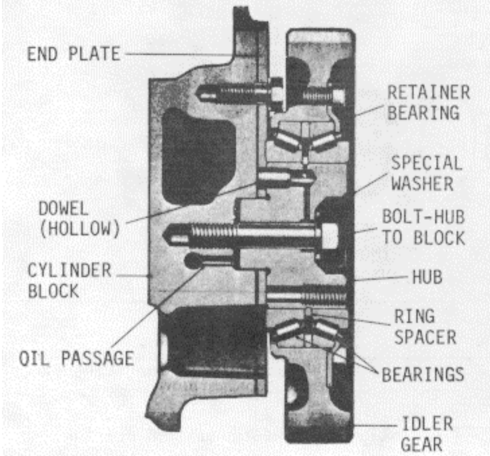


*Fig. 1*
*Idler Gear Mounting*

The idler gear (Fig. 1) is mounted on a double-row, tapered roller bearing, which in turn is supported on a stationary hub. This hub is secured directly to the cylinder block by a bolt which passes through the hub and rear end plate. A dowel in the hub correctly positions the hub and prevents it from rotating.

The idler gear is pressure lubricated by oil from the cylinder block rear cross oil gallery. Oil enters an opening between the cylinder block and the idler gear hub and circulates around the idler gear hub bolt which has a smaller outside diameter than the inside diameter of the gear hub bolt hole. The oil is forced through a drilled passage in the gear hub to the roller bearing.

The idler gear bearing consists of two cups, two cones and an outer and an inner spacer ring.

The cones of the idler gear bearing are pressed onto the gear hub and, therefore, do not rotate. Spacer rings separate the bearing cups and cones. The bearing cups are a light press fit in the idler gear and are held against a flanged lip inside the idler gear on one side and by a bearing retainer secured with six lock bolts on the other side.

A left-hand helix gear is provided for right-hand rotation engines.

An idler gear hole spacer (dummy hub) is used on the side opposite the idler gear (Fig. 8).
Note: On this engine, the idler gear hole spacer is cast integral in the flywheel housing, on the side opposite the idler gear.

25.1 Remove Idler Gear, Hub and Bearing Assembly (Flywheel Housing Previously Removed)

(1) Remove the idler gear hub to cylinder block bolt and special washer and withdraw the assembly from cylinder block rear end plate trig(Fig. 1)

Note: Before removing the idler gear, check the idler gear, hub and bearing assembly for any perceptible wobble or shake when pressure Ts applied by firmly grasping the rim of the gear with both hands and rocking the gear in relation to the bearing. The bearing must be replaced if the gear wobbles or shakes. If the gear assembly is satisfactory, it is only necessary to check the pre-load before reinstallation.

(2) If necessary, remove the idler gear hole spacer (dummy hub) in the same manner.

25.2 Disassemble Idler Gear, Hub and Bearing Assembly While removing or installing an idler gear bearing, the bearing MUST be rotated to avoid the possibility of damaging the bearing by brinelling the bearing cones. Brinelling refers to the marking of the cones by applying a heavy load through the rollers of a non-rotating bearing in such a way that the rollers leave impressions on the contact surfaces of the cones. These impressions may not be easily discerned during normal inspection. For example, a bearing any be brinelled if a load were applied to the inner cone of the bearing assembly in order to force the outer cone into the idler gear bore, thus transmitting the force through the bearing rollers. A brinelled bearing may have a very short life.

Refer to Fig. 3 for the location and identification of parts and disassemble the bearing as follows:

(1) Remove the six bolts which secure the bearing retainer to the idler gear and remove the bearing retainer.

Note: The component parts of the idler gear bearing are matched; therefore, matchmark the parts during disassembly to ensure reassembly of the parts in their original positions.

**WARNING**

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(2) Clean the idler gear assembly with fuel oil and dry it with compressed air.

(3) Place the idler gear assembly in an arbor press, with the inner bearing cone supported on steel blocks as shown in Fig. 2. While rotating the idler gear assembly, press the hub out of the bearing. Remove the gear assembly from the arbor press and remove the bearing cones and spacer rings. Tap the bearing cups from the idler gear by using a brass drift alternately at the four notches provided around the shoulder of the gear.

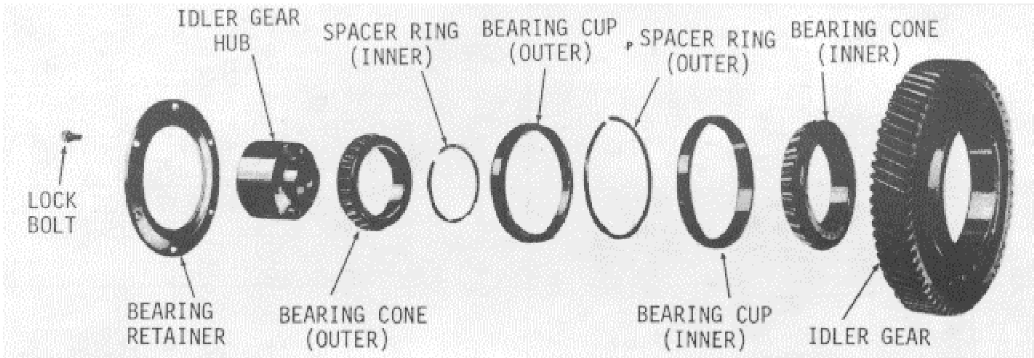


*Fig. 3*
*Idler Gear Details and Relative Location of Parts*

Note: Unless it is determined that the bearing assembly is to be replaced, the inner and outer bearing cups should not be removed from the idler gear. If the cups are loose in the gear bore, the bearing assembly and gear (if the bore is worn) should be replaced.

25.3 Inspection

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Wash the idler gear, hub and bearing components thoroughly in clean fuel oil and dry them with compressed air.

Check the idler gear hub to ensure that no chips or foreign material is deposited in the holes so as to cause interference with the flywheel housing attaching bolts.

Inspect the bearing carefully for wear, pitting, scoring or flat spots on the rollers or cones. Replace the bearing if it is defective.

Examine the gear teeth for evidence of scoring, pitting and wear. If severely damaged or worn, replace the gear. Also inspect the other gears in the gear train.

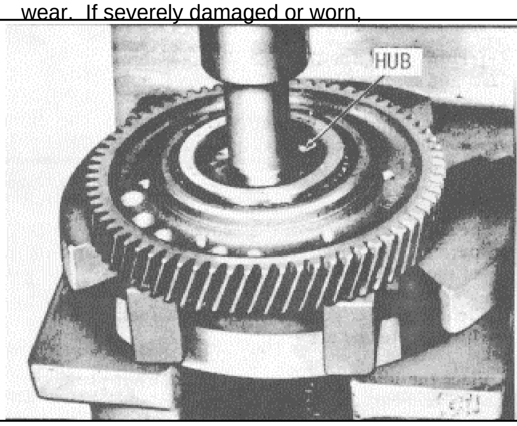


*Fig. 2*
*Pressing Hub Out Of Idler Gear Bearing*

25.4 Assembly Idler Gear, Hub and Bearing

Refer to Fig. 3 and assemble the bearing components in their original positions (refer to identification marks made during disassembly) as outlined below:

Note: The idler gear bearing is a matched assembly. Do not mix the components with another bearing assembly.

(1) Support the idler gear, shoulder down, on the bed of an arbor press. Start one of the bearing cups, numbered side up, squarely into the bore of the gear. Then press the bearing cup against the shoulder of the gear. Use a flat steel plate (pre-load test plate) between the ram of the press and the bearing cup.

(2) Lay the outer spacer ring on the face of the bearing cup.

(3) Start the other bearing cup, numbered side down, squarely into the bore of the gear. Then press the cup tight against the spacer ring. Use a flat steel plate (pre-load test plate) between the ram of the press and the bearing cup.

(4) Press the inner bearing cone (numbered side up) on the idler gear hub, flush with the inner hub mounting face. Use the pre-load test plate (with the large center hole) between the ram of the press and the bearing.

(5) Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 180° from the gap in the inner spacer ring.

(6) Position the gear with both cups over the hub and the inner bearing cone.

(7) Press the outer idler gear bearing cone over the hub while rotating the gear to seat the rollers properly between the cones. The bearing cones must be supported so as not to load the bearing rollers during this operation (Fig. 4).

(8) Before installing the gear and bearing assembly, check the pre-load.

25.6 Check Idler Gear Bearing Pre-Load

The rollers in the bearing are loaded between

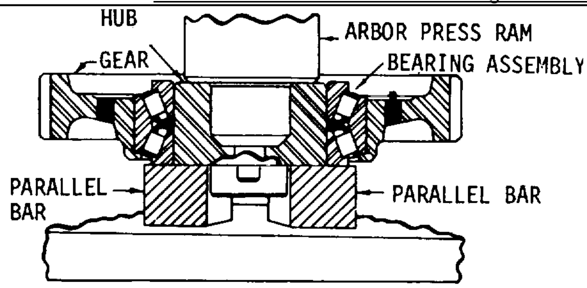


*Fig. 4*
*Pressing Hub into Idler Gear Bearing*

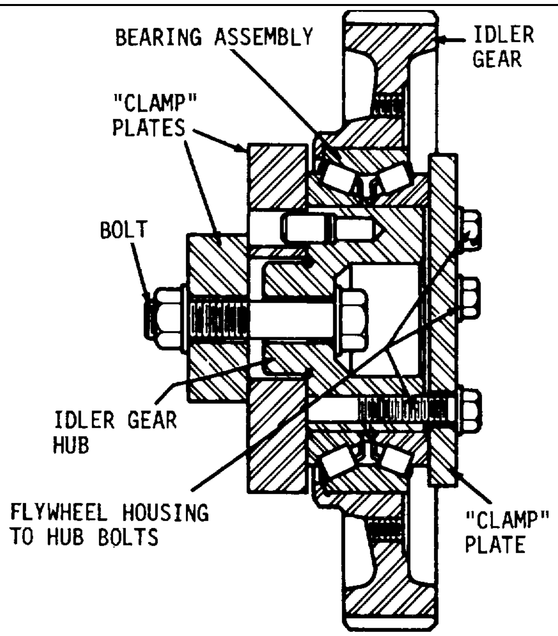


*Fig. 5*
*Fixture for Testing Bearing Pre-Load*

the bearing cup and the bearing cones in accordance with design requirements to provide a rigid idler gear and bearing assembly. As the bearing cones are moved toward each other in a tapered roller bearing assembly, the rollers will be more tightly held between the cones and the cup. A slight pre-load is applied by means of a selected spacer ring between the bearing cones, to provide rigidity of the gear and bearing assembly when it is mounted on its hub. This method of pre-loading is measured, in terms of "pounds pull", by the effort required at the outer diameter of the gear to turn the bearing cup in relation to the bearing cones.

Any time an idler gear assembly has been removed from an engine for servicing or inspection, while performing engine overhaul or other repairs, the pre-load should be measured as part of the operation.

the idler gear bearing must be clean and lubricated with light engine oil prior to the pre-load test. Idler gear assemblies which include new bearings should be "worked in" by grasping the gear firmly by hand and rotating the gear back and forth several times.

After the idler gear, hub and bearing are assembled together, the bearing should be checked to ascertain that the gear may be rotated on its bearing without exceeding the maximum torque specifications, nor be so loose as to permit the gear to be moved in relation to the hub by tilting, wobbling or shaking the gear.

If the mating crankshaft and camshaft gears are not already mounted on the engine, the torque required to rotate the idler gear may be checked by mounting the idler gear in position on the engine, using a steel plate 4" square (pre-load test plate) against the hub and cone as outlined below.

(1) Mount the idler gear assembly on the engine.

(2) Install the center bolt and washer through the gear hub and thread it into the cylinder block. Tighten the bolt to 80-90 ft/lb. (108-122 N.m) torque.

(3) Place the steel plate (lower plate shown in Fig. 6) against the hub and bearing. Insert three 3/8"-16 bolts through the plate and thread them into the hub. Tighten the bolts to 25-40 ft/lb. (34-54 Nm) torque.

(4) Tie one end of a piece of lintless 1/8" cord around a 1/8" round piece of wood (or soft metal stock). Place the wood between two of the gear teeth and wrap the cord around the periphery of the gear several times. Attach the other end of the cord to a spring scale J 8129 (Fig. 7). Maintain a straight steady pull on the cord and scale, $^{90^\circ}$ to the axis of the hub, and note the pull, in pounds and ounces, required to start the gear rotating. Make several checks to obtain an average reading. If the pull is within 1/2 lb. minimum to 4 lbs. maximum, and does not fluctuate more than 2 lbs. 11 oz., the idler gear and bearing assembly is satisfactory for use.

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture, which may be held in a vise, can be made as shown in Fig. 5. Three plates (shown in Fig. 6), a 1/2"-13 x 2-3/4" bolt and a plain washer are used with a 1/2"-13 nut and plain washer for mounting. One of the plates is used to take the place of the flywheel housing, and the other two plates, the cylinder block. "Engine-mounted" conditions are simulated by tightening the nut to 80-90 ft/lb. (108-122 N.m) torque and tightening the three plate-to-hub attaching bolts to 25-40 ft/lb. (34-54 N-m) torque.

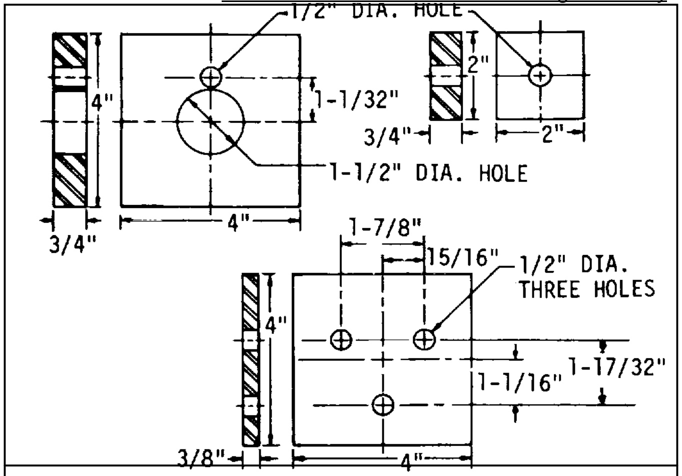


*Fig. 6*
*Plates for Bearing Test Failure*

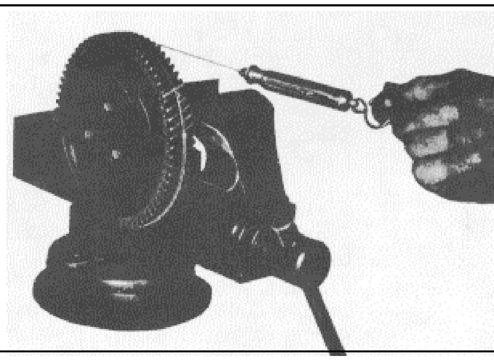

*Fig. 7*
*Checking Idler Gear Bearing Pre-Load*

Check the pre-load on the bearings as follows:

(1) Attach two of the plates (two upper plates shown in Fig. 6) to the idler gear hub with the 1/2"-13 bolt washers and nut as shown in Fig. 5. Tighten the bolt to 80-90 ft/lb. (108-122 N.m) torque.
(2) Attach the third plate to the idler gear hub with three 3/8"-16 bolts. Tighten the bolts to 25-40 ft/lb. (34-54 N.m) torque.
(3) Clamp the idler gear assembly and fixture in a vise (Fig. 7).
(4) Attach a cord to the idler gear and spring scale and check the bearing pre-load as outlined in step 4 of the previous method.

If the scale reading is within the 1/2 to 4 pounds specified, but fluctuates more than 2 pounds 11 ounces, the idler gear and bearing assembly must NOT be installed on the engine. Fluctuations in scale reading may be caused by the cones not being concentric to each other, damaged cones or rollers, or dirt or foreign material within the bearings. In these cases, the bearing should be inspected for the cause of fluctuation in the scale readings and corrected or a new bearing installed. A scale reading which exceeds the specified maximum indicates binding of the bearing rollers, or rollers improperly installed, When the scale reading is less than the specified minimum, the bearing is more likely worn and the bearing should be replaced.

After the pre-load check is completed, remove the steel plates and install the bearing reatiner.

Attach the bearing retainer to the idler gear with six 5/16"-24 x 1/2" lock bolts. Tighten the bolts to 24-29 ft/lb. (33-39 N-m) torque.

Note: The lock bolts are coated with a locking compound. Do not use standard bolts, With use of the lock bolts, the former bolt locks are no longer required and will not be serviced.

25.7 Install Idler Gear, Hub and Bearing Assembly

(1) Position the crankshaft gear and camshaft gear so the timing marks will align with those on the idler gear (refer to SM1-63-22.0).

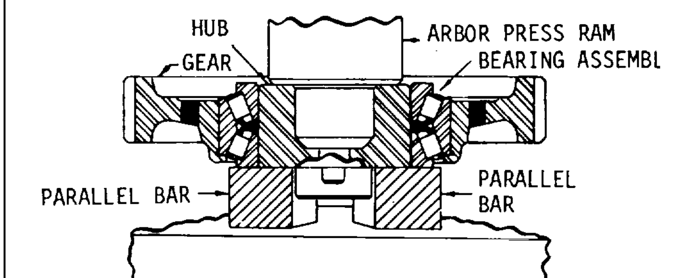


*Fig. 8*
*Installing Idler Gear, Hub and Bearing Assembly*

(2) With these marks in alignment, start the idler gear into mesh with the crankshaft gear and camshaft gear, and simultaneously rotate the gear hub so the dowel in the hub registers with the hole in the end plate.
(3) Roll the idler gear into position and align the hollow dowel with the oil hole in the end plate. Then gently tap the hub until it seats against the end plate.
(4) After making sure the hub is tight against the end plate, secure the idler gear assembly with the 1/2"-13 bolt and special washer. Tighten the bolt to 80-90 ft./lb. (108-122 N.m) torque.
(5) If previously removed, install the idler gear hole spacer (dummy hub) (Fig. 8). Secure the spacer to the cylinder block end plate and cylinder block with a 1/2"-13 bolt and special washer. Tighten the bolt to 80-90 ft/lb. (108-122 N-m) torque.
(6) Lubricate the idler gear bearing and gear teeth liberally with clean engine oil.
(7) Check the backlash between the mating gears. The backlash must be .002" to .008" between new gears and must not exceed .010" between worn gears.

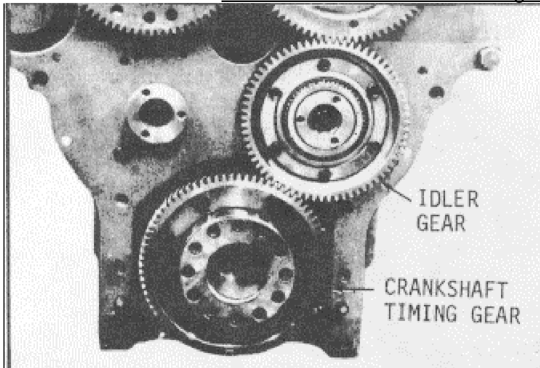


*Fig. 1*
*Crankshaft Timing Gear Mounting*

The crankshaft timing gear (Fig. 1) is bolted to the flange at the rear end of the crankshaft and drives the camshaft gears, as well as the blower drive gear, through an idler gear.

Since the two camshafts must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft gears (refer to SM1-63-22.0).

26.1 Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft gear is a press fit on the crank-shaft. Remove the gear as follows:

(1) Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.
(2) Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.
(3) Remove the six bolts which secure the gear to the crankshaft.
(4) Provide a base for the puller screw by placing a steel plate across the cavity in the end of the crankshaft. Then remove the gear with a gear puller.

26.2 Inspection

**WARNING**

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**WARNING**

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HC238A

Clean the gear with fuel oil and dry it with compressed air. Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also check the other gears in the gear train.

26.3 Install Crankshaft Timing Gear

(1) Position the gear on the rear end of the crankshaft with the bolt holes in the gear aligned with the tapped holes in the crankshaft. One bolt hole is offset so the gear can be attached in only one position.
(2) Align the proper timing mark on the crank-shaft gear with the corresponding mark on the idler gear (refer to SM1-63-22.0).
(3) Start the six 3/8"-24 bolts through the gear and into the crankshaft. Then draw the gear tight against the shoulder on the crankshaft. Tighten the bolts to 35-39 ft/lb. (47-53 N-m) torque.
(4) Check the backlash with the mating gear. The backlash should be .002" to .008" with new gears or .010" maximum with used gears.
(5) Install a new crankshaft rear oil seal sleeve, if required, as outlined in SM1-63- 10.0.

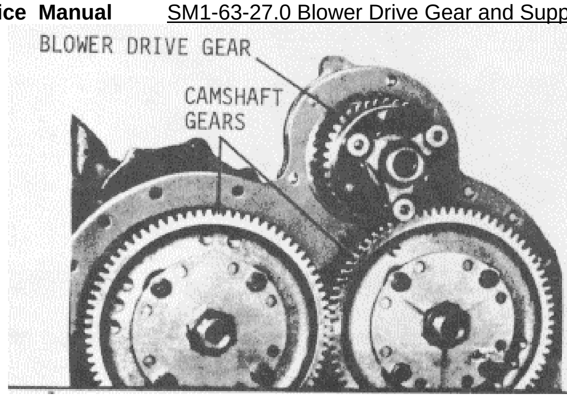



*Fig. 1*
*Blower Drive Gear Mounting (Turbocharged Engine)*

Since the camshaft gear runs at engine speed, the blower drive gear, which has about half as many teeth as the camshaft gear, runs approximately twice engine speed.

The blower to engine speed ratio for the turbo-charged engines is 2.05:1 (blower drive gear has 38 teeth).

The blower drive gear is mounted on a support which is attached to the cylinder block rear end plate. The blower drive gear bearings are pressure lubricated through an external line from the blower rear end plate to the blower drive support.

27.1 Remove Blower Drive Gear and Support Assembly (Flywheel Housing Removed)

Removal of the flywheel housing is not necessary when removing the blower drive gear. However, an inspection of the gear train is advisable when any one of the gears require service. The procedures for removal of the flywheel and flywheel housing are found in SM1-63-14.0 and 16.0.

(1) Remove the blower(s) and the blower drive support lubrication tube as outlined in SM1-63-42.0.
(2) Remove the two blower drive support-to-cylinder block rear end plate attaching bolts with copper washers.
(3) Tap the blower drive support to loosen it, then carefully withdraw the support from the cylinder block rear end plate so the blower drive gear teeth will not be damaged. Discard the gasket.

27.2 Disassemble Blower Drive Gear and Support Assy.

Refer to Fig. 2, and disassemble as follows:
(1) Secure the blower drive gear support in the soft jaws of a bunch vise
(2) Remove the three bolts securing the drive gear hub and spring plates to the blower drive gear. Then remove the spring plates and blower drive gear hub as an assembly from the gear. If necessary, the spring plates may be removed from the hub. 1
(3) Straighten the lugs on the lock washer and remove the blower drive gear support nut.
(4) Withdraw the lock washer, blower drive gear thrust washer, thrust bearings and gear from the support.

27.3 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean the parts with fuel oil and dry them with compressed air. Make sure the oil passage in the blower drive gear support is clean. Check the inside diameter of the support hub for wear or excessive heat. Also check the clearance between the bushings and the support hub. Refer to the wear specifications in SM1-63-70.0. Install new parts whenever the clearance exceeds the limit.

If new bearings are installed, the outer end of each bearing must be pressed in flush to .010" below the face of the gear. The bearings must be reamed to size (1.6260" to 1.6265 inside diameter) and to a finish of 20 microinches after installation. The bearing bores must also be square with the machined faces of the bolt bosses on the gear within .003" total indicator reading and concentric with the pitch diameter of the gear teeth.

The thrust washer retaining pin must extend approximately .080" above the threaded end of the hub.

Examine the blower drive support thrust washer and thrust bearing for scoring and wear. Replace them if necessary. Refer to SM1-63-10.0 for the thickness of a new blower drive support thrust washer and thrust bearing. Inspect the gear teeth for evidence of scoring,

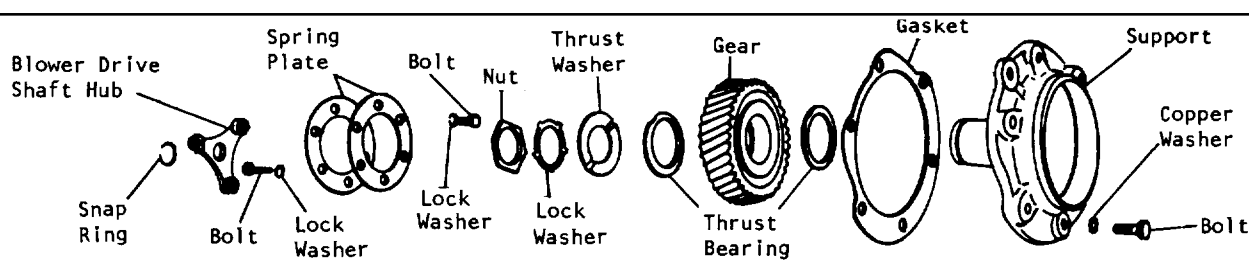



*Fig. 2*
*Blower Drive Gear and Support Assembly and Relative Location of Parts (Turocharged Engine)*

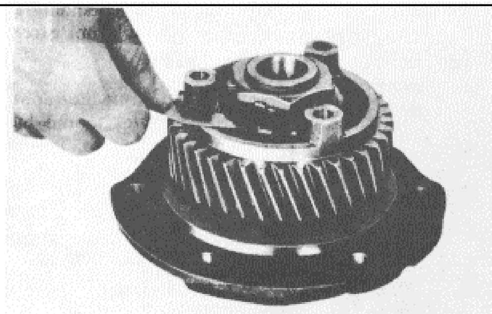


*Fig. 3*
*Checking Clearance Between Blower Drive Gear Support Thrust Washer and Thrust Bearing*

pitting, burning and wear. If necessary, install a new gear.

Inspect the spring plates for cracks or other damage. Replace the plates, if necessary.

Check the serrations in the blower drive shaft hub for wear or other damage. Replace the hub, if necessary.

27.4 Assemble Blower Drive Gear and Support Assembly (Fig. 2)

(1) With the blower drive support clamped in the soft jaws of a bench vise, position one of the blower drive thrust bearings on the support so that the tangs on the bearing register with the holes in the support.
(2) Lubricate the hub of the support, the bushings in the gear, both thrust bearings and the blower drive gear support thrust washer with clean engine oil.
(3) Slide the gear on the hub with the flat side of the gear down.
(4) Install the second thrust bearing on the support with the tangs on the bearing facing up.
(5) Position the blower drive support thrust washer on the support so that the slots in the thrust washer register with the tangs on the bearing.
(6) Secure the gear on the support with a lock washer and nut. Tighten the nut to 50-60 ft/lb. (68-81 N.m) torque and bend the lugs on the lock washer against the flats on the nut to secure the nut.
(7) Check the clearance between the blower drive gear support thrust washer and the blower drive gear thrust bearing as shown in Fig. 3. The clearance should be .005" to .010" with new parts and should not exceed .012" between worn parts.
(8) If the spring plates were removed from the blower drive gear hub, attach the spring plates to the hub with three bolts, flat washers and lock washers. Tighten the bolts to 35-39 ft/lb. (47-53 N.m) torque.

Note: Do not install the lock washers against the steel plates.

(9) Then assemble the spring plates and the hub to the gear with three bolts and lock washers. Tighten the bolts to 35-39 ft/lb. (47-53 N.m) torque.

27.5 Install Blower Drive Gear and Support Assembly

(1) Affix a new gasket to the blower drive gear support and attach the gear and support assembly to the cylinder block rear end plate with two bolts and copper washers. Tighten the bolts to 25-30 ft/lb. (34-41 N.m) torque.
(2) Check the gear backlash between the blower drive gear and the step-up gear attached to the camshaft gear. To accurately check the backlash. all of the flywheel housing attaching bolts must be tightened to their proper torque as outlined in SM1-63-16.0. Backlash should be .002" to .008", and should not exceed .010" with worn parts.

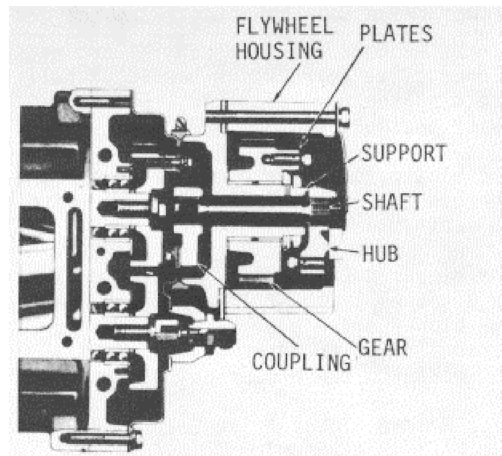
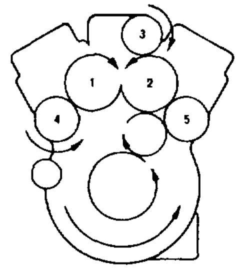



*Fig. 4*
*Blower Drive Components*

(3) Remove the four flywheel housing-to-blower drive support bolts. Then install the blower(s) as outlined in SM1-63-42.0.

| ACCESSORY DRIVE POSITIONS | DRIVE RATIO |
|---|---|
| 1 | 1:1 |
| 2 | 1:1 |
| *3 | 2.60:1 OR 2.05 |
| 4 | 2.05:1 |
| 5 | NOT A DRIVE POSITION |




* Depends upon engine application.

*Fig. 1*
*Accessory Drive Locations*

Accessories such as an air compressor and battery charging alternator may be direct-driven or belt-driven from various locations on the engine.

For the possible accessory drive location and rotation of the drive at a particular position, refer to Fig. 1.

Accessories may also be driven by/the blower drive gear, left-bank accessory drive gear or either camshaft gear at the rear of the engine.

28.1 Rear Accessory Drive (Camshaft Driven)
The camshaft driven accessory drive consists of a drive plate bolted to either one of the camshaft gears.

A direct-driven accessory is flange mounted on the flywheel housing and is driven by a coupling which is splined to both the accessory drive plate and a drive hub on the accessory shaft
(Fig. 2).

28.2 Remove Accessory Drive
Refer to Fig. 2 and remove the accessory drive used with a direct-drive accessory as follows:

(1) Disconnect any external piping or hoses at the accessory.
(2) Remove the bolts and lock washers securing the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing. Remove the gasket. 131 Remove the drive coupling. Place a clean, lintless cloth in the
flywheel housing opening (under the accessory
(3) Remove the drive coupling
(4) Place a clean, lintless cloth in the flywheel housing (under the accessory drive plate) to prevent bolts from accidentally falling into the gear train. Then remove the four shoulder bolts (and lock washers, if used) and withdraw the accessory drive plate

28.3 Inspection

**WARNING**

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Clean all of the parts with fuel oil and dry them with compressed air.

Check the teeth on the drive plate and the drive coupling or drive shaft for wear. Re- place any parts which are worn excessively.

Inspect the ball bearing used to support the accessory drive shaft shown in Fig. 2. Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Wipe the outside of the bearing clean, then hold the inner race and revolve the outer race slowly by hand. If the bearing is worn or does not roll freely, replace the bearing.

28.4 Install Accessory Drive

If an accessory drive plate is used, refer to Fig. 2 and proceed as follows:
(1) Align the bolt holes in the accessory drive plate with the tapped holes in the camshaft gear. Then secure the drive plate with the four special shoulder bolts. Tighten the bolts to 45-50 ft/lb (61-68 N.m)

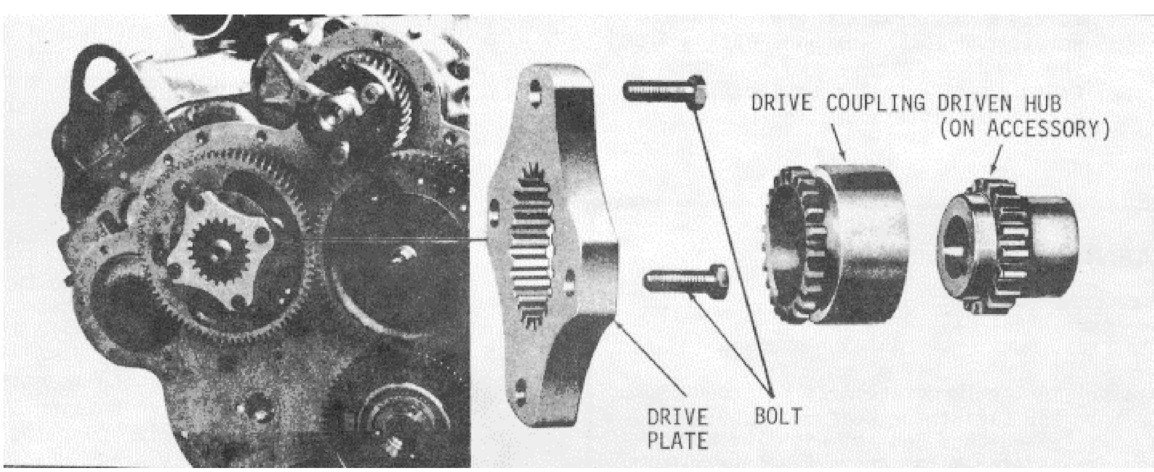


*Fig. 2*
*Components of Accessory Drive for Direct-Driven Accessories*

torque.

(2) Install the drive coupling (Fig. 2) and proceed as follows:
   (a) Affix a new gasket to the mounting flange on the accessory.
   (b) Place the accessory in position against the flywheel housing and rotate it, if necessary, to align the teeth of the drive hub with those in the drive coupling. Then secure the accessory to the flywheel housing with bolts and lock washers.

28.5 Rear Accessory Drive (Blower Drive)

Whenever an accessory is to be driven by the blower drive gear, a hub with two lugs replaces the standard hub in the blower drive assembly (Fig. 3). An accessory drive assembly consisting of a pulley, shaft, double-row bearing, oil seal and oil seal spacer and a driven hub and a housing is bolted to the flywheel housing.

A slotted coupling, which engages the lugs on the two hubs, provides the connection between the accessory drive and the blower drive gear.

28.6 Remove Accessory Drive

(1) Loosen the alternator adjusting strap and alternator mounting bolts. Remove the drive belts.
(2) Remove the bolts and lock washers and carefully withdraw the accessory drive assembly and the drive coupling.
(3) Remove the blower drive shaft retaining ring. Then thread a No. 10-32 screw in the tapped hole and withdraw the blower drive shaft. Remove the screw used to withdraw the shaft.
(4) Remove the three bolts and lock washers and withdraw the drive hub and two drive plates.
(5) Disassemble the accessory drive as follows:
   (a) Remove the pulley retaining nut. Then remove the pulley and the retaining key. Remove the oil seal spacer.
   (b) Press the shaft and hub from the bearing.
   (c) Press the shaft from the hub and remove the key from the shaft.
   (d) Remove the lock ring and bearing from the housing.
   (e) Press the oil seal from the housing with a suitable tool.

28.7 Inspection

**WARNING**

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Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

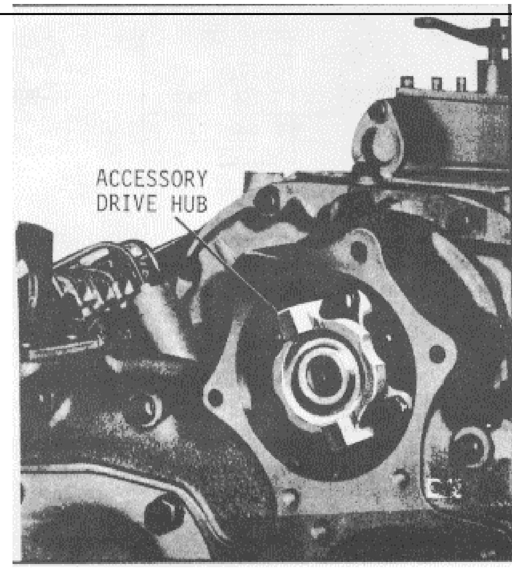


*Fig. 3*
*Accessory Drive Attached to Blower Drive Gear*

Wash all of the parts except the bearing, with fuel oil and dry them with compressed air. A shielded type bearing should not be washed because of the difficulty in draining out all of the solvent.

Inspect the bearing for rough spots by holding the inner race and revolving the outer race slowly by hand. Any indication of rough spots is sufficient cause for rejection of a bearing.

Replace excessively worn or damaged parts.

28.8 Assemble Accessory Drive

(1) Install a key in the hub end of the shaft. Lubricate the shaft and press the hub tight against the shoulder on the shaft.
(2) Install a new oil seal in the housing.
(3) Install the bearing in the housing. Install the lock ring.
(4) Use a sleeve to support the inner race of the bearing, lubricate the shaft and press the hub and shaft assembly in the bearing until the shoulder on the shaft contacts the inner race of the bearing.
(5) Install a key in the pulley end of the shaft. Lubricate the shaft and press the pulley on the shaft until it contacts the inner race of the oil seal spacer.
(6) Install the 3/4"-16 pulley retaining nut and tighten it to 120-140 ft/lb. (163-190 N.m) torque.

28.9 Install Accessory Drive

(1) Install the drive hub and the two drive plates on the blower drive gear.
(2) Install the blower drive shaft and secure it in place with the snap ring.
(3) Place a new gasket on the mounting flange of the accessory drive housing.
(4) Place the slotted drive coupling on the hub of the accessory drive assembly. Then align the slots in the coupling with the

lugs on the drive hub which is attached to the blower drive gear and carefully position the accessory drive against the flywheel housing. Secure the accessory drive assembly to the flywheel housing with bolts and lock washers.

(5) Place the drive belts over the pulleys and adjust the tension on the belts. Then tighten the accessory mounting bolts.

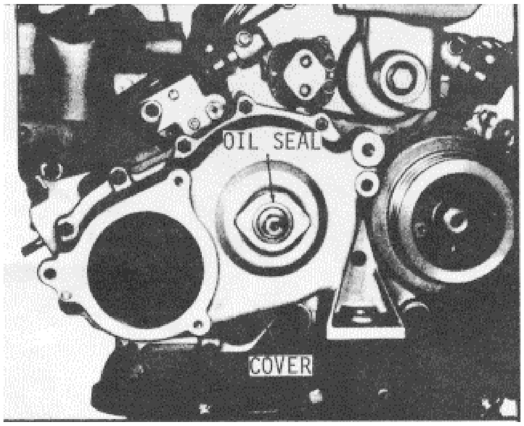


*Fig. 1 Balance Weight Cover Mounting*

The balance weight cover (Fig. 1) enclosed the combination balance weight and water pump drive gear on the front end of the right cylinder bank camshaft. This cover also serves as a support for the water pump.

The balance weight cover requires no servicing. However, when an engine is being completely reconditioned, or the right bank camshaft, camshaft bearings or water pump drive gear need replacing, the balance weight cover must be removed.

29.1 Remove Cover

(1) Drain the cooling system.
(2) Remove the water pump and any other parts required to permit removal of the balance weight cover.
(3) Remove the bolts, washers and lock washers which secure the balance weight cover to the front end plate and the cylinder block.
(4) Since the cover is doweled to the end plate, it will be necessary to tap the ends of the cover with a soft hammer to loosen it.
(5) Remove all traces of the old gasket material from the cover and the end plate.

29.2 Install Cover

(1) Affix a new gasket to the balance weight cover.
(2) An accessory drive shaft oil seal is pressed into the balance weight cover on some engines (Fig. 1). If necessary, replace the oil seal as follows:
    (a) Drive the old oil seal out of the cover.
    (b) The new oil seal is plastic coated on the outside diameter for sealing purposes. Do not remove this coating. Position the seal with the sealing oil pointing toward the inner side of the cover.
    (c) Drive the seal in with installer J 9791 until it is flush with the outer surface of the cover.
    (d) Coat the lip of the seal with grease.
(3) Install the balance weight cover on the engine and secure it with bolts, nuts, lock 3/8"-16 bolts to 30-35 ft/lb. 141-47 N-m) torque; the 3/8"-24 bolts and nuts to 35-39 ft/lb. (47-53 N-m) torque; the 1/2"43 bolts to 71-75 ft/lb. (96-102 N-m) torque; and the 5/8"-11 bolts to 137-147 ft/lb. (186-200 N-m) torque.

(5) Fill the cooling system

30.1 Teflon Wrapped Pipe Plug

Pipe plugs with a baked teflon coating are available for service. However, pipe plugs can be hand wrapped satisfactorily with teflon tape to provide a better seal and facilitate plug removal. When a teflon wrapped plug is installed, it is extremely important that the specified torque not be exceeded.

Hand wrap a pipe plug with teflon tape as follows:

(1) Be sure the pipe plug is thoroughly clean and dry prior to applying the teflon tape. All dirt, grease, oil and scale must be removed.

(2) Start the tape one or two threads from the small or leading edge of the plug, joining the tape together with an overlap of approximately 1/8 inch.

(3) Wrap the tape tightly in the same direction as you would turn a nut. The tape must conform to the configuration of the threads (be pressed into the minor diameter of the threads) without cutting or ripping the tape.

(4) Hand tighten and hand torque the pipe plug and do not exceed the specified torque. Do not use power tools.

30.2 Checking Bearing Clearances

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially and is available in three sizes and colors. Type PG-1 (green) has a clearance range of .001" to .003"; type PR-1 (red) has a range of .002" to .006"; and type PB-l (blue) has a range of .004" to .009".

The plastic strip may be used for checking the bearing clearances as follows:

(1) Remove the bearing cap and wipe the oil from the bearing shell and the crankshaft journal.

Note: When checking the main bearing clearances with the engine in a position where the main bearing caps are supporting the weight of the crankshaft and the flywheel, an erroneous reading, due to the weight of the crankshaft and the flywheel, can be eliminated by supporting the weight of the crankshaft with a jack under the counterweight adjoining the bearing being checked.

(2) Place a piece of the plastic strip the full width of the bearing shell, about 1/4" off center (Fig. 1).

(3) Rotate the crankshaft about 300 from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.

(4) Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.

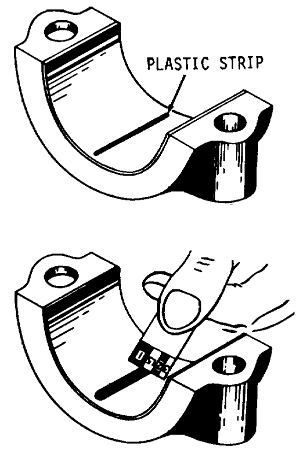


*Fig. 1 Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance*

(5) Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope (Fig. 1). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end. of the flattened plastic strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

30.3 Replacing Cylinder Head Bolt Hole Plug

The cylinder head bolt hole plugs are designed to seal the head bolt holes from the coolant passages. Tool kit J 26620 is available for removing and installing the plugs. Replace a cylinder head bolt hole plug in the cylinder block as follows:

(1) Remove the old plug and clean the threads of all old sealant by running bottom tap J 25384 down the hole (do not deepen the tapped hole). The threads must be clean and dry before applying sealant.

(2) Screw the plug in until it bottoms. The top of the plug must be at least 1.960" below the block surface for bolt clearance. After the plug is installed and tightened to 50-60 ft/lb. (68-81 N.m) torque, apply a small quantity of Loctite 290 sealant, or equivalent, to the top thread area of the plug. Exercise care to prevent sealant getting on the threads of the cylinder head bolt thread area. Allow the sealant to set for twelve hours and pressure check for five minutes at 40 psi (276 kPa).

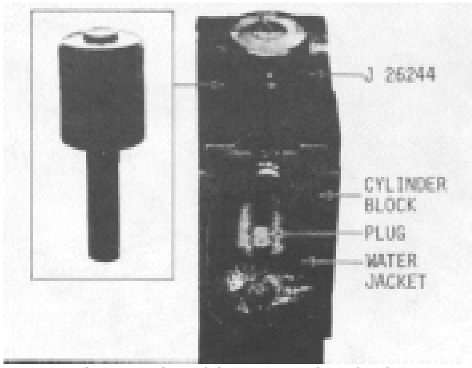


*Fig. 2 Checking Depth of Plug*

Note: Some commonly used pipe sealants have been found to be ineffective for this application.

(3) Place depth gage J 26244 (Fig. 2) in the cylinder head bolt hole and loosen the set screw. If the depth gage is flush with or below the knurled gage holder, the plug is installed and sealed at the proper depth.

(4) Remove excess Loctite from the bolt hole threads by running an 11/16" bottom tap until it bottoms on the plug. Run the tap in by hand. Power equipment (impact gun, etc.) should not be used as they may cause the tap to disturb the Loctite seal.

Inspect the bolt hole for debris before and after these operations.

If the plug cannot be removed with relative ease, drill through the plug and remove it with an appropriate size "easy-out". If the threads of the tapped hole become stripped during plug removal, then proceed as follows:

(a) Tap the hole through to accept a thread insert, clean the new threads with solvent and dry them with compressed air.

(b) Install a short thread insert (about .625" long) so that the top of the insert is 1.960" below the top face of the block. Coat the insert and the tapped hole with sealant.

(c) Install the plug as outlined in Step 2.

(d) Install a long thread insert (about 1.500" long) as deep as possible so that the top of the thread insert is approximately .800" below the top face of the block.

30.4 Cylinder Block Line Boring

Tool set J 29005 is designed to repair the main bearing saddles and line bore the repaired saddles and service line bore caps in the cylinder blocks which have been damaged by spun main bearings.

Damaged main bearing saddles can be repaired by machining to accept an insert bushing. The bushing and newly fitted service line bore main bearing cap are line bored to the proper dimensions to accept standard main bearing shells.

The line bore operation is an acceptable warranty procedure. Instructions for using the cylinder block line boring tool J 29005 are listed below:

(1) Remove all the plugs and main bearing caps and clean the useable cylinder block.

Note: The use of this tool is dependent upon the existence of two undamaged main bearing saddles.

(2) Determine which two undamaged main bearing saddles are to be used as alignment locations. These saddles should be as far apart as possible. Since the rear main bearing saddle cannot be repaired with this tool set, it MUST be one of the undamaged saddles. In a block where the front and rear main bearing cap and saddle are serviceable, the journals in between can be repaired successively without removal of the centering rings from the front and rear positions. In the case where the only good main bearing bores are next to each other, the centering rings will have to be mounted there and marked for indexing. The closest bore will then be repaired. The rear centering ring will remain in position, but the other centering ring will be moved into the just repaired saddle so that the next damaged saddle can be re-paired. The centering ring being moved should be indexed the same when moved from saddle to saddle.

(3) Set the centering rings (4.8125") into the alignment saddles and install the main bearing caps. Do not tighten the bolts.

(4) Slide the boring bar through the centering rings. Lubricate the ring hole during installation. The bar should rotate freely (Fig. 3). Tighten the main bearing cap bolts to the torque specified, 165-175 ft/lb.

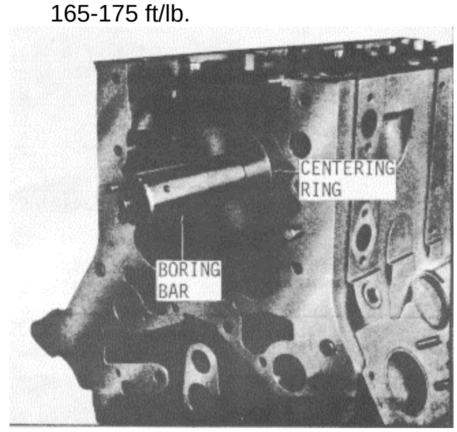


*Fig. 3 Location of Boring Bar*

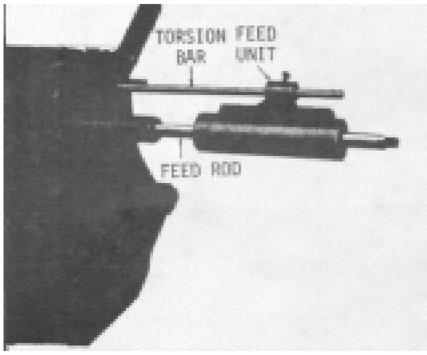


*Fig. 4 Location of Feed Rod and Unit*

(224-238 N.m) torque.

Note: If the centering rings are loose in the saddle after tightening the bolts, use .001" paper shims as necessary between the ring and the main bearing cap.

(5) Install the caps and tighten the bolts on all the remaining saddles, except the saddle to be machined. Do not torque the bolts. This is only to keep chips out of the bolt holes.

(6) Fasten the torsion bar and the hydraulic feed unit on either end of the cylinder block. Index the flat on the feed rod into the boring bar. Snug the set screw (Fig. 4).

(7) Zero the micrometer with the test lock supplied (Fig. 5).

Note: The micrometer is .050" per revolution, not .025" as normally seen on micrometers.

(8) Install the cutting tool holder on the micrometer test fixture. Use only the straight allen wrench supplied in the kit. See the cutting tool for the first cut of .040" (Fig. 6).

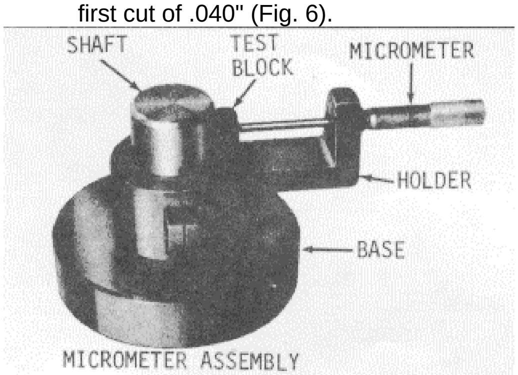


*Fig. 5 Test Fixture and Micrometer*

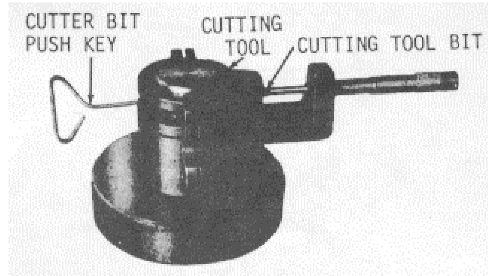


*Fig. 6 Installing Cutting Tool Holder*

| EXAMPLE: | Block | Insert |
|---|---|---|
| Bore diameter | 4.812" | 4.712" |
| First cut | +.040" | +.040" |
| Set tool | 4.852" | 4.752" |
| Second cut | +.040" | +.040" |
| Set tool | 4.892" | 4.792" |
| Final cut | +.020" | +.020" |
| Set tool | 4.912" | 4.812" |

(9) Install the cutting tool on the boring bar. Excessive tightening of the Allen head screws is not required.

Note: The tool feeds away from the operator and rotates clockwise as viewed by the operator (Fig. 7). Whenever installing the cutter, be sure- the-sharp portion of the bit is in the cutting position.

(10) Lubricate the boring bar with engine oil at the centering rings before each cut.

(11) Use a 1/2" drill motor of 300-400 RPM and install the universal drive (lubricate) into the drill chuck. Move the hydraulic feed unit lever to the "closed" position (Fig. 8).

(12) Line bore the distressed saddle using the three cuts and the dimensions given in

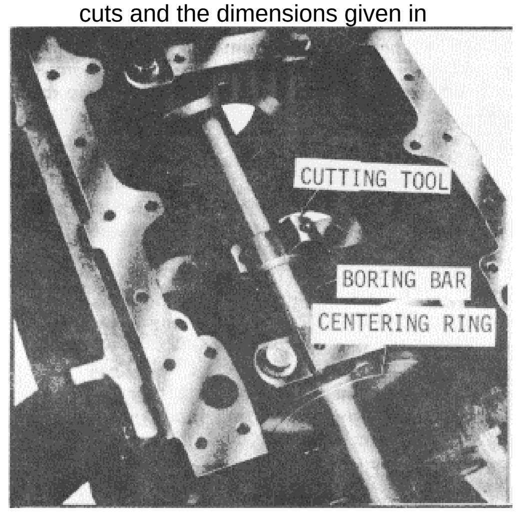


*Fig. 7 Position of Cutting Tool*

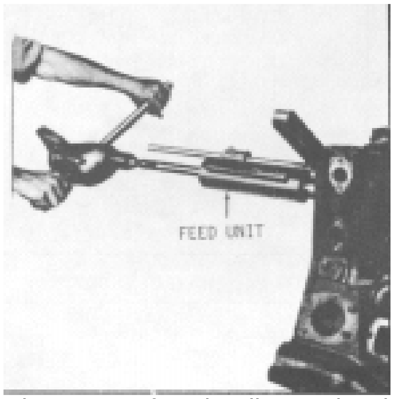


*Fig. 8 Use of Hydraulic Feed Unit*

step 8.

(13) If other bores are to be machined, install the cap and tighten the bolts to the torque specified (section 1.1) on the completed saddle and proceed to the next saddle. Start with step 7.

(14) Remove the boring bar and clean the reworked saddles.

(15) Install and align the insert with the hold down bolts to plates provided. Tighten the bolts to 20 ft/lb. (27 N.m) torque.

Note: Use the plate with a "step" on the side of the insert opposite the tang.

(16) Check the insert for alignment and fit.

(17) Mark the drill 1/4" from the end, using a 1/8" drill bit.

(18 Drill the saddle through the four predrilled holes in the insert.

(19) Clean the drilled holes with compressed air and install the rivets.

(20) Secure the rivets with a hammer and punch. retention of the insert. Be careful not to strike the insert directly, as the insert will distort. Two or three blows on the punch are usually sufficient to secure the rivets (Fig. 9). Note: Rivets are intended for locating more than retention. The bearing and cap provide

(21) File off the excess rivet material (Fig. 9).

(22) Remove both the insert hold downs and file the excess material on the insert flush with the saddle-cap parting surface. If the insert is loose, secure the rivets.

(23) Install and tighten the bolts for the Service Line Bore cap to the torque specified (section 1.1).

(24) Line bore the cap and insert to the standard bore dimensions, using previous procedure and dimensions in step 8.

(25) Remove burrs, debris and clean with spray

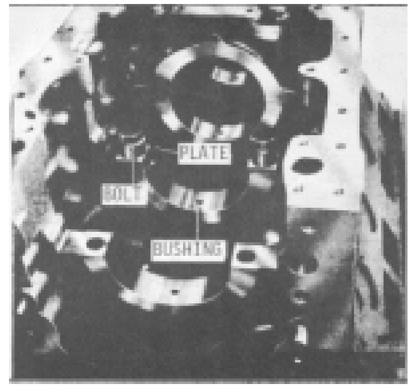


*Fig. 9 Position of Bushing and Hold Down Plate*

lube.

(26) Check the finished bore with the Go-NoGo test rings mounted on the boring bar. The ring should go through the reworked bore with a light drag.

Note: If centering rings are removed during the line boring operation, mark the ring and saddle to insure proper installation alignment.

(27) Clean the cylinder block, reinstall the plugs and proceed with the rebuild.

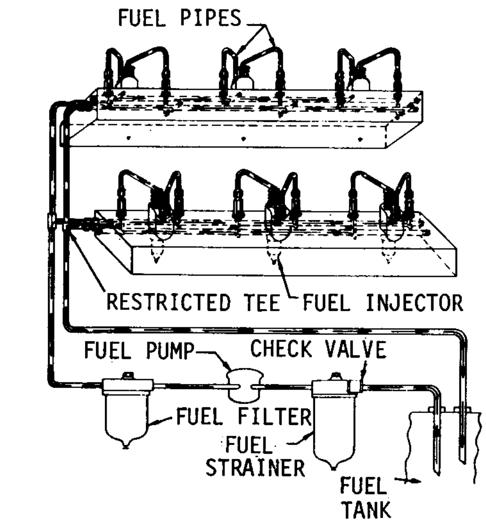


*Fig. 1 Schematic Diagram of Typical Fuel System*

The fuel system (Fig. 1) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter and fuel lines.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter and into the inlet fuel manifold, then through fuel pipes into the inlet side of each fuel injector.

The fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage) which are cast or stamped in several places in the side of the cylinder head. This aids installation of the fuel lines.

Surplus fuel returns from the outlet side of the injectors to the fuel return manifold and then back to the supply tank.

All engines are equipped with a restrictive fitting in the fuel outlet manifold in one of the cylinder heads to maintain the fuel system pressure. Refer to SM1-63-66.0 for the size fitting required.

A check valve may be installed in the supply line between the fuel tank and the fuel strainer to prevent fuel from draining back when the engine is shut down.

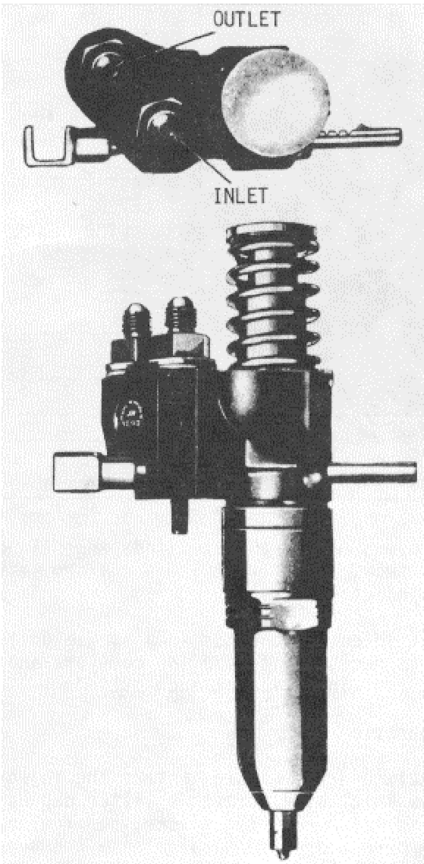


*Fig. 1 Fuel Injector Assembly*

The fuel injector (Fig. 1 and 2) is a lightweight compact unit which enables quick, easy starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air-fuel mixing or vaporizing devices are required.

The fuel injector performs four functions:

(1) Creates the high fuel pressure required for efficient injection.

(2) Meters and injects the exact amount of fuel required to handle the load.

(3) Atomizes the fuel for mixing with the air in the combustion chamber.

(4) Permits continuous fuel flow.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder.

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Fig. 3 illustrates the fuel metering from no-load to full-load by rotation of the plunger in the bushing.

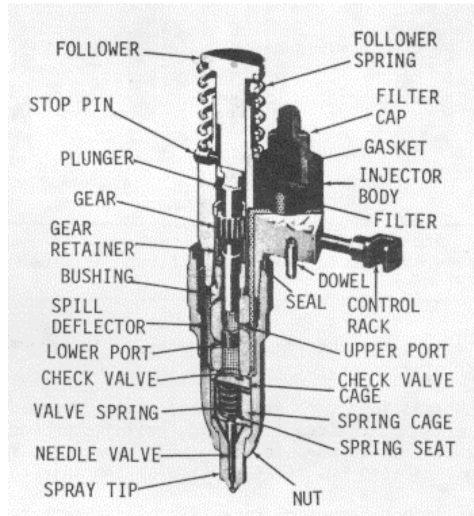


*Fig. 2 Cutaway View of Fuel Injector*

Fig. 4 illustrates the phases of injector operation by the vertical travel of the injector plunger.

The continuous fuel flow through the injector serves in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the helix angle of the plunger and the type of spray tip used. Refer to Fig. 5 for the identification of the injectors and their respective plungers and spray tips.

Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

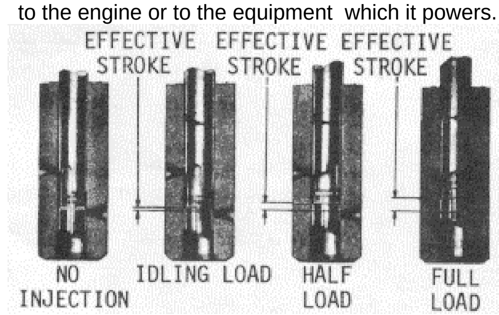


*Fig.3 Fuel Metering from No-Load to Full-Load*

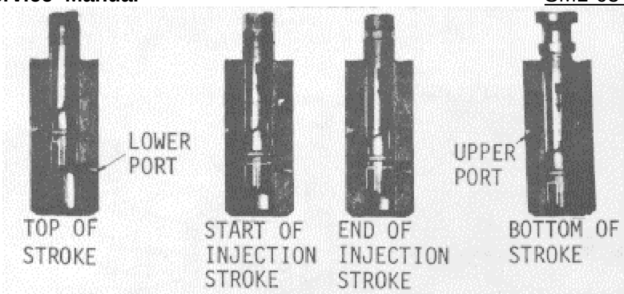


*Fig. 4 Phases of Injector Operation through Vertical Travel of Plunger*

Note: Do not intermix the needle valve injectors with other types of injectors in an engine.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 5). The identification tag indicates the relative size of the injector.

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod.

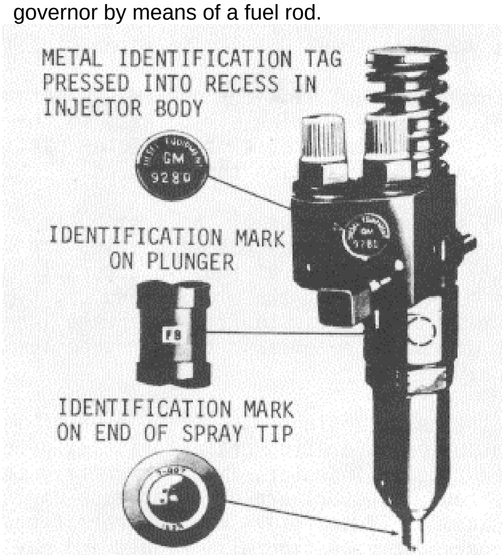


*Fig. 5 Injector Identification Chart*

| INJECTOR | SPRAY TIP* | PLUNGER |
|---|---|---|
| **9C90** | **8-.0068-165A** | **G9** |

*****First numeral indicates number of spray holes, followed by size of holes and angle formed by spray from holes.

Fig. 5
Injector Identification Chart

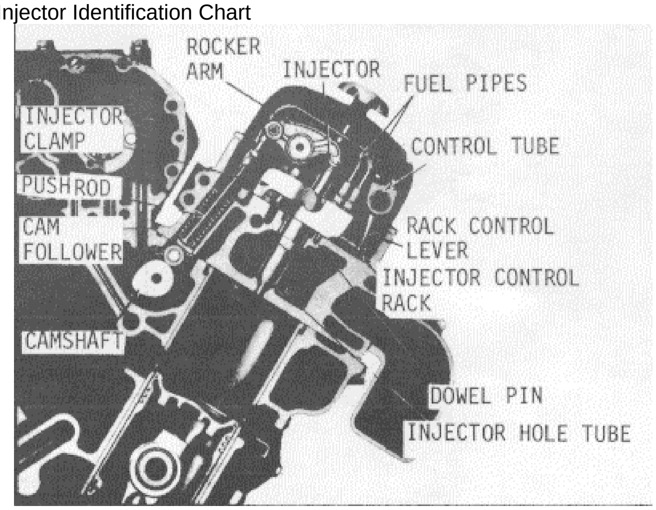


*Fig. 6 Fuel Injector Mounting*

These levers can be adjusted independently on the control tube, thus permitting a uniform setting of all injector racks.

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

32.1 Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (Fig. 2). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port, until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat, non-return check valve. The fuel in the check valve cage, spring cage, tip passages and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

When the lower hand of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection. A pressure relief passage has been provided in the spring cage to permit bleed-off of fuel leaking past the needle pilot in the tip assembly.

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its original position by the injector follower spring. Fig. 4 shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. Fig. 3 shows the various plunger positions from no-Toad to full-load. With the control rack pulled out all the way (no injection), the upper port is not closed by-the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this no injection

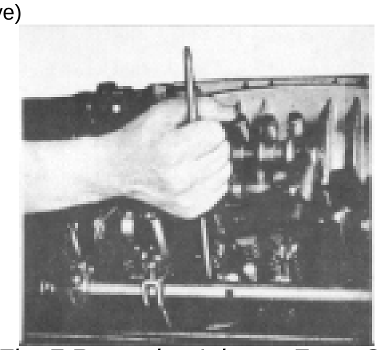

*Fig. 7 Removing Injector From Cylinder Head*

position to full injection position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

32.2 General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required. Perform all injector repairs in a clean, well- lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by mean. of an electric fan which draws air into the room through a filter. This pressure pre- vents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air. Also provide a source for 110 volt alternating current electric power.

Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust-proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning agent, usually clean fuel oil, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at

the bottom of the pans.
Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free cleaning tissue is a good, inexpensive material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

(1) Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors. Also protect the fuel pipes and fuel connectors from the entry of dirt or other foreign material.

(2) After an injector has been operated in an engine, do not remove the filter caps or filter while the injector is in the engine. Replace the filter only at the time of complete disassembly and assembly of an injector.

Note: In the offset injector, a filter is used in the inlet side only. No filter is required on the outlet side (Fig. 35).

(3) Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in SM1-63-68. O.
  (a) Time the injector.
  (b) Position the injector control rack.

(4) Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to the Operators Manual ).

(5) When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. Do not use fuel oil. Install shipping caps on both filter caps immediately after filling. Store the injector in an upright position to prevent test oil leakage.

32.3 Remove Injector

(1) Clean and remove the valve rocker cover.
(2) Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

Note: Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also protect the fuel pipes and fuel connectors from entry of dirt or foreign material.

(3) Crank the engine to bring the outer ends of the push rods of the injector and valve rocker arms in line horizontally.
(4) Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).
(5) Remove the injector clamp bolt, special washer and clamp.
(6) Loosen the inner and outer adjusting screws (certain engines have only one adjusting screw and lock nut) on the injector rack control lever and slide the lever away from the injector.
(7) Lift the injector from its seat in the cylinder head.
(8) Cover the injector hole in the cylinder head to keep foreign material out.
(9) Clean the exterior of the injector with clean fuel oil and dry it with compressed air.

32.4 Test Injector

**WARNING**

The Fuel Spray From An Injector Can Penetrate The Skin. Fuel Oil Which Enters The Blood Stream Can Cause A Serious Infection. Therefore, Follow Instructions And Use The Proper Equipment To Test An Injector.

If inspection does not reveal any external damage, then perform a series of tests to deter- mine the condition of the injector to avoid unnecessary overhauling. Tests must be per- formed using injector test oil J 26400.

An injector that passes all of the tests out- lined below may be considered to be satisfactory for service.

However, an injector that fails to pass one or more of the tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct any one condition.

Identify each injector and record the pressure

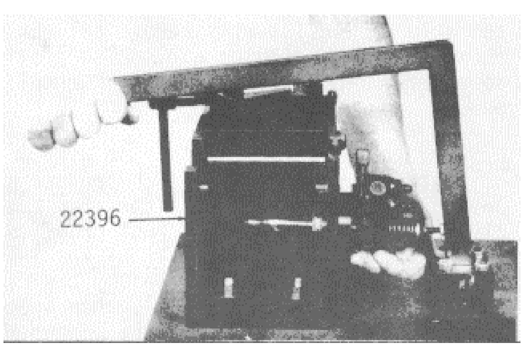


*Fig. 8 Checking Rack and Plunger for Free Movement*

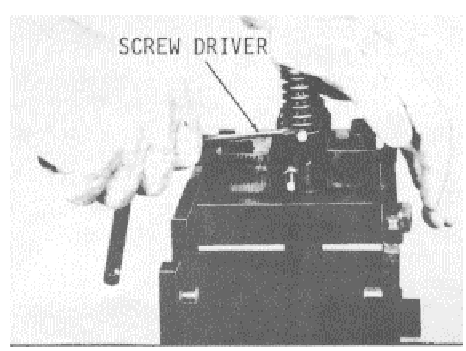


*Fig. 9 Removing Injector Follower Stop Pin*

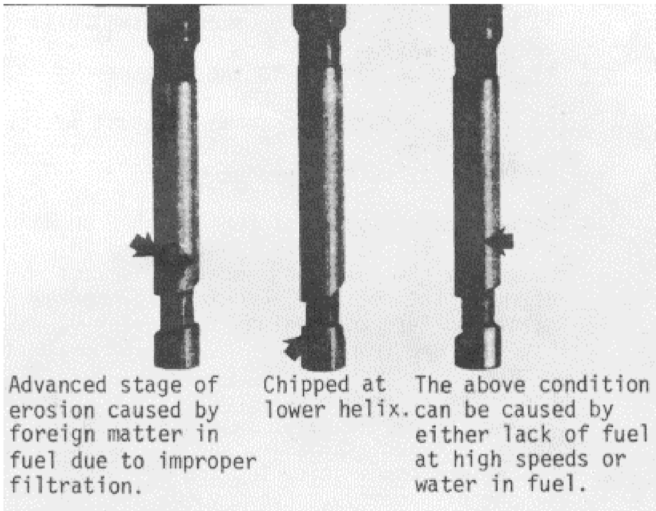


*Fig. 10 Unusable Injector Plungers*

drop and fuel output as indicated by the following tests:

32.5 Injector Control Rack and Plunger Movement Test

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw, in the handle to ensure the contact screw is at the center of the follower when the follower spring is compressed.

With the injector control rack held in the no- fuel position, push the handle down and depress the follower to the bottom of its stroke. Then very slowly release the pressure on the handle while moving the control rack up and down as shown in Fig. 8 until the follower reaches the top of its travel. If the rack does not fall freely, loosen the injector nut, turn the tip then retighten the nut. Loosen and retighten the nut a couple of times if necessary. Generally this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the

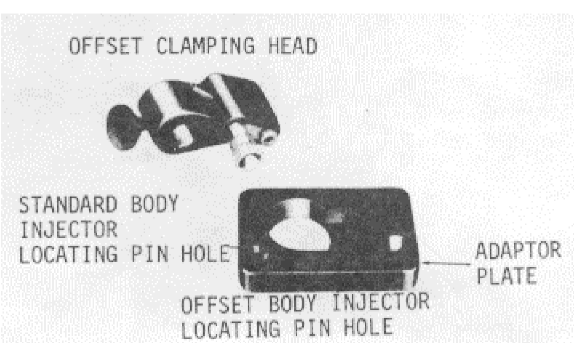


*Fig. 11 Injector Tester J 23010 Clamping Heads Injector to eliminate the cause of the misaligned parts.*

32.6 Visual Inspection of Plunger

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests.

Remove the plunger from the injector as follows:

(1) Support the injector, right side up, in holding fixture J 22396.
(2) Compress the follower spring. Then raise the spring above the stop pin with a screw driver and withdraw the pin (Fig. 9). Allow the spring to rise gradually.
(3) Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.
(4) Inspect the plunger. If the plunger is shipped (Fig. 10), replace the plunger and bushing assembly.
(5) Re-install the plunger, follower and spring.

32.7 Installing Fuel Injector in Tester J 23010

(1) Select the proper clamping head (Fig. 11). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 12).
(2) Connect the test oil delivery piping into the clamping head.
(3) Connect the test oil clean discharge tubing onto the pipe on the clamping head.
(4) Locate the adapter plate on top of the support bracket by positioning the 3/8" diameter hole at the far right of the adapter plate onto the 3/8" diameter dowel pin. This allows the adapter plate to swing out for mounting the fuel injector.

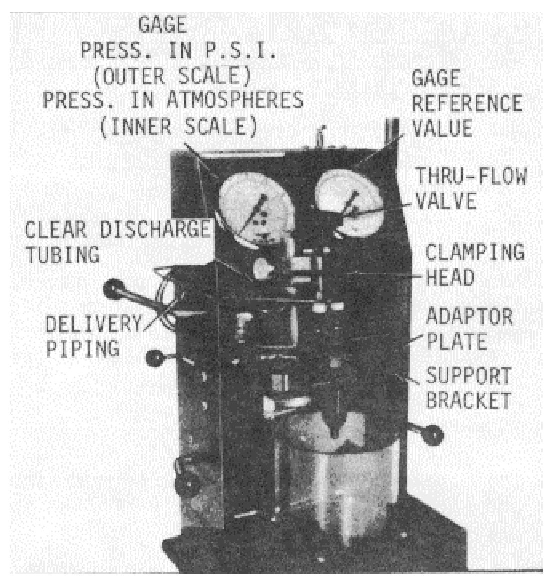


*Fig. 12 Injector Installed in Tester J 23010 VW Clamping Head*

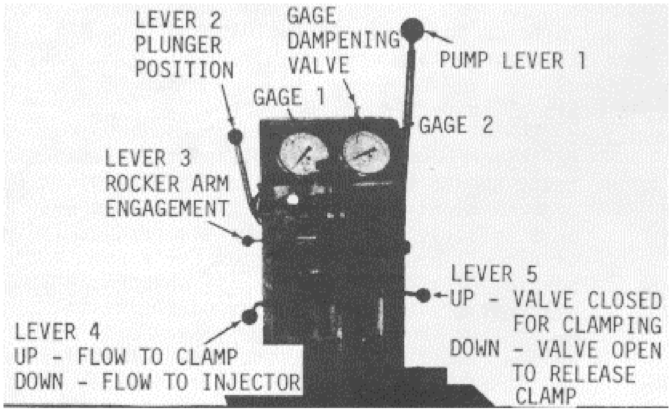


*Fig. 13 Injector in Position for Testing with Tester J 23010*

(5) Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. 11).
(6) Swing the mounted injector and adapter plate inward until they contact the stop pin at the rear of the support bracket.

32.8 Clamping the Fuel Injector

(1) Refer to Fig. 13 and position the injector tester levers as follows:
Lever 2 up and to the rear
Lever 3 in the rear detent
Lever 4 up (horizontal)
Lever 5 up (horizontal)
(2) Align the clamping head nylon seals over the injector filter caps.
(3) Back off the Thru-Flow valve about halfway to allow the self-aligning nylon seals to seat properly during the clamping operation
(4) Hold the clamping head in position over the filter caps and, with the left hand, operate pump lever 1 evenly to move the clamping head down to seal the filter cpps.

Note: The Thru-Flow valve should still turn freely. If it does not, turn the valve counter- clockwise until it rotates freely and re-apply clamping pressure.

Note: Excessive force on lever 1 during clamping can damage the seals in the valves operated by levers 4 and 5.

32.9 Purging Air from the System

Move lever 4 down and operate pump lever 1 to produce a test oil flow through the injector. When air bubbles no longer pass through the clear discharge tubing, the system is free of air and is now ready for testing.

32.10 Injector Valve Opening and Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the injector valve opens and fuel injection begins.

(1) Clamp the injector properly and purge the air from the system.
(2) Move lever 4 down.
(3) Position the injector rack in the full fuel position.
(4) Place pump lever 1 in the vertical position.
(5) Move lever 3 to the forward detent position.
(6) Operate pump lever 1 uniformly and observe the spray pattern produced.

The highest pressure reference number shown on gage 2 will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector. Reference values for Series 92 injectors are from 138 minimum to 162 maximum.

Note: The reference value obtained when pop testing the needle valve injectors is to be used as a trouble shooting and diagnosis aid. This allows comparative testing of injectors without disassembly. Exact valve opening pressure values can only be determined by he Needle Valve Tip Test using tester J 23010 and tip test adapter J 23010-129 or auxiliary tester J 22640.

32.11 Injector High Pressure Test

This test checks for leaks at the filter cap gaskets, body plugs and nut seal ring.
(1) Clamp the injector properly and purge the air from the system.
(2) Close the Thru-Flow valve, but do not overtighten.

Note: Make sure lever 4 is in the down position before operating pump lever 1.

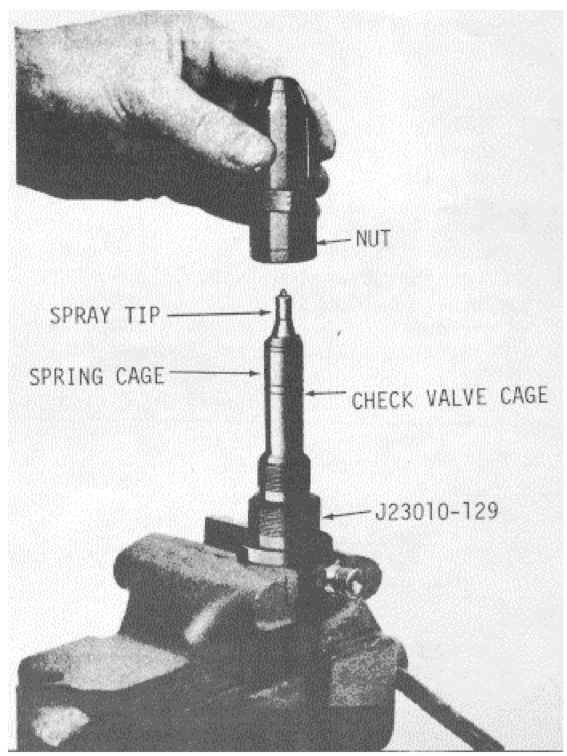


*Fig. 14 Assembling Injector Valve Parts on Tip Tester Adapter J 23010-129*

(3) Operate pump lever 1 to build up to 1600 to 2000 psi on gage 1. Check for leakage at the injector filter cap gaskets, body plugs, and injector nut seal ring.

32.12 Injector Pressure Holding Test

This test determines if the body-to-busing mating surfaces in the injector are sealing properly and indicates proper plunger-to-bushing fit.

(1) Clamp the injector properly and purge the air from the system.
(2) Close the Thru-Flow valve, but do not over-tighten.
(3) Move lever 2 to the rear, horizontal position.
(4) Operate pump lever 1 until gage 1 reads approximately 700 psi.
(5) Move lever 4 to the up position.
(6) Time the pressure drop between 450 to 250 psi. If the pressure drop occurs in less than 15 seconds, leakage is excessive.

Refer to the "Trouble Shooting Charts" in SM1-63-69.0 if the fuel injector does not pass any of the preceding tests.

If the fuel injector passes all of the above tests, proceed with the Fuel Output Test.

32.13 Unclamping the Injector

(1) Open the Thru-Flow valve to release pressure in the system.
(2) Move lever 5 down to release the clamping pressure.
(3) Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clear of the injector filter caps.
(4) Carefully return lever 5 to the up (horizontal) position.

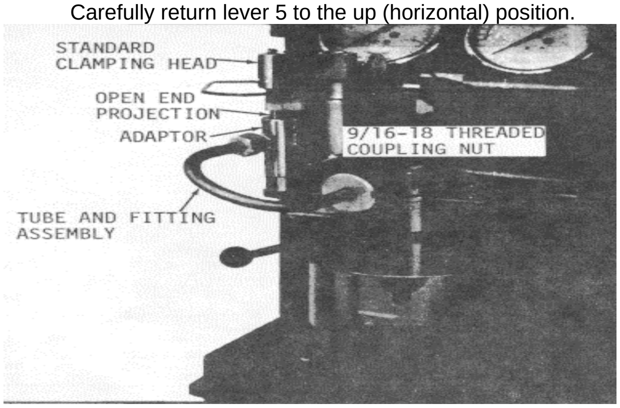


Fig. 15
Adaptor and Tube Assembly on Injector Tester J 23010

32.15 Needle Valve Test [Using J 23010 Tester and Tip-Test Adaptor)

Assembly injector parts on tip test adaptor as follows:

(1)' Clamp the flat sides of the tip test adaptor J 23010-129 firmly in a vise and assemble the cleaned injector parts, including the check valve cage, spring, spring seat, spring cage and spray tip assembly.
(2) Carefully pilot the injector nut over the spray tip and valve parts and thread it onto the adaptor (Fig.14).
(I3) Tighten the injector nut.
(4) Mount the adaptor and assembled injector parts in the support bracket (adaptor plate not needed).Refer to Fig. 15.
(5) Install the offset clamping head on the clamping post (on J 23010 testers without serial numbers, use the upper detent position and on J 23010 testers numbered 1051 and higher, use the lower detent position.)
(6) Select the (larger) 9/16"-18 threaded coupling nut J 23010-20 and thread it on tubing J 23010-75.

Install the tubing and fitting to adaptor J 23010-167.

(7) Connect the tubing to tip test adaptor J 23010-129 by threading the coupling nut on the tip test adaptor.

32.16 Installing Adaptor and Tube Assembly on Tester J 23010

(1) Position the adaptor and tubing assembly with the solid projecting end located in the hole on the left side of the support bracket.
(2) Swing the clamping head over the adaptor and clamp it with the oil supply outlet aligned over the open projecting end of the adaptor (Fig. 15).

Note: Use the fuel injector clamping_ procedure to clamp adaptor J 23010-167 in the injector tester.

32.17 Spray Tip Test

(1) Move lever 4 down and operate pump lever 1 with even strokes (Fig. 13).
(2) Note the pressure at which the needle valve opens on gage 1. The valve should open between 2300 and 3200 psi.

The opening and closing action should be sharp and produce a normal, finely atomized spray pattern.

If the valve opening pressure is below 2300 psi and/or atomization is poor, the cause is usually a weak valve spring or a poor needle valve seat.

If the valve opening pressure is within 2300-3200 psi, proceed to check for spray tip leakage as follows:

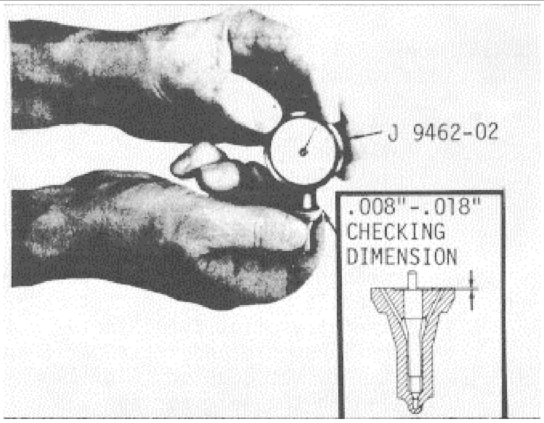


*Fig.* 16
Checking Needle Valve Lift

(a) Actuate pump lever 1 several times and hold the pressure at 1500 psi for 15 seconds.

(b) Inspect the spray tip for leakage. There should be no fuel droplets ,although a slight wetting at the spray tip is permissable.

32.18 Needle Valve Lift Test

To measure the needle valve list, use tool J 9462-01 (Fig. 16) as follows:

(1) Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

(2) Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

(3) While holding the spray tip and needle valve assembly tight against the gage, read 'J' the needle valve lift on the indicator. The lift should be .008" to .018". If it exceeds .018",the tip assembly must be replaced. If it is less than .008", inspect for foreign material between the needle valve and the tip seat.

(4) If the needle valve list is within limits install a new needle valve spring and recheck the valve opening pressure and valve action. Low valve opening pressure or poor atomization with a new spring and seat indicates the spray tip and needle valve assembly should be replaced.

(5) Re-assemble the injector as outlined under 32.26 "Assemble Injector" and check the injector output with calibrator J 22410.

33.19 Needle Valve Tip Test (Using Auxiliary Tester J 22640)

(1) Connect the pipe from the ausiliary tester J 22640 to the rear of the J 23010 tester at the connection located near the bottom of the tester (Fig. 17).

(2) Assemble cleaned injector parts, including the check valve cage, spring, spring seat, spring cage and spray tip assembly, on the auxiliary tester J 22640 (Fig.18).

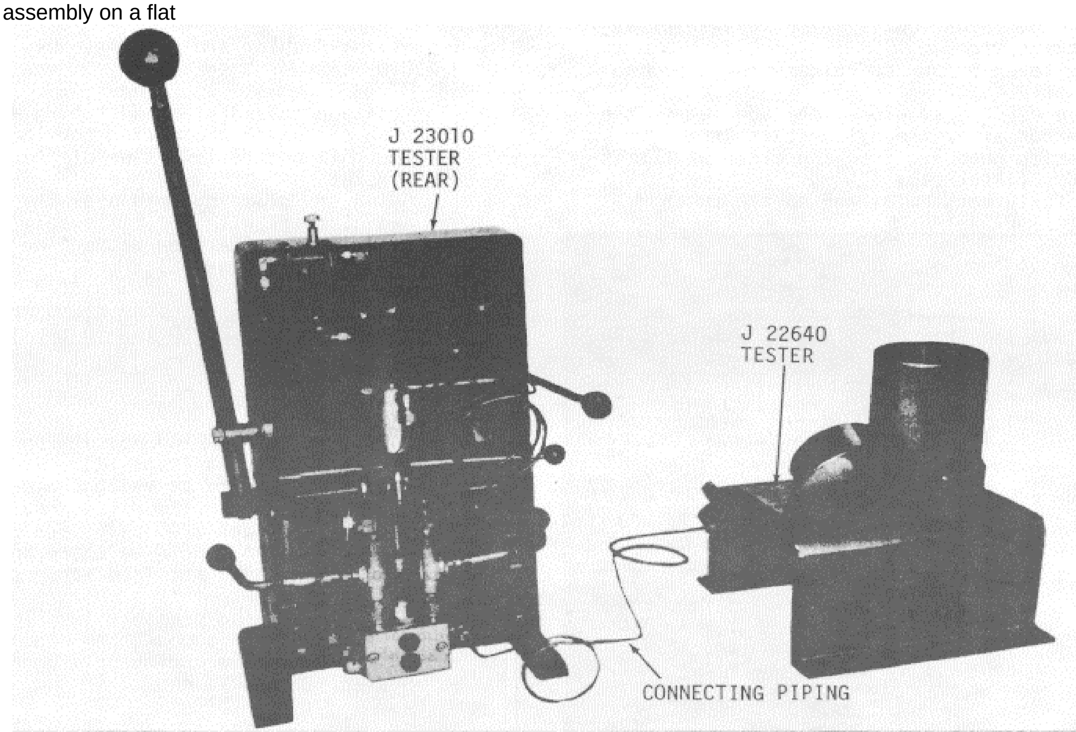


Fig. 17
Injector Needle Valve Tester J 23010 with Auxiliary Tester J 22640

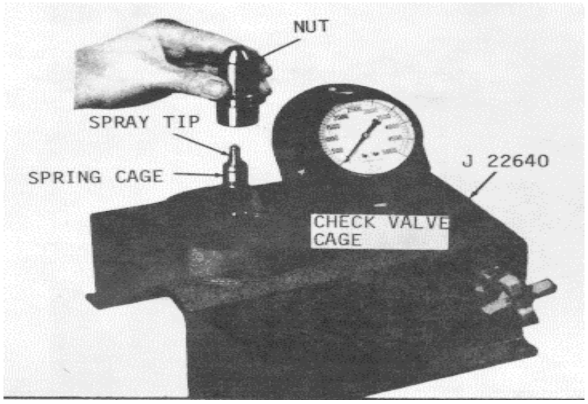


Fig.18
Installing Injector Valve Parts on Auxiliary Tester J 22640

(3) Carefully pilot the injector nut over the spray tip and valve parts and thread it on the auxiliary tester.

(4) Tighten the injector nut.

(5) Open the valve on the auxiliary tester and place lever 4 in the up (horizontal) position.

(6) Install the shield on the auxiliary tester and operate pump lever 1 until the' needle valve has opened several times to purge the air from the system.

(7) Operate pump lever 1 with smooth, even strokes and note the pressure on gage 1 when the needle valve opens. The valve should open between 2300 and 3200 psi. The opening and closing action should be sharp and produce a finely atomized spray.

If the valve opening pressure is below 2300 psi and/or atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

If the valve opening pressure is within 2300-3200 psi, proceed to check for spray tip leakage as follows:

(a) Actuate the pump lever several times and
hold the pressure at 1500 psi for 15 seconds.

(b) Inspect the spray tip for leakage. There should be no fuel droplets although a slight wetting at the spray tip is permissable.

| *Injector | Calibrator J 22410 | |
|---|---|---|
| | Min. | Max. |
| 9C90 | 85 | 91 |

*First two digits identify injector for series "92" engines.

Fig. 19
Fuel Output Chart

Perform the needle valve list test.

32.20 Fuel Output Test

Perform the injector fuel output test in calibrator J 22410. When injectors are removed from an engine for fuel output testing and, satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

Before removing an injector from the engine, note the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the braided fuel inlet tube and the plastic fuel outlet tube on the calibrator (Fig.20) depends on the adaptor being used and the direction of fuel flow through the injector.

32.21 Calibrator J 22410

To check the fuel output, operate the injector in calibrator J 22410 (Fig. 21) as follows:

Note: Place the cam shift index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch and preheat the test oil to 95-105° F (35-40° C).

(1) Place the proper injector adaptor between the tie rods and engage it with the fuel block locating pin. Then slide the adaptor forward and up against the fuel block face.

(2) Place the injector seat J 22410-226 into the permanent seat (cradle handle in vertical position).Clamp the injector into position by operating the air valve.

Note: Make sure the counter (Fig. 22) on the calibrator is pre-set at 1000 strokes. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and holding the reset lever in the full up position;

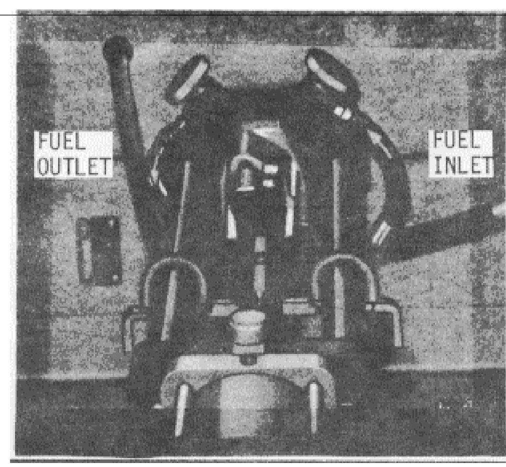


Fig. 20
Position of Calibrator Fuel Flow Pipes

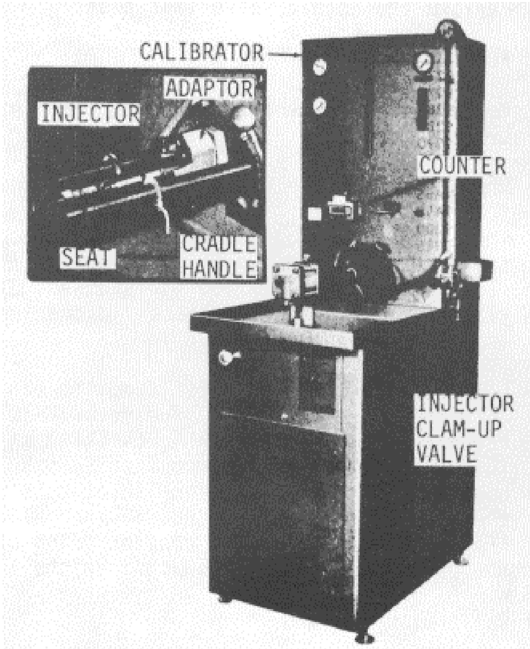


*Fig.* 21
Injector in Calibrator J 22410

while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

(3) Pull the injector rack out to the no-fuel position.
(4) Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

Note: The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

(5) After the calibrator has started, set the injector rack into the full-fuel position Allow the injector to operate for approximately 30 seconds to purge the air that maybe in the system.
(6) After the air is purged, press the fuel flow start button (red). This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after 1000 strokes.

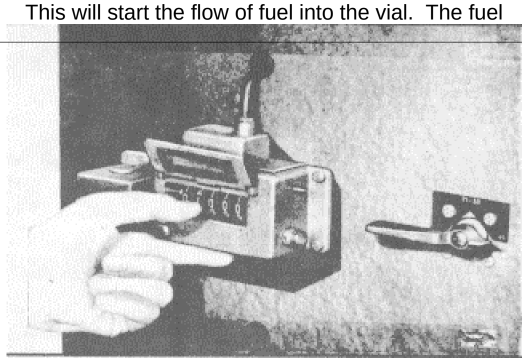

*Fig.* 22
Setting Calibrator Stroke Counter

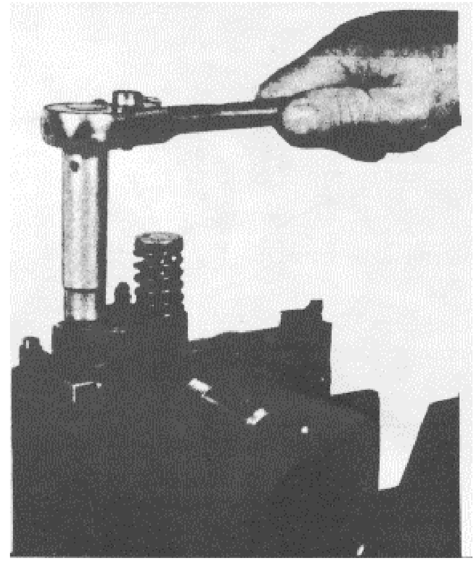

*Fig.* 23
Removing or Installing Filter Cap

(7) Shut the calibrator off (the calibrator will stop in less time at full-fuel).
(8) Observe the vial reading and refer to Fig. 19 to determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to SM1-63-69.0 and SM1-63-39.0 for the cause and remedy.

Note: Refer to SM1-63-39.0 for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

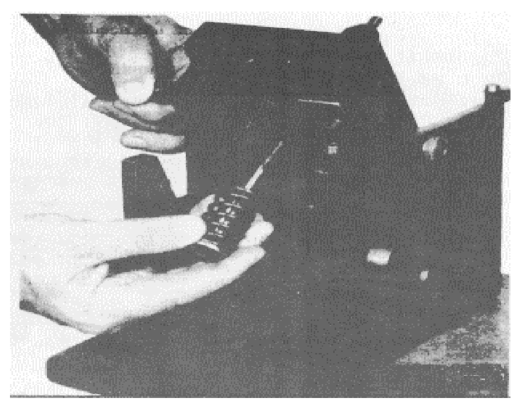

*Fig.* 24
Removing or Installing Plunger, Follower and Spring

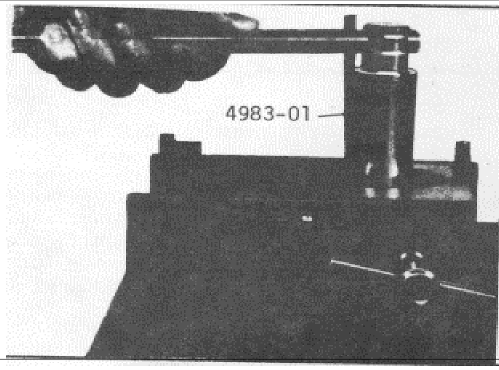


*Fig.* 25
Removing Injector Nut

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on-the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

32.22 Disassemble Injector

If required, disassemble an injector as follows:

(1) Support the injector upright in injector holding fixture J 22396 (Fig. 23) and remove the filter caps, gaskets and filters.

Note: Whenever a fuel injector is disassembled, discard the filter and gaskets and replace with new filter and gaskets. In the offset injector a filter is used in the inlet side only. No filter is required in the outlet side (Fig.35).

(2) Compress the follower spring as shown in Fig. 11. Then raise the spring above the stop pin with a screw driver and withdraw the pin. Allow the spring to rise gradually.

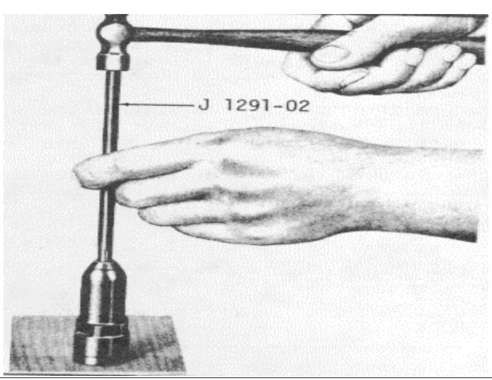


*Fig.* 26
Removing Spray Tip from Injector Nut

(3) Refer to Fig. 24 and remove the plunger follower, plunger and spring as an assembly.

(4) Invert the fixture and, using socket J4983-01, loosen the nut on the injector body (Fig.25).

(5) Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly. When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291-02 as shown in Fig. 26.

(6) Refer to Fig. 37 and remove the spill deflector. Then lift the bushing straight out of the injector body.

(7) Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

(8) Withdraw the injector control rack from the injector body. Also remove the seal ring from the body.

32.23 Clean Injector Parts

Since most injector difficulties are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

**WARNING|**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wash all of the parts with clean fuel oil or a suitable cleaning solvent and dry them with clean, filtered compressed air. Do not use waste or rags for cleaning purposes. Clean out all of the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation: Methyl Ethyl' Ketone J 8257 solution is recommended for this purpose.

Clean the spray tip with tool J 24838 (Fig.27).

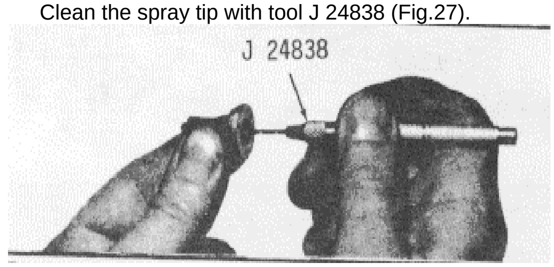


*Fig.* 27
Cleaning Injector Spray Tip

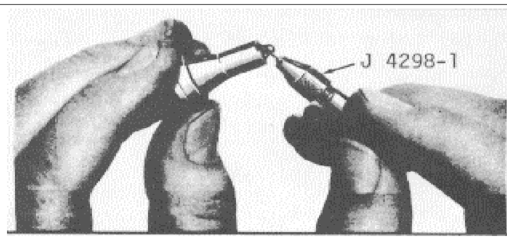


*Fig.* 29
Cleaning Spray Tip Orifices

Note: <u>Care must be exercised when inserting the carbon remover J 24838 in the spray tip to avoid contacting the needle valve seat in the tip.</u>

Wash the tip in fuel oil and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1 and the proper size spray tip cleaning wire. Use wire J 21460 to clean .0055" diameter holes and wire J 21461 to clean .006" diameter holes (Fig. 28).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16" with stone J 8170. Allow the wire to extend 1/8" from tool J 4298-1.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

Note: <u>Do not buff excessively. Do not use a steel wire buffing wheel or the spray tip holes may be distorted.</u>

When the body of the spray tip is clean, lightly buff the tip end in the same manner. This cleans the spray tip orifice area and will not plug the orifices.

Wash the spray tip in clean fuel oil and dry it with compressed air.

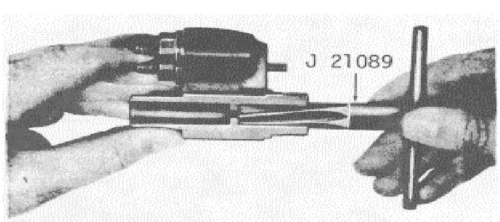


*Fig.* 29
Cleaning Injector Body Ring

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully insert reamer J 21089 in the injector body (Fig. 29). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a clock wise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.

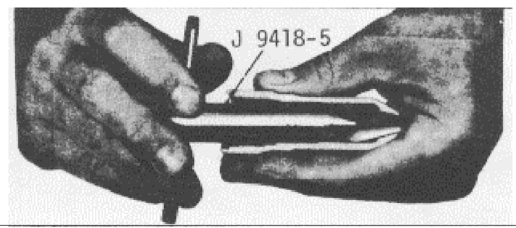


*Fig.* 30
Cleaning Injector Nut Spray Tip Seat

Remove the carbon deposits from the lower in side diameter taper of the injector nut with carbon remover J 9418-5 (Fig. 30). Use care to minimize removing metal or setting up burrs on the spray tip seat. Remove only enough metal to produce a clean uniform seat to prevent leakage between the seat and the nut. Carefully insert carbon remover J 9418-1 in the injector nut. Turn it clockwise to remove the carbon deposits on the flat spray tip seal.

Wash the injector nut in clean fuel oil and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean fuel oil and dry them with compressed air. Be sure the high pressure bleed hole in

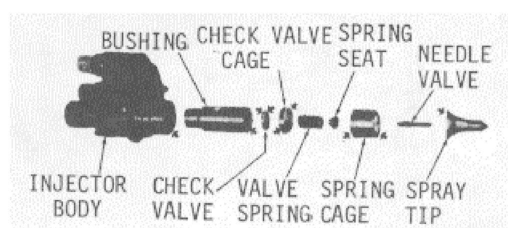


*Fig.* 31
Sealing Surfaces Which May Require Lapping

the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. Keep the plunger and bushing together as they are mated parts.

After washing, submerge the parts in a clean receptable containing clean fuel oil. Keep the parts of each injector assembly together.

32.24 Inspect Injector Parts

Inspect the teeth on the control rack and the control rack gear for excessive wear or damage. Also check for excessive wear in the bore of the gear and inspect the gear retainer. Replace the damaged or worn parts.

Inspect the injector follower and pin for wear. Refer to SM1-63-70.0.

Inspect both ends of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500 grit stone.

Inspect the follower spring for visual defects. Then check the spring with spring tester J 22738-02.

The injector follower spring (.142" diameter wire) has a free length of approximately 1.504" and should be replaced when a load of less than 70 pounds will compress it to 1.028".

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Injector Bushing Inspectalite J 21471 can be used to check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and check for free movement. Replace the plunger and bushing as an assembly if any of the above damage is noted, since they are mated parts. Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

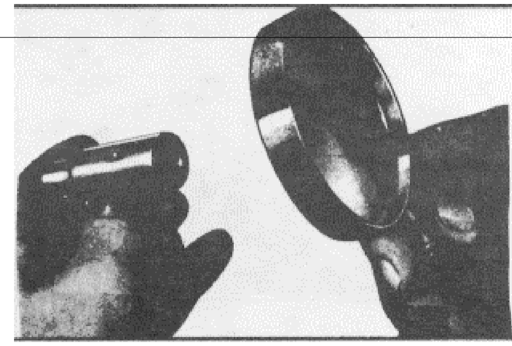

*Fig.* 32
Examining Sealing Surface with a Magnifying Glass

Examine the spray tip seating surface of the injector nut and spray tip for nicks, burrs, erosion or brinelling. Reseat the surface or replace the nut or tip if it is severely damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

Inspect the sealing surfaces of the injector parts indicated by arrows in Fig. 31. Examine the sealing surfaces with a magnifying glass as shown in Fig. 32 for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. Also check for enlarged orifices in the spray tip. Replace damaged or excessively worn parts. Check the minimum thickness of the lapped parts as noted in the chart (Table 1).

| Part Name | Minimum Thickness |
|---|---|
| Spray Tip (shoulder) | .199" |
| Check Valve Cage | .165" - .163" |
| Check Valve | .022" |
| Valve Spring Cage | .602" |

Table 1
Minimum Thickness (Used Parts)

Examine the seating area of the needle valve for wear or damage. Also examine the needle quill and its contact point with the valve spring seat. Replace damaged or excessively worn parts.

Examine the needle valve seat area in the spray tip for foreign material. The smallest particle of such material can prevent the needle valve from seating properly. Polish the seat area with polishing stick J 22964. Coat only the tapered end of the stick with polishing compound of the spray tip until it bottoms. Rotate the stick 6 to 12 times, applying a light pressure with the thumb and forefinger.

Note: <u>Be sure that no compound is accidentally_ placed on the lapped surfaces located higher up in the spray tip. The slightest lapping</u>

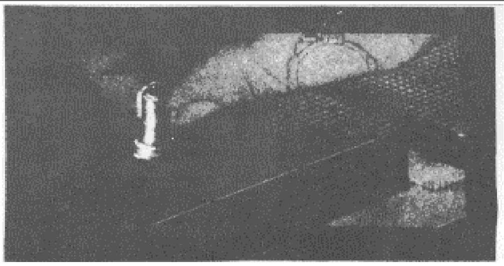

Fig. 33
Lapping Spray Tip on Lapping Blocks J 22090

action on these surfaces can alter the near-perfect fit between the needle valve and tip.

Before reinstalling used injector parts, lap all of the sealing surfaces indicated by the arrows in Fig. 31. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

Note: The sealing surface of current spray tips is precision lapped by a new process witch leaves the surface with a dull satin-like finish; the lapped surface on former spray tips was bright and shiny (Fig. 34). It is not recommended to lap the surface of a new current spray tip.

32.25 Lapping Injector Parts

Lap the sealing surfaces indicated in Fig. 31 and Table 1 as follows:

(1) Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.
(2) Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.
(3) Place the part to be lapped flat on the block as shown in Fig. 33 and, using a figure-eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.
(4) After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. Do not lap excessively (refer to Table 1).

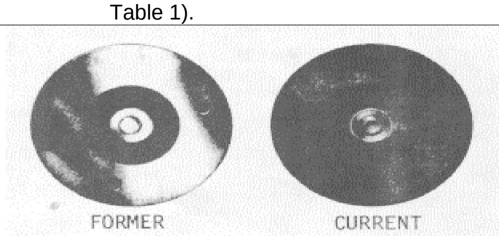


*Fig.* 34
Spray Tip Sealing Surface Identification

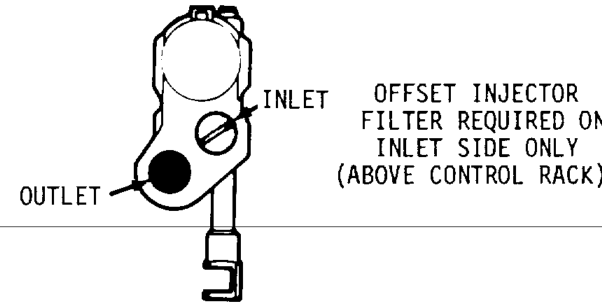


*Fig.* 35
Location of Filter in Injector Body

(5) When the part is flat, wash it in cleaning solvent and dry it with compressed air.
(6) Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. Do not lap excessively. Again wash the part in cleaning solvent and dry it with compressed air.
(7) Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.
(8) Wash all of the lapped parts in clean fuel oil and dry them with compressed air.

32.26 Assemble Injector

Use an extremely clean bench to work on and to place the parts on when assembling an injector. Also be sure all of the injector parts, both new and used, are clean.

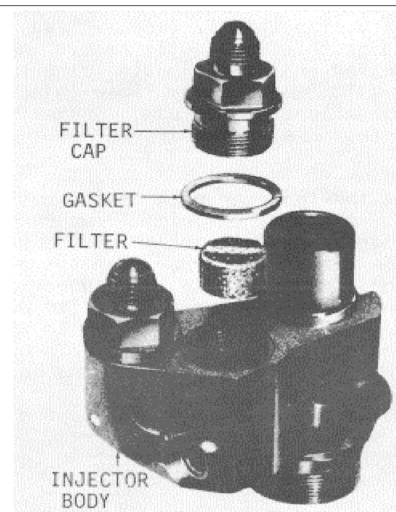


Fig. 36
Details of Injector Filters and Caps and their Relative Location

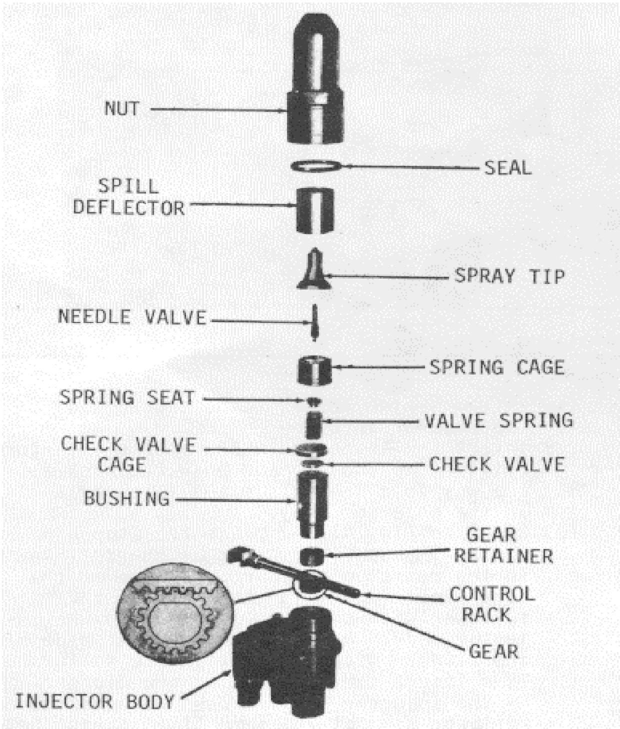


*Fig.* 37
Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

Study Fig. 35 through 38 for the proper relative position of the injector parts, then proceed as follows.

32.27 Assemble Injector Filters

Always use new filters and gaskets when reassembling an injector.

(1) Insert a new filter, dimple end down, slotted end up, in each of the fuel cavities in the top of the injector body (Fig. 36).

Note: <u>Install a new filter in the inlet side (located over the injector rack) in a fuel injector with an offset body. No filter is required in the outlet side of the offset body injector (Fig. 35).</u>

(2) Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps to 65-75 ft/lb. (88-102 N-m) torque with a 9/16" deep socket (Fig. 23).

(3) Purge the filter after installation by directing compressed air or fuel through the filter caps.

(4) Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

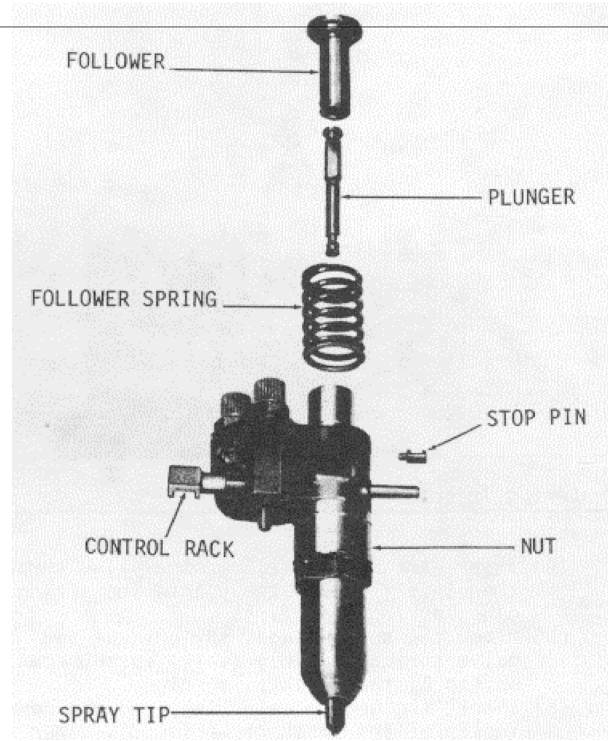


*Fig.* 38
Injector Plunger, Follower and Relative Location of Parts

32.28 Assemble Rack and Gears

Refer to Fig. 37 and note the drill spot marks on the control rack and gear. Then proceed as follows:

(1) Hold the injector body, bottom end up, and slide the rack through the hole in the body. Look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

(2) Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 37). 3) Place the gear retainer on top of the gear. 4) Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

32.29 Assemble Spray Tip, Spring Cage and Check Valve Assemblies

Refer to Fig. 37 and assemble the parts as follows:

(1) Support the injector body, bottom end up, in injector holding fixture J 22396.

(2) Place a new seal ring on the shoulder of the body. Then place the spill deflector over the barrel of the bushing.

(3) Place the check valve (without the .010" hole) centrally on the top of the bushing. Then place the check valve cage over the check valve and against the bushing.

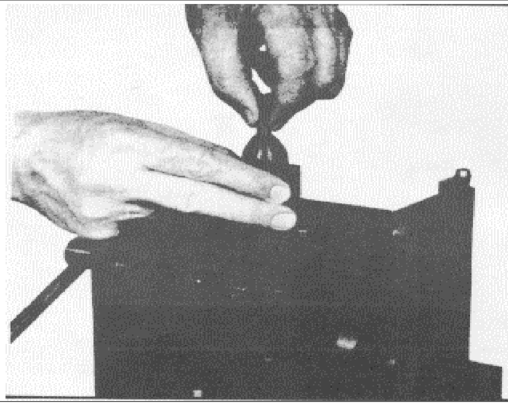

*Fig.* 39
*Tightening Injector Nut by Hand*

(4) Insert the spring seat in the valve' spring, then insert the assembly into the spring cage, spring seat first.

(5) Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

(6) Insert the needle valve, tapered end down, inside of the spray tip (Fig. 2). Then place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

(7) Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 39). Tighten the nut as tight as possible by hand. At this point, there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

(8) Use socket J 4983-01 and a torque wrench to tighten the injector nut to 75-85 ft/lb. (102-115 N-m) torque (Fig. 40).

Note: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

32.30 Assemble Plunger and Follower

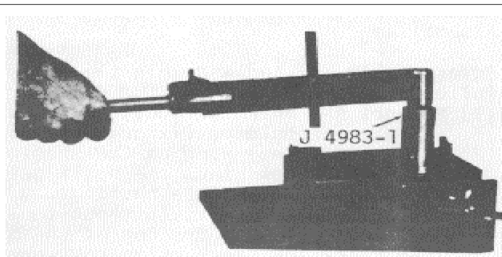


*Fig. 40*
Tightening Injector Nut with Torque Wrench

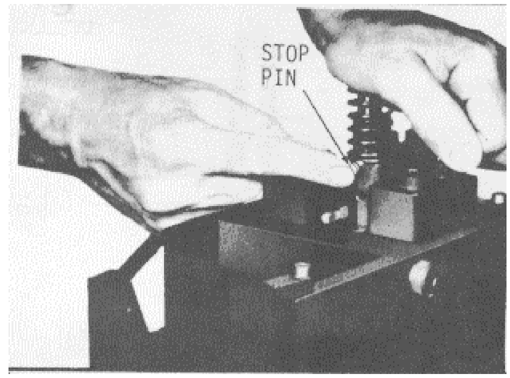


*Fig. 41*
*Installing Injector Follower Stop Pin*

(1) Refer to Fig. 38 and slide the head of the plunger into the follower.

(2) Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way in. Then place the follower spring on the injector body.

(3) Refer to Fig. 41 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. Then align the slot in the follower with the stop pin hole in the injector body. Next, align the flat side of the plunger with the slot in the follower. Then insert the free end of the plunger in the injector body. Press down on the follower and, at the same time, press the stop pin into position. When in place, the spring will hold the stop pin in position.

32.31 Check Spray Tip Concentricity

To assure correct alignment, check the concentricity of the spray tip as follows:

(1) Place the injector in the concentricity gage J 5119 as shown in Fig. 42 and adjust the dial indicator to zero.

(2) Rotate the injector 360° and note the total runout as indicated on the dial.

(3) If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 75-85 ft/lb. (102-115 N.m) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

32.32 Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under 32.4 Test Injector.

The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble and test the injector again.

32.33 Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286-9, SM1-63-33.0, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

(1) Refer to Fig. 6 and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.

(2) Slide the injector rack control lever over so that it registers with the injector rack.

(3) Install the injector clamp, special washer (with curbed side toward injector clamp) and bolt. Tighten the bolt to 20-25 ft/lb. (27-34 N.m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

Note: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

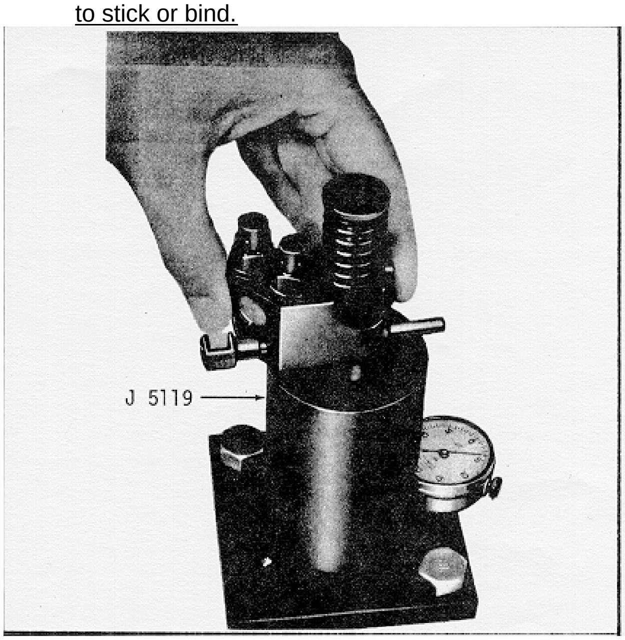


*Fig. 42 Checking Injector Spray Tip Concentricity*

(4) Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in SM1-63-70.0.

Note: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Therefore, note the position of the exhaust valve bridge before, during, and after tightening the rocker shaft bolts.

(5) Remove the shipping caps. Then install the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932- 01 to tighten the connections to 12-15 ft/lb. (16-20 N.m) torque.

Important: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

Note: An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filter cap. When any of the above are detected, remove the valve rocker cover. A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel Apes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectors. Reinstall the rocker cover. Then drain the lubricating oil and change the oil filter elements. Refer to the Operators Manual and refill the crankcase to the proper level with the recommended grade of oil.

(6) Perform a complete engine tune-up as outlined in SM1-63-68.0. However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control lever.

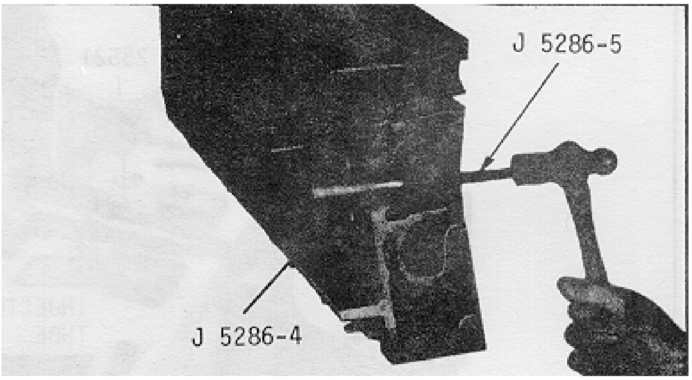


*Fig. 1 Removing Injector Tube*

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Fig. 1. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at the top with a neoprene ring and upset into a flare on the lower side of the cylinder head to create water-tight and gas-tight joints at the top and bottom.

33.1 Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 22525 as follows:

(1) Remove, disassemble and clean the cylinder head as outlined in SM1-63-5.0.
(2) Place the injector tube installer J 5286-4 in the injector tube. Insert the pilot J 5286-5 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer (Fig. 1 ).
(3) Tap on the end of the pilot to loosen the injector tube. Then lift the injector tube, installer and pilot from the cylinder head.

3.2 Install Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove dirt, burrs or foreign material that may prevent the tube from seating at the lower end or sealing at the upper end. Then install the tube as follows:

(1) Place a new injector tube seal ring in the counterbore in the cylinder head.
(2) Place the installer J 52864 in the injector tube. Then insert the pilot J 5286-5 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig. 2).
(3) Slip the injector tube into the injector bore and drive it in place as shown in Fig. 2. Sealing is accomplished between the head counterbore (inside diameter) and the outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.
(4) With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:

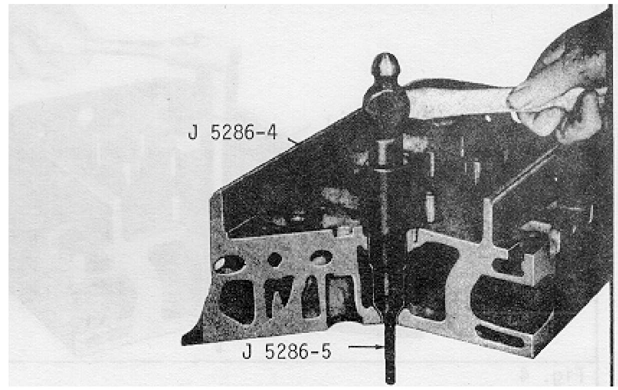


*Fig. 2 Installing Injector Tube*

(a) Turn the cylinder head bottom side up, remove the pilot J 5286-5 and thread the upsetting die J 5286-6 into the tapped end of the installer J5286-4 (Fig. 3).
(b) Then, using a socket and torque wrench, apply approximately 30 ft/lb. (41 N.m) torque on the upsetting die.
(c) Remove the installing tools and ream the injector tube as outlined below.

33.3 Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations: first, hand reamed, as shown in Fig. 4, to receive the injector body nut and spray tip; second, spot-faced to remove excess stock at the lower end of the injector tube; and third, hand reamed, as shown in Fig. 5, to provide a good seating surface for the bevel or the lower end of the injector nut. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

Note: <u>The reamer should be turned in a clock- wise direction only, both when inserting and when withdrawing the reamer, because movement in the</u>

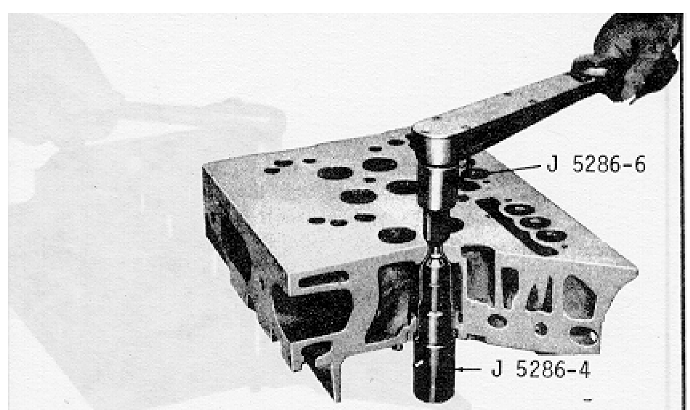


*Fig. 3 Upsetting Injector Tube*

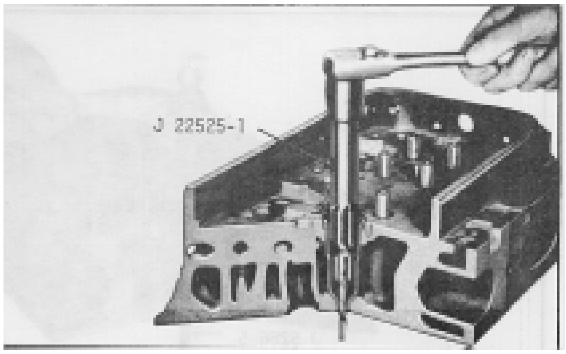


*Fig. 4 Reaming Injector Tube for Injector Body Nut and Spray Tip*

<u>opposite direction will dull the cutting edges of the flutes.</u>

(1) Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:
   (a) Place a few drops of light cutting oil on the reamer flutes, then carefully position the reamer J 22525-1 in the injector tube.
   (b) Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 4). Clean out all chips.

(2) Remove excess stock:
   (a) With the cylinder head bottom side up, insert the pilot of cutting tool J 5286- 8 into the small hole of the injector tube.
   (b) Place a few drops of cutting oil on the tool. Then, using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to .005" below the finished surface of the cylinder head.

(3) Ream the bevel seat on the injector tube.

*Fig. 5 Reaming Injector Tube for Injector Nut*

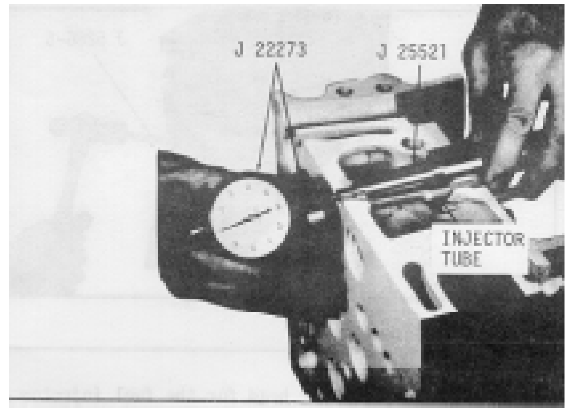


*Fig. 6 Measuring Relationship of Bevel Seat of Injector Tube to Fire Deck of Cylinder Head*

The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip in the combustion chamber. There- fore, to determine the amount of stock that must be reamed from the seat of the tube, refer to Fig. 6.

Install gage J 25521 in the injector tube. Zero the sled gage dial indicator J 22273 to the fire deck. Gage J 25521 should be flush t .014" with the fire deck of the cylinder head (Fig. 7).

Note: <u>Any fire deck resurfacing work must be done prior to the final injector tube seat gaging. Refer to SM1-63-5.0 for resurfacing instructions.</u>

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

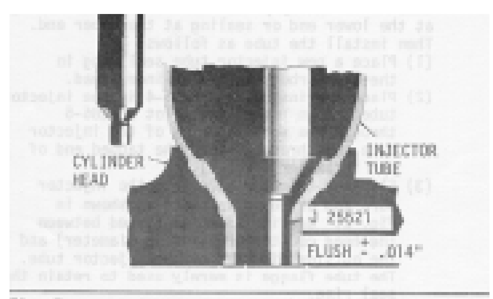


*Fig. 7 Measuring Relationship of Gage to Fire Deck of Cylinder Head*

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

With the first reaming operation completed and the injector tube spot-faced, wash the interior of the injector tube with clean solvent and dry it with compressed air. Then perform the second reaming operation as follows: (a) Place a few drops of cutting oil on the bevel seat of the tube. Carefully lower the reamer J 5286-9 into the injector tube until it contacts the bevel seat.

(b) Make a trial cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips and look at the bevel seat to see what portion of the seat has been cut.

(c) Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress.

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**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

(d) Remove the chips from the injector tube and, using gage J 25521, continue the reaming operation until the shoulder of the spray tip is flush to t .014" with the fire deck of the cylinder head as shown in Fig.

7. Then wash the interior of the injector tube with clean solvent and dry it with compressed air.

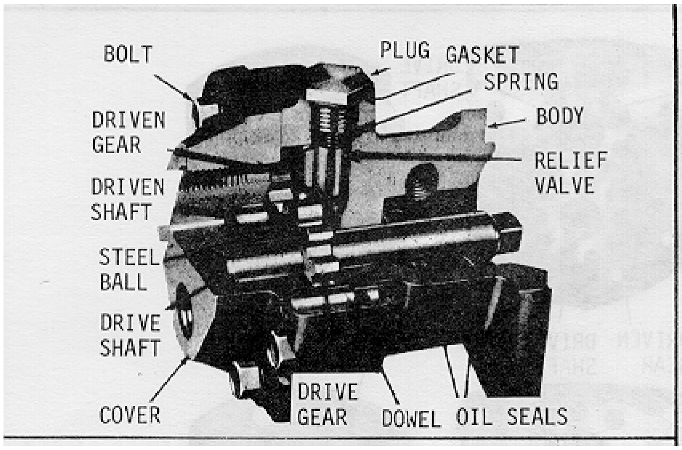


*Fig. 1 Typical Fuel Pump Assembly*

The positive displacement gear-type fuel pump (Fig. 1) transfers fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return manifold and fuel return line.

The fuel pump is attached to the governor housing with three nylon patch bolts which prevents the oil in the governor housing from seeping out around the bolt threads. The pump is driven off the end of the right-hand helix blower rotor by means of a drive coupling fork attached to the end of the pump drive shaft and mating with a drive disc attached to the blower rotor as shown in Fig. 2. The fuel pump is a left-hand rotating pump. Regardless of engine rotation, the pump will always rotate in a left-hand rotation.

The fuel pump cover and body are positioned by means of two dowels. The dowels aid in maintaining gear shaft alignment. The mating surface of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since pump clearances are set up on the basis of metal-to metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

The fuel pump body is recessed to provide running space for the pump gears (Fig. 3). Recesses are also provided at the inlet and outlet positions of the gears. The small hole 'A' permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole 'B' and provides for relief of excess discharge pressures. Fuel reenters the inlet side of the pump through hole 'C' when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole 'C'. The cavity 'D' provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

Two oil seals pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the governor housing (Fig. 4). The oil seals are installed with the lips of the seals facing toward the flanged end of the pump body. A small hole 'E' (Fig. 3) serves as a vent passageway in the body, between the inner oil seal and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the. inner seal.

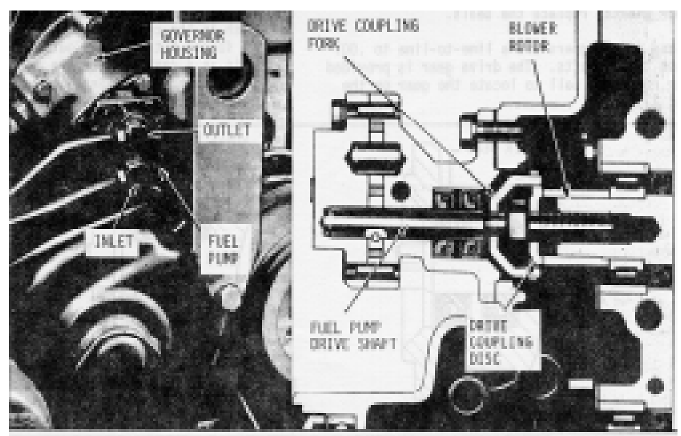


*Fig. 2 Typical Fuel Pump Mounting and Drive*

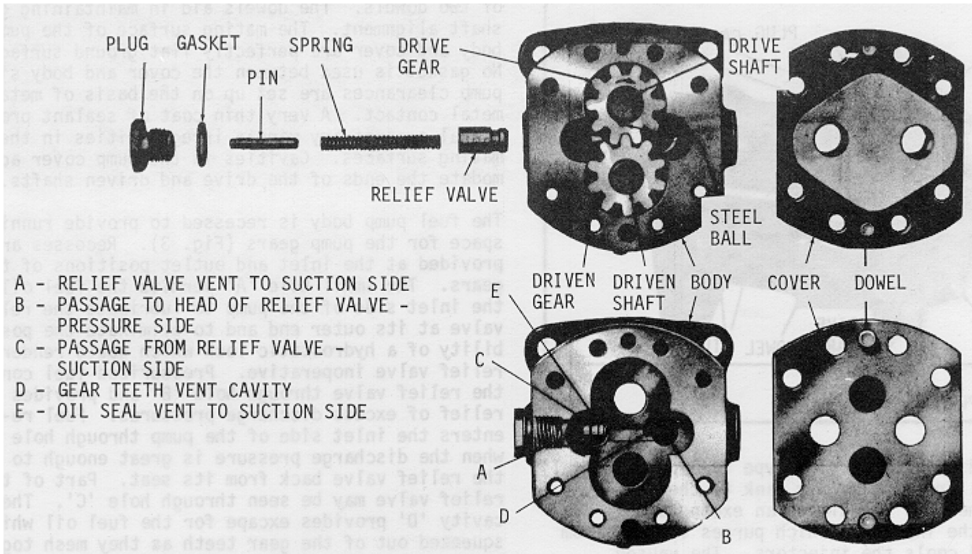


*Fig. 3 Fuel Pump Valving and Rotation*

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have-not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seep- age, Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

The drive and driven gears are a line-to-line to .001" press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft (Fig. 2). A spring-loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to / the fuel filter) reaches approximately 65 psi (448 kPa).

34.1 Operation

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel oil is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the

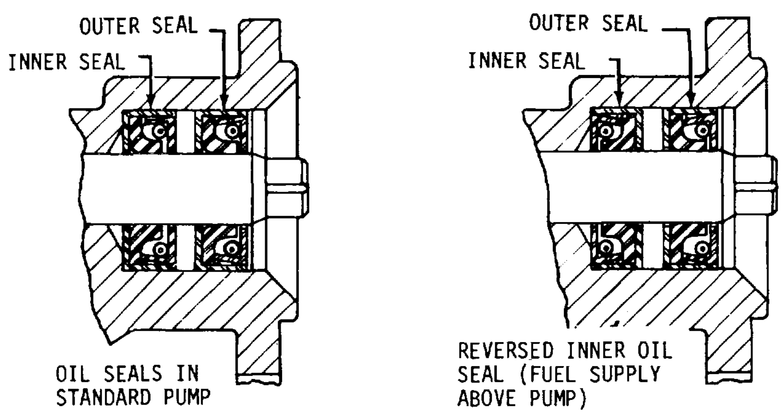


*Fig. 4 Fuel Pump Oil Seal Arrangements*

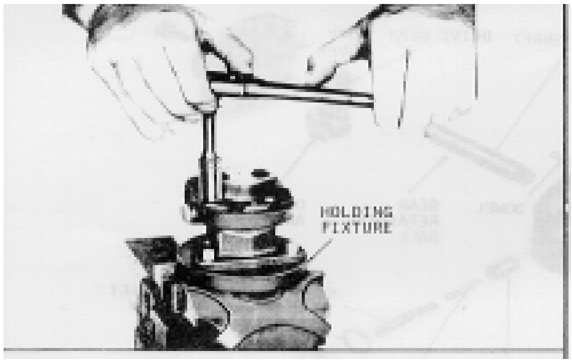


*Fig. 3 Removing Fuel Pump Cover*

fuel lines and through the engine fuel system under pressure.
The pressure relief valve relieves the discharge pressure by bypassing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 65 to 75 psi (448-517 kPa).
The fuel pump should maintain the fuel pressure at the fuel inlet manifold as shown in SM1-63-66.0.

34.2 Remove Fuel Pump

(1) Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.
(2) Remove the three pump attaching bolt and seal assemblies and withdraw the pump from the governor housing.
(3) Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

34.3 Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508-10 as shown in Fig. 5, refer to Fig. 1 and Fig. 7 and disassemble the pump as follows:

(1) Remove eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.
(2) Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.
(3) Press the drive shaft just far enough to remove the steel locking ball. Then invert the shaft and gear assembly and press the shaft from the gear. Do not misplace the steel ball. Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.
(4) Remove the driven shaft and gear as an assembly from the pump body. Do not remove the gear from the shaft. The driven gear and shaft are serviced only as an assembly.
(5) Remove the relief valve plug and copper gasket.
(6) Remove the valve spring, pin and relief valve 1 from the valve cavity in the pump body.
(7) If the oil seals need replacing, remove them with oil seal remover J 1508-13 (Fig. 6). Clamp the pump body in a bench vise and the end of the tool with a hammer to remove the outer and inner seals.

Note: Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position. 34.4 Inspection

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Clean all of the parts in clean fuel oil and dry them with compressed air.

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts if necessary. The driven shaft is serviced as a gear and shaft assembly only.

34.5 Assemble Fuel Pump

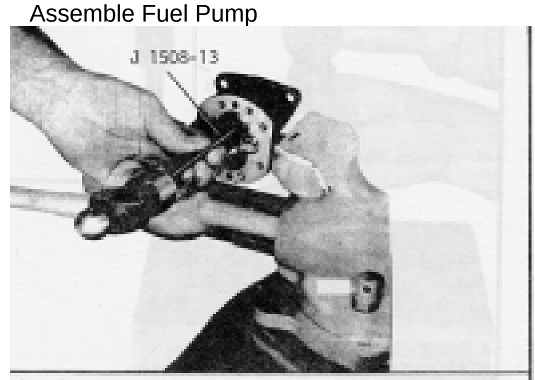


*Fig. 6 Removing Oil Seals*

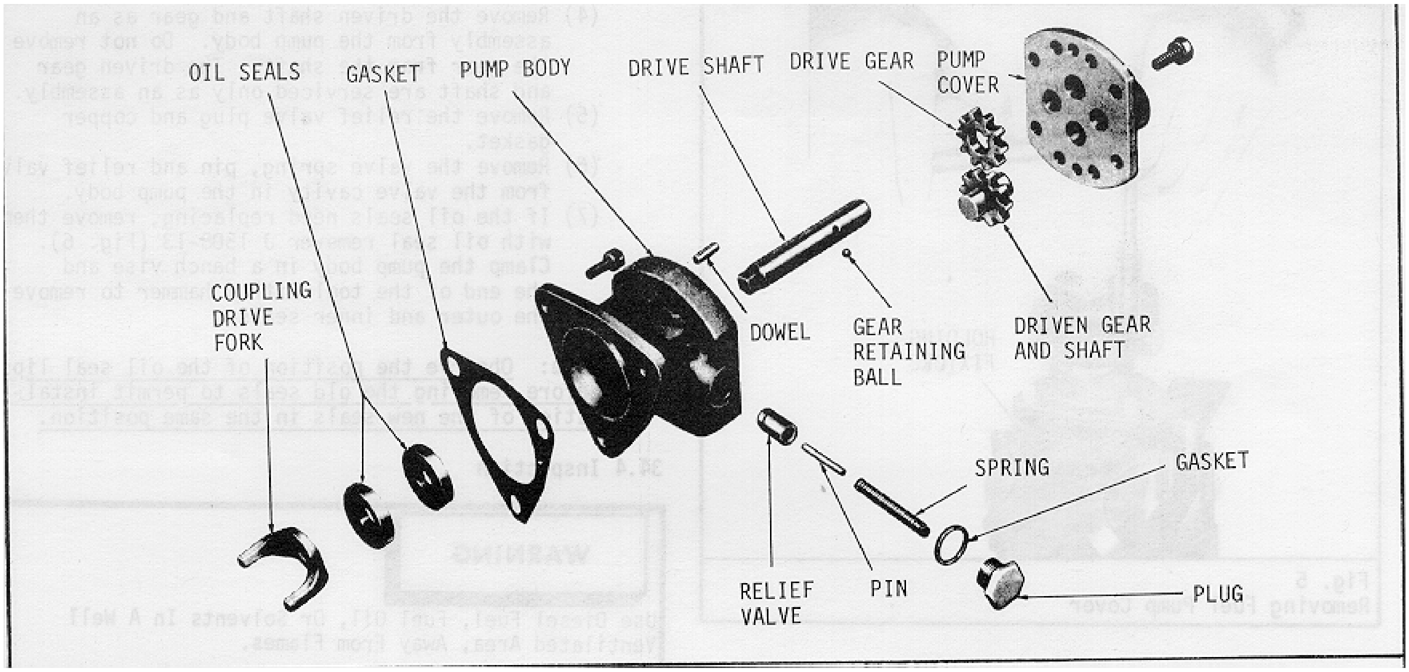


*Fig. 7 Fuel Pump Details and Relative Location of Parts*

The mating faces of the pump body and cover must be flat and smooth and fit tightly together. Any scratches or slight damage may result in pressure leaks. Also check for wear at areas contacted by the gears and shafts. Replace the pump cover or body, If necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

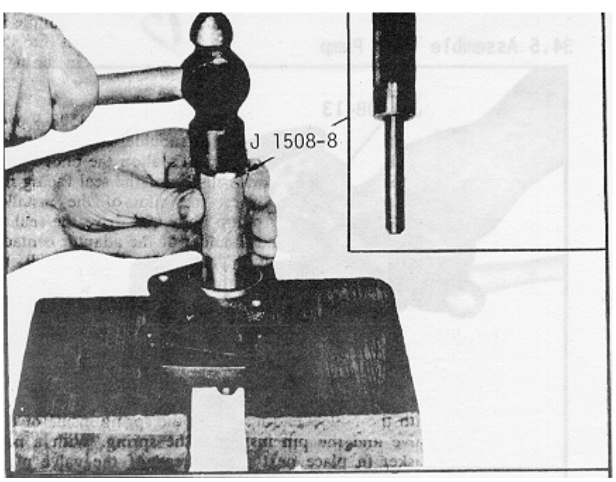


*Fig. 8 Installing Inner Oil Seal*

Refer to Fig. 1, 3 and 7 and assemble the pump as follows:

(1) Lubricate the lips of the oil seals with a light coat of vegetable shortening, then install the oil seals in the pump body as follows:

(a) Place the inner oil seal on the pilot of the installer handle J 1508-8 so that the lip of the seal will face in the same direction as the original seal which was removed, or according to the application as previously described.

(b) With the pump body supported on wood blocks (Fig. 8), insert the pilot of the installer handle in the pump body so

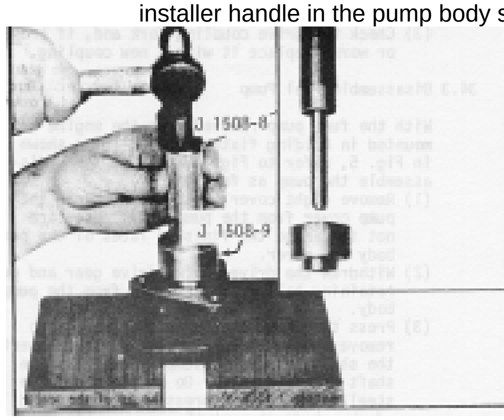


*Fig. 9 Installing Outer Oil Seal*

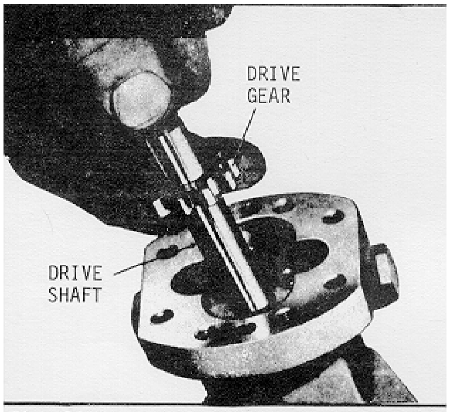


*Fig. 10 Installing Fuel Pump Drive Shaft and Gear Assembly*

the seal starts straight into the pump flange. Then drive the seal in until it bottoms.

(c) Place the shorter end of the adapter J 1508-9 over the pilot and against the shoulder of the installer handle. Place the outer seal on the pilot of the installer handle with the lip of the seal facing the adapter. Then insert the pilot of the installer handle into the pump body and drive the seal in (Fig. 9) until the shoulder of the adapter contacts the pump body. Thus the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

(2) Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring in- side of the valve and the pin inside of the spring. With a new gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the 1/2"-20 plug to 18-22 ft/lb. (24-30 N.m) torque.

(3) Install the fuel pump drive gear over the end of the drive shaft which is not squared (so the slot in the gear will face the plain end of the shaft). This operation is very important, otherwise fine score marks caused by pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the gear retaining ball detent. Then place the ball in the detent and press the gear back until the end of the slot contacts the ball.

(4) Lubricate the pump shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals as shown in Fig. 10.

(5) Place the driven shaft and gear assembly in the pump body.

Note: <u>The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.</u>

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(6) Lubricate the gears and shafts with clean engine oil.

(7) Apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area. Then place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

Note: <u>The coating of sealant must be extremely may result. thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too much sealant could increase the clearances and affect efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts</u>

(8) Secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.

(9) After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely attempt to free it by tapping a corner of the pump.

(10) Install 1/8" pipe plugs in the upper unused drain holes.

(11) If the pump is not to be installed immediately, place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

34.6 Install Fuel Pump

The pump must always be installed with the inlet opening in the pump cover (marked "L.H. IN") next to the balance weight cover. Refer to Fig. 2 and note that the fuel pump is bolted to the governor housing and is driven by the drive coupling fork and the drive disc which is attached to the blower rotor. Install the pump as follows:

(1) Affix a new gasket to the pump body mounting flange. Then place the drive coupling fork on the square end of the drive shaft.

(2) Place the fuel pump against the governor housing, being certain that the drive coupling fork registers with the slots in the drive disc.

(3) Secure the pump to the governor housing with three nylon patch bolts.

Note: To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

(4) If removed, install the fuel inlet and outlet elbows in the pump cover.

(5) Connect the inlet and outlet fuel lines to the fuel pump elbows.

(6) If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine. This will prevent the possibility of pump seizure upon initial starting.

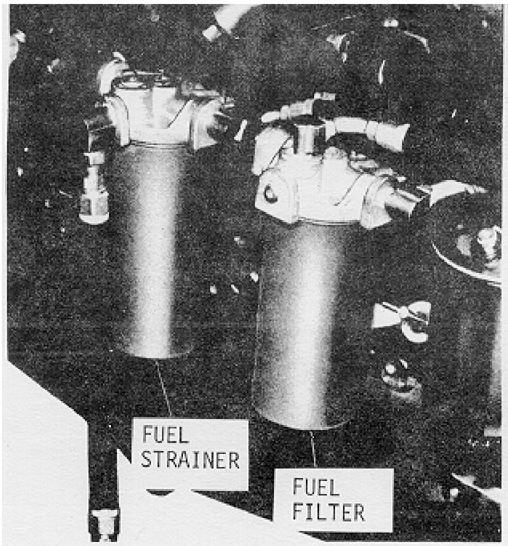


*Fig. 1 Typical Spin-On Filter Mounting*

A spin-on type fuel strainer and fuel filter (Fig. 1) is used. The spin-on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly. No separate springs or seats are required to support the filters.

The filter covers incorporate a threaded sleeve to accept the spin-on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

No drain cocks are provided on the spin-on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter.

Refill the filter with clean fuel oil before reinstalling it.

## 35.1 Operation

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The fuel filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters through the inlet passage in the cover and into the shell surrounding the filter element. Pressure or suction created by the pump causes the fuel to flow through the filter element where dirt particles are removed. Clean fuel flows to the interior of the filter element, up through the central passage in the cover and into the outlet passage, then to the fuel inlet manifold in the cylinder head.

If engine operation is erratic, indicating shortage of fuel or flow obstructions, refer to SM1-63-69.0 for corrective measures.

## 35.2 Filter Replacement

A 1-inch diameter twelve-point nut on the bottom of the filter is provided to facilitate removal and installation. Replace the filter as fol- lows:

(1) Unscrew the filter (or strainer) and discard it.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(2) Fill a new filter replacement cartridge about two-thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

(3) Install the new filter assembly and tighten it to two-thirds of a turn beyond gasket contact.

(4) Start the engine and check for leaks.

Horsepower requirements on an engine may vary due to fluctuating loads. Therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the throttle control and the fuel injectors. The govern- or is mounted on the front end of the blower and is driven by one of the blower rotors. The following type of mechanical governor is used:

Limiting Speed Mechanical Governor.

The governor has an identification plate located on the control housing, containing the governor assembly number, type, idle speed range and drive ratio. The maximum engine speed, not shown on the identification plate, is stamped on the option plate attached to the valve rocker cover.

36.1 Check Governor Operation

Governor difficulties are usually indicated by speed variations of the engine. However, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations are present, check the engine as follows:

(1) Make sure the speed changes are not the result of excessive load fluctuations.
(2) Check the engine to be sure that all of the cylinders are firing properly (refer to SM1-63-69.0). If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined in SM1-63-32.O.
(3) Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

(1) If an injector rack sticks or moves too hard, it may be due to the injector hold- down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolt to 20-25 ft/lb. (27-34 N-m) torque.
(2) An injector which is not functioning properly may have a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in SM -63-32.0.
(3) An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, re- locate the lever on the control tube and position the rack as outlined in SM1-63- 70.0.
(4) The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their no-fuel position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be re-positioned as outlined in SM1-63-70.0.
(5) A bent injector control tube return spring may cause friction in the operation of the injector control tube. If the spring has been bent or otherwise distorted, install a new spring.
(6) Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

The limiting speed mechanical governors used on the -92 engines performs the following two functions:

(1) Controls the engine idling speed.

(2) Limits the maximum operating speed of the engine. The limiting speed governors used on the V-92 engines are double-weight type.

Each governor has an identification plate located on the governor housing, containing the governor assembly number, type and idle range speed.

The governor is mounted on the front end of the blower. The governor consists of two sub-assemblies:

(1) Control Housing Cover

(2) Control and Weight Housing

37.1 Operation (Double-Weight Governor)

The governor holds the injector racks in the advanced fuel position for starting when the speed control lever is in the idle position. Immediately after starting, the governor moves the injector racks to that position required for idling.

To limit fuel input during engine start-up, when the speed control lever is in its idle position, the turbocharged engines use a starting aid screw. The starting aid screw is externally mounted in the front of the governor housing. It has a domed end and cannot be removed from the outside of the housing (Fig. 1).

The centrifugal force of the revolving governor low and high-speed weights (Fig. 1) is converted into linear motion which is transmitted through the riser and the operating shaft to the operating shaft lever. One end of this lever operates against the high and low-speed springs through the spring cap, while the other end provides a moving fulcrum on which the differential lever pivots.

When the centrifugal force of the revolving governor weights balances out the tension on the high or low-speed spring (depending on the speed range), the governor stabilizes the engine speed for a given setting of the speed control lever.

In the low-speed range, the centrifugal force of the low and high-speed weights together operate against the low-speed spring. As the engine speed increases, the centrifugal force of the low and high-speed weights together compress the low-speed spring until the low-speed weights are against their stops, thus limiting their travel, at which time the low-speed spring is fully

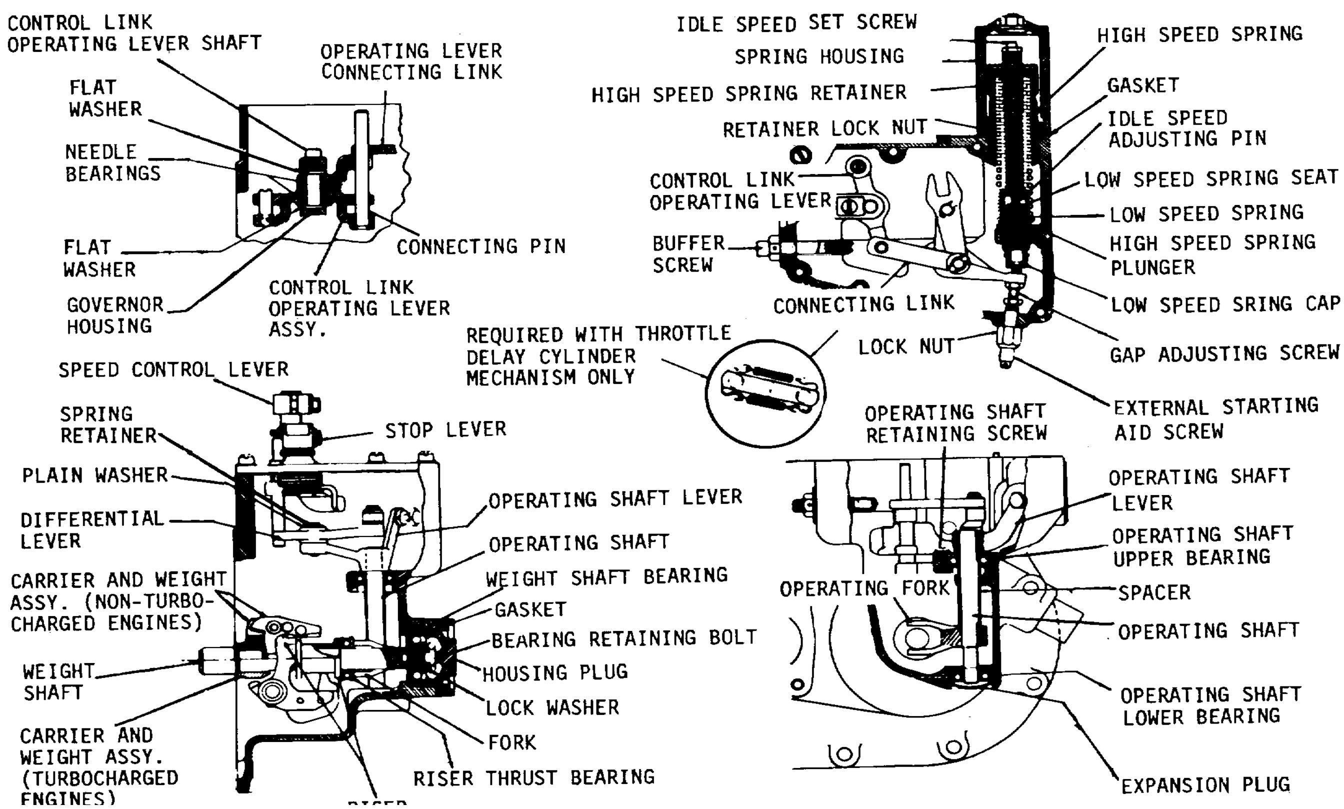


*Fig. 1 Cross Section of Double Weight Limiting Speed Mechanical Governor*

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compressed and the low-speed spring cap is within .0015" of the high-speed spring plunger.

Throughout the intermediate speed range the operator has complete control of the engine because both the low-speed spring and the low- speed weights are against their stops, and the high-speed weights are not exerting enough force to overcome the high-speed spring.

As the speed continues to increase, the centrifugal force of the high-speed weights increases until this force can overcome the high-speed spring and the governor again takes control of the engine, limiting the maximum engine speed.

Fuel rods are connected to the differential lever and injector control tube levers through the control link operating lever and connecting link. This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the force exerted by the governor low-speed spring. When the governor speed control lever is placed in the idle position, the engine will operate at the speed where the force exerted by the governor low-speed weights will equal the force exerted by the governor low-speed spring.

Adjustment of the engine idle speed is accomplished by changing the force on the low-speed spring by means of the idle adjusting screw. Refer to SM1-63-68.0 for idle speed adjustment.

The engine maximum no-load speed is determined by the force exerted by the high-speed spring. When the governor speed control lever is placed in the maximum speed position, the engine will operate at a speed where the force exerted by the governor high-speed weights will equal the force exerted by the governor high-speed spring.

Adjustment of the maximum no-load speed is accomplished by the high-speed spring retainer. Movement of the high-speed spring retainer will increase or decrease the tension on the high- speed spring. Refer to SM1-63-68.0 for the maximum no-load speed adjustment.

37.2 Lubrication

The governor is lubricated by a spray of lubricating oil from the blower end plate. The governor weights distribute this oil to all parts of the governor assembly requiring lubrication.

Oil returning from the governor is directed through passages in the blower end plate and cylinder block to the engine oil pan.

37.3 Remove Governor From Engine

Governor operation should be checked as outlined in SM1-63-36.0 before the governor is removed from the engine. If, after performing these checks, the governor fails to control the engine properly, it should be removed and reconditioned.

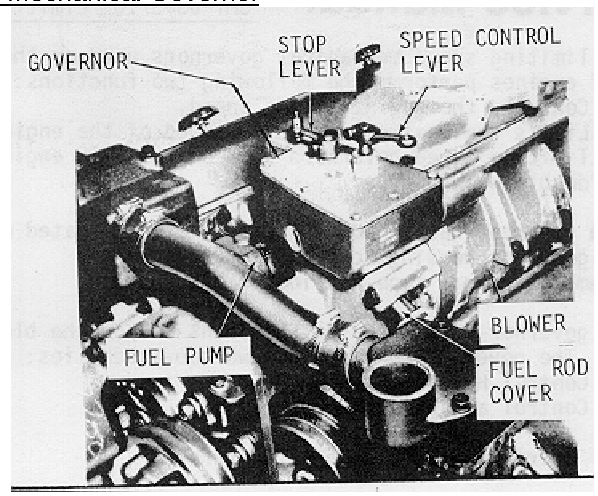


*Fig. 2 Limiting Speed Mechanical Governor Mounting*

(1) Open the drain cocks and drain the engine cooling system.
(2) Remove any accessories attached to the cylinder head, governor or front end of the engine that interfere with the removal of the governor assembly.
(3) Disconnect the control linkage from the speed control and stop levers (Fig. 2).
(4) Remove the eight screws and lock washers securing the governor cover to the housing. Lift the cover and gasket from the housing.
(5) Remove the fuel rods from the control link operating lever assembly (Fig. 1) and the injector control tube levers as follows:
(a) Remove the valve rocker covers from the cylinder heads.
(b) Remove the right bank fuel rod by re- moving the screw type pin, in the control link operating lever, and the clevis pin in the control tube lever and withdraw the fuel rod from the governor.
(c) Remove the left bank fuel rod by removing the clevis pin in the control tube lever and lift the connecting pin up out of the control link operating lever approximately three-quarters of an inch. Then withdraw the fuel rod from the governor.
(6) Loosen the hose clamps at each end of the water bypass tube. Slide the hoses and clamps onto the bypass tube and remove the tube from the engine.
(7) Disconnect and remove the fuel oil lines attached to the fuel pump and the crossover fuel oil line attached to each cylinder head.
(8) Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head and slide each hose and clamp up on the tube in the governor housing.
(9) Note the location of the two copper, one plain and eight lock washers on the governor-to-blower bolts before removing them. Then remove the ten bolts and washers

(two inside and eight outside) securing the governor and fuel pump assembly to the blower.

(10) Tap the sides of the governor housing light- ly with a plastic hammer to loosen the governor from the blower. Then pull the governor and fuel pump assembly straight out from the dowels in the blower end plate. Remove the governor-to-blower gasket.

Note: The fuel pump drive coupling fork may stay on either the fuel pump or the blower rotor shaft. Remove the drive coupling fork.

(11) Remove the three bolt and seal assemblies securing the fuel pump assembly to the governor housing. Remove the fuel pump and gasket from the governor housing.

37.4 Disassemble Governor

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Before removing any parts from the governor, wash the entire unit in clean fuel oil, dry it with compressed air and inspect for worn or damaged parts which may be repaired or replaced without complete disassembly.

(1) Disassemble the governor cover (Fig. 3) as follows:

(a) Remove the lubrication fitting from the speed control shaft.

(b) Loosen the speed control lever retaining bolt and lift the control lever from the speed control shaft.

(c) Remove the spacer, snap ring and two seal ring retaining washers, and seal ring from the speed control shaft. Withdraw the shaft from the cover.

(d) Loosen the bolt securing the stop lever to the stop lever shaft and remove the stop lever.

(e) Remove the snap ring, two seal ring retaining washers, and seal ring from

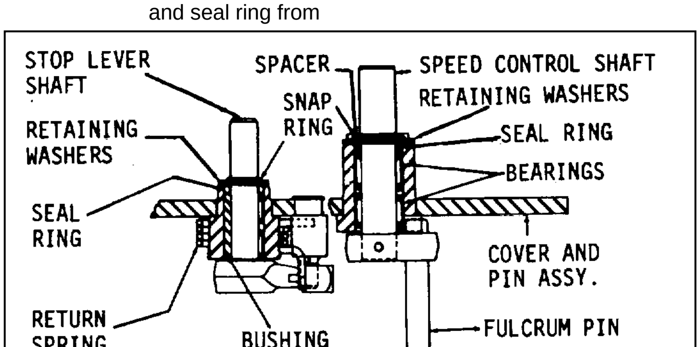


*Fig. 3*
*Cross Section of Governor Cover*

lever shaft and the lever shaft return spring from the cover.

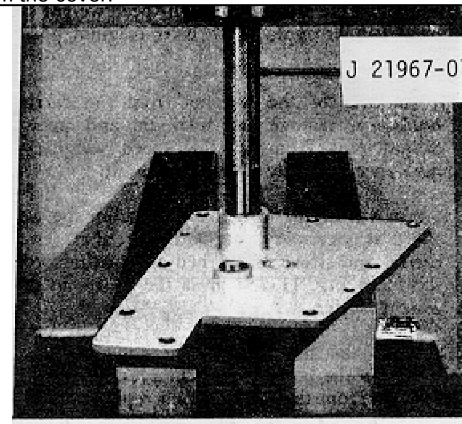


*Fig. 4*
*Removing Speed Control Shaft Bearing from Governor Cover*

the stop lever shaft. Withdraw the

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

(f) Wash the cover assembly thoroughly in clean fuel oil and inspect the needle bearings and bushings for wear or damage. If the bearings and bushings are satisfactory for further use, removal is un- necessary.

(g) If needle bearing removal is necessary, place the inner face of the cover over the opening on the bed of an arbor press. Place remover J 21967-01 on the top of the bearing and under the ram of the press, then press both bearings out of the cover as shown in Fiq. 4.

(h) Remove the bushing from the stop lever shaft opening using remover J 8985 as shown in Fig. 5.

(2) Refer to Fig. 1 and Fig. 17 and disassemble the high and low-speed springs, plunger and adjusting screw.

(a) Clamp the flange of the governor housing ,in a vise equipped with soft jaws.

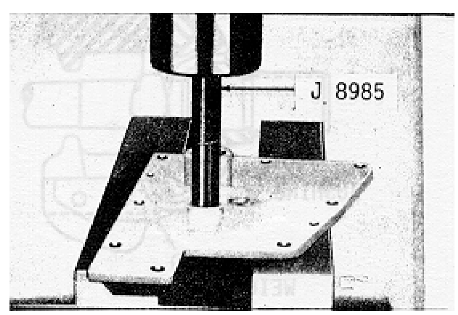


*Fig. 5*
*Removing Stop Lever Shaft Bushings from Governor Cover*

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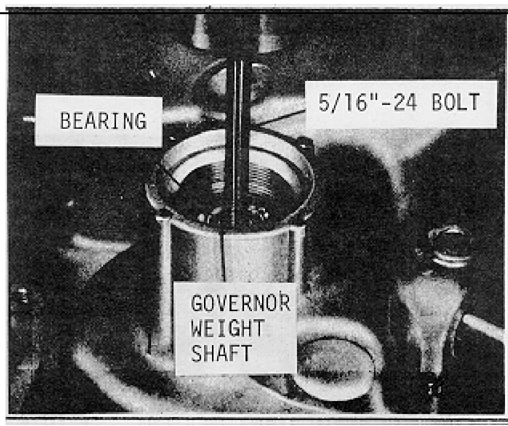


*Fig. 6*
*Removing Governor Weight Shaft Assembly from Governor Housing*

(b) Remove the two bolts and copper washers securing the high-speed spring retainer housing to the governor housing and withdraw the retainer housing and gasket.

(c) Loosen the high-speed spring retainer lock nut (Fig. 1) with a spanner wrench J 5345-5. Then remove the high-speed spring retainer, idle speed adjusting screw, high-speed spring, spring plunger, low-speed spring, spring seat and spring cap as an assembly.

(d) Remove the low-speed spring cap, spring and spring seat from the high-speed spring plunger. Depress the high speed spring by hand and remove the idle speed adjusting screw lock nut. Remove the high-speed spring retainer, high-speed spring and idle speed adjusting screw from the high-speed plunger.

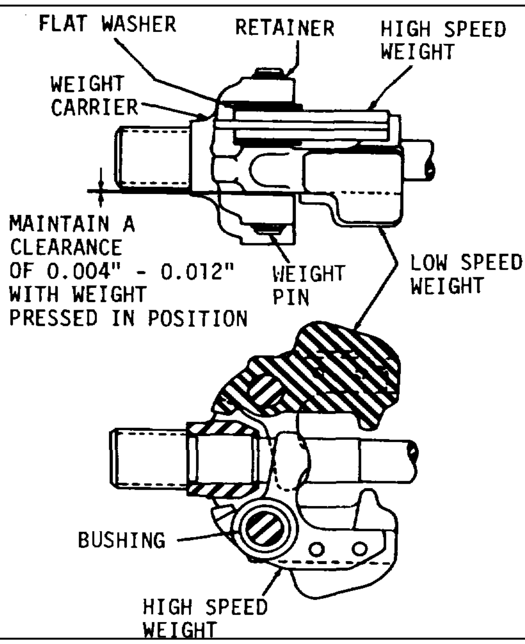


*Fig. 7*
*Cross Section of Governor Weight Assemblies*

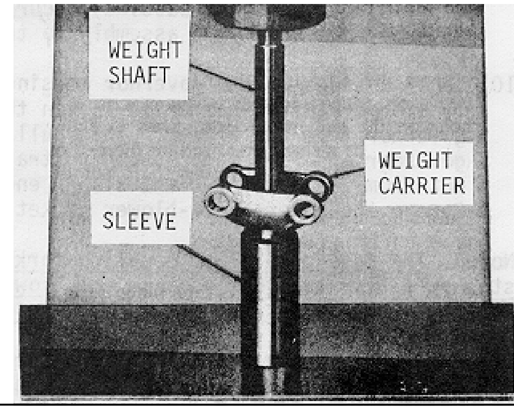


*Fig. 8*
*Removing Governor Weight Shaft from Weight Carrier*

(3) Remove the governor weights and shaft assembly from the governor housing as follows:

(a) Clamp the flange of the governor housing in a vise equipped with soft jaws.

(b) Remove the governor weight housing plug and gasket (Fig. 1).

(c) Bend the tang on the lock washer away from the head of the bolt. Then, while holding the weight carrier from turning, remove the bearing retaining bolt, flat washer and lock washer.

(d) Thread a 5/16"-24 x 3" bolt into the bearing retaining bolt hole. Support the governor housing on the bed of an arbor press and press the governor weight shaft from the bearing as shown in Fig. 6.

(e) Slide the governor riser thrust bearing and riser from the weight shaft.

Note: <u>The thrust bearing is specially designed to absorb thrust load; therefore, looseness between the mating parts does not indicate excessive wear.</u>

(f) Remove the weight shaft bearing from the governor housing. If necessary, use a small brass rod and hammer and tap the bearing out of the housing.

(4) Disassemble the governor weights and shaft assembly on turbocharged engines as follows:

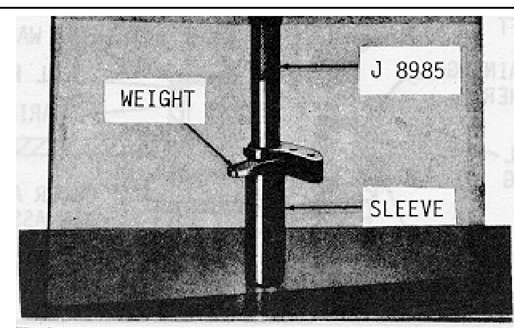


*Fig. 9*
*Removing Governor Weight Bearings*

(a) Matchmark the low and high-speed weights and carrier with the paint or a center punch for identification; also note the position of the flat washer at the side of the high-speed weight so the parts can be replaced in their original positions (Fig. 7).

(b) If removal of the weights from the carrier is necessary, remove the retainers and press the weight pins from the low-speed weights. The high-speed weights are not a press fit.

(c) If removal of the weight carrier from the weight shaft is necessary, support the shaft, weight carrier and sleeve on the bed of an arbor press as shown in Fig. 8 and press the shaft out of the weight carrier.

(d) Position the high-speed governor weight on a sleeve on the bed of an arbor press and press the bearing from the weight using replacer J 8985 as shown in Fig. 9.

(5) Remove the governor linkage and operating shaft from the governor housing as follows:

(a) Remove the spring retainer and plain washer securing the connecting link to the differential lever and remove the connecting link.

(b) Remove the spring retainer and plain washer securing the differential lever to the operating shaft lever and remove the differential lever.

Note: Remove the low-speed gap adjusting screw from the operating shaft lever, if necessary.

(c) Remove the screw, lock washer and lock clip securing the control link operating lever shaft in the housing. Lift the shaft out of the housing and remove the operating lever and two flat washers at each side of the operating lever.

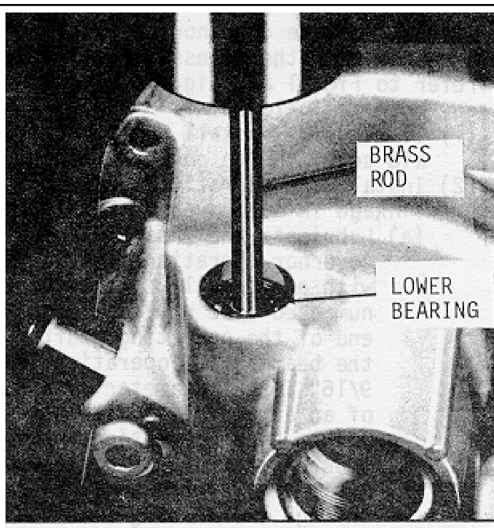


*Fig. 10*
*Removing Operating Shaft from Operating Shaft Lower Bearing*

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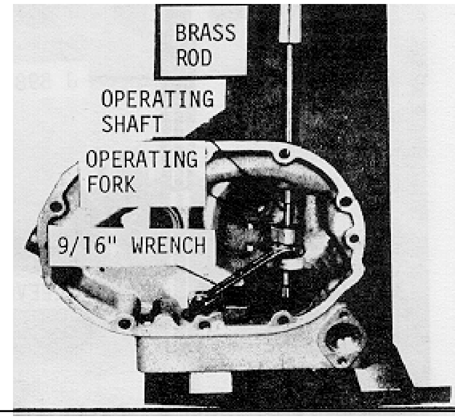


*Fig. 11*
*Removing Operating Fork Shaft and Lever Assembly from Governor Housing*

Note: Be sure not to lose the two flat washers located between the top and bottom of the lever assembly and the governor housing.

(d) Remove the expansion plug from the bottom of the governor housing (Fig. 1).

(e) Remove the operating shaft upper bearing retainer screw, lock washer and flat washer securing the bearing in the governor housing.

(f) Support the governor housing bottom side up on the bed of an arbor press, with the two dowel pins in the top of the housing between the two steel supports. Place a small brass rod on the end of the operating shaft and press the shaft out of the bearing (Fig. 10).

(g) With the housing still supported on the bed of the press, place a 9/16" open end wrench under the operating fork as shown in Fig. 11. Place a brass rod on the end of the shaft and press the fork off of the operating shaft. Remove the shaft, operating lever and bearing as

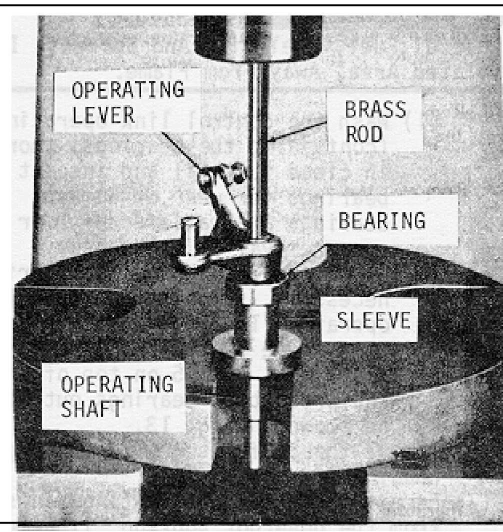


*Fig. 12*
*Removing Operating Lever and Upper Bearing from Operating Shaft.*

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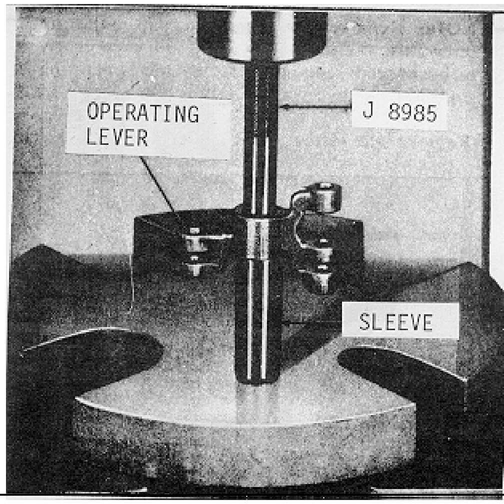


*Fig. 13*
*Removing Operating Lever Needle Bearings*

an assembly from the housing.

(h) Remove the operating shaft lower bearing from the bottom of the governor housing.

(i) Slide the governor operating shaft spacer from the shaft.

(j) Place a short 9/16" inside diameter sleeve over the end of the operating shaft and rest it against the inner race of the bearing on the operating shaft.

(k) Support the operating shaft, lever, bearing and sleeve on a large washer or plate, with a 5/8" hole on the bed of an arbor press, as shown in Fig. 12. Place a small brass rod on the end of the shaft and press the operating shaft out of the operating lever and bearing. Catch the shaft by hand when pressed from the lever and bearing to prevent it from falling and being damaged.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(l) Wash the control link operating lever (containing the bearings) thoroughly in clean fuel oil and inspect the needle bearings for wear or damage. If the bearings are satisfactory for further use, removal is unnecessary.

(m) If removal of the needle bearing is necessary, support the control link operating lever on a sleeve and rest the sleeve on the bed of an arbor press. Place tool J 8985 on top of the bearing and press both bearings out of the lever as shown in Fig. 13.

(6) Remove the buffer screw from the governor housing.

(7) Remove the external starting aid screw from the governor housing, if necessary.

37.5 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames. Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wash all of the governor parts in clean fuel oil and dry them with compressed air.

Examine the bearings for any indications of corrosion or pitting. Lubricate each bearing with light engine oil. Then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion.

Examine the weight carrier pins and bushings in the weights for wear.

Examine the control link operating lever shaft and needle bearings for wear or damage.

If the speed control and stop lever shaft are worn excessively due to worn or damaged needle bearings and bushing, replace the shafts, needle bearings and bushing in the cover.

Inspect the spring seats, plunger, adjusting screws, lock nuts, pins, seal rings and any other parts in the governor housing for wear or defects that might affect governor operation.

Replace all of the parts that are worn or damaged.

37.6 Assemble Governor

With all of the governor parts cleaned and inspected and the necessary new parts on hand, refer to Fig. 1 and Fig. 14 and assemble the governor as follows:

(1) If removed, install the external starting aid screw in the governor housing.

(2) Install the operating shaft and governor linkage in the governor housing as follows:

(a) Lubricate the inside diameter of the governor operating shaft upper bearing with engine oil. Start the bearing, numbered side up, straight on the large end of the operating shaft. Support the bearing and operating shaft on a 9/16" inside diameter sleeve on the bed of an arbor press, with the inner race of the bearing resting on the sleeve, then press the shaft into the bearing until 1/4" of the shaft protrudes through the bearing. Install the bearing, numbered side up, on the shaft and press it tight against the bearing washer.

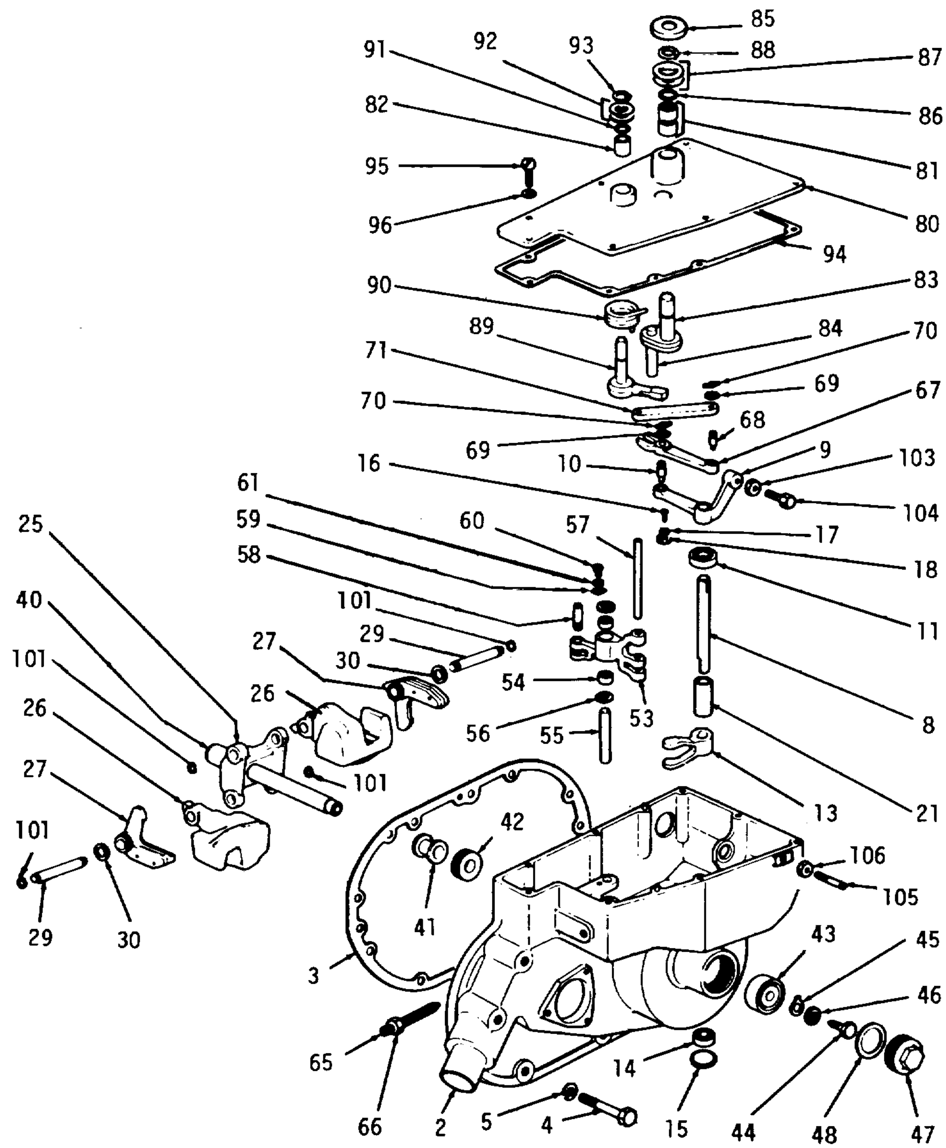


*Fig. 14*
*Limiting Speed Double Weight Governor Details and Relative Locating of Parts*

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(2) Housing - Governor (44) Bolt - Bearing Retainer (71) Link - Operating Lever
(3) Gasket - Housing to Blower (45) Lock Washer - Special Connecting
(4) Bolt - Housing to Blower (46) Flat Washer (80) Cover - Governor Housing
(5) Lock Washer (47) Plug - Governor Housing (81) Bearing - Speed Control Shaft
(8) Shaft - Governor Operating (48) Gasket - Housing Plug (82) Bushing - Stop Lever Shaft
(9) Lever - Operating Shaft (53 Lever - Control Link Operating (83) Shaft - Speed Control Lever
(10) Pin - Shaft Lever (54) Bearing - Operating Lever (84) Pin - Fulcrum Lever
(11) Bearing - Operating Shaft, Upper (55) Shaft - Operating Lever (85) Spacer - Speed Control Shaft
(13) Fork - Operating Shaft (56) Washer - Operating Lever Shim (86) Ring - Control Shaft Seal
(14) Bearing - Operating Shaft, Lower (57) Pin - Fuel Rod Connecting (87) Washer - Seal Ring Retainer
(15) Plug - Expansion (Long) (88) Snap Ring - Speed Control Shaft
(16) Screw - Bearing Retaining (58) Pin - Fuel Rod Connecting (89) Shaft - Stop Lever
(17) Lock Washer (Short) (90) Spring-Stop Lever Shaft Return
(18) Flat Washer (59) Clip - Operating Lever Shaft (91) Ring - Stop Shaft Seal
(21) Spacer - Operating Shaft Lock (92) Washer - Seal Ring Retainer
(25) Carrier - Governor Weight (60) Screw - Lock Clip (93) Snap Ring - Stop Shaft
(26) Weight - Low Speed (61) Lock Washer (94) Gasket - Governor Housing Cover
(27) Weight - High Speed (65) Screw - Buffer (95) Screw - Housing Cover
(29) Pin - Weight (66) Lock Nut - Buffer Screw (96) Lock Washer
(30) Flat Washer (67) Lever - Governor Differential (101) Ring - Weight Pin Retainer
(40) Shaft - Weight Carrier (68) Pin - Differential Lever (103) Locknut
(41) Riser - Governor (69)Washer - Differential Lever & (104)Screw, Gap Adjusting, External
(42) Bearing - Riser Thrust Connecting Link Flat (105) Screw, Starting Aid Adjusting
(43) Bearing - Weight Carrier Shaft (70) Retainer - Spring (External)
End (106) Locknut

*Fig. 14*
*Limiting Speed Double weight Governor Details and Relative Location of Parts*

(b) Lubricate the inside diameter or the governor operating shaft lever with engine oil. Start the lever, pivot pin in operating lever facing up, straight on the operating shaft with the flat on the shaft registering with the flat surface in the lever. Support the operating lever, bearing and shaft on the bed of an arbor press with a steel support directly under the center of the lever, then press the operating shaft through the bearing and lever until the end of the shaft contacts the steel support.

Note: The upper end of the shaft must be flush with the top surface of the lever.

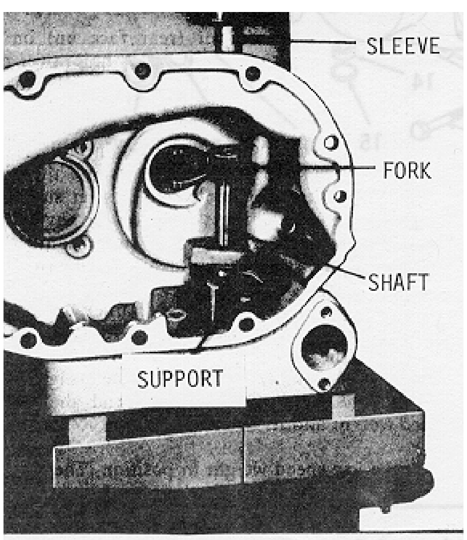



*Fig. 15*
*Installing Governor Operating Shaft Fork on Shaft*

(c) Place the operating shaft over the lower end of the shaft and slide it against the upper bearing inner race.

(d) Insert the end of the governor operating shaft, bearing, spacer and lever assembly through the upper bearing bore in the governor housing with the lever positioned as shown in Fig. 1

Note: If removed, install the low-speed gap adjusting screw in the operating shaft lever and thread the starting aid screw in the g adjusting screw (Fig. 1).

(e) Lubricate the inside diameter of the governor operating shaft fork with engine oil, then place the operating fork over the lower end of the shaft with the finished cam surfaces on the fork fingers facing the rear of the governor housing and the flat on the shaft registering with the flat surface in the fork.

(f) Support the governor housing and operating shaft assembly on the bed of an arbor press with the upper end of the operating shaft resting on a steel support as shown in Fig. 15. Place a 7/16" inside diameter sleeve over the end of the shaft and against the fork, then press the fork right against the shaft spacer on the shaft.

(g) Lubricate the governor operating shaft lower bearing with engine oil. Start the bearing, numbered side up, straight in the governor housing and over the end of the operating shaft.

(h) Support the governor housing and operating shaft assembly on the bed of an arbor press with the upper end of the operating shaft resting on a steel support as shown in Fig. 15. Place a 7/16" inside diameter sleeve on the inner race of the bearing and under the ram of the press, then press the bearing on the shaft until it seats on the shoulder in the housing.

(i) Install the governor operating shaft upper bearing retaining flat washer, lock washer and screw in the governor housing (Fig. 1).

(j) Apply a thin coat of good quality sealant around the edge of a new expansion plug. Place the plug, concave side up, in the opening in the housing next to the lower operating shaft bearing. Tap the center of the plug with a hammer to secure the plug in the housing.

(k) Place the differential lever over the pivot pin in the operating lever, pin in lever up, and secure it in place with a plain washer and spring retainer.

(l) If removed, place the control link operating lever on the bed of an arbor press with steel support under the bearing bore. Lubricate the bearing with engine oil and start the bearing, numbered end up, straight into the bore of the lever. Insert the pilot end of installer J 8985 in the bearing and under the ram of the press. Then press the bearing into the lever until it is flush with the top surface of the lever. Reverse the lever on the press and install the second bearing in the same manner.

(m) Lubricate the control link operating lever needle bearings with Shell Alvania No. 2 grease, or equivalent. Place the operating lever in position between the two bosses inside the governor housing. Insert a flat washer on each side of the lever (Fig. 1). Then install the operating lever shaft with the slot (in the side at one end of the shaft) up.

(n) Align the slot in the operating lever shaft with the lock clip screw hole in the boss next to the shaft. Install the lock clip, lock washer and screw and tighten it securely.

(o) Place one end of the connecting link over the differential lever pin and secure it in place with a washer and spring retainer (Fig. 1). Place the opposite end of the connecting link on top of the control link operating lever and install the connecting pin.

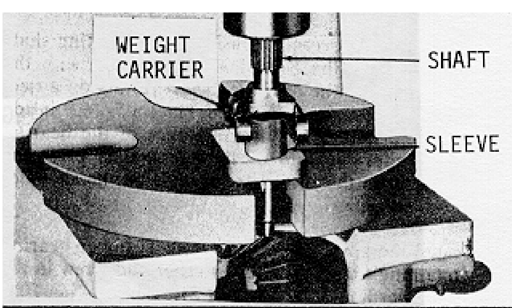



*Fig. 16*
*Installing Governor Weight Shaft in Weight Carrier*

(p) If removed, thread the lock nut on the buffer screw and thread the buffer screw into the governor housing.

(3) Assemble the governor double weight and shaft assembly on turbocharged engines (Fig. 15) as follows:

If the governor weight carrier assembly was removed from the weight shaft, the low and high-speed weights must be removed from the carrier before attempting to install the carrier on the shaft.

(a) Support the weight carrier (rear face up) on a sleeve and a steel support (with 1" hole) over an opening in the bed of an arbor press as shown in Fig. 16.

(b) Lubricate the weight shaft with engine oil. Then insert the non-splined end of the shaft through the carrier, sleeve and hole in the steel support. Bring the ram of the press down on the shaft and press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.

(c) Refer to Fig. 7 and install a retainer on either end of the weight pin. Note the match marks placed on the weight carrier and weights at the time of disassembly. Then slide the weight pin through the carrier, flat washer, and the high-speed weight and its bushing.

(d) Place the low-speed weight in position. Then press the weight pin through the low-speed weight and carrier until the retainer bottoms against the carrier. Maintain a clearance of .004" to .012" with the weight pressed in position.

Note: To maintain this clearance, insert a .004" to .012" shim between the low-speed weight and carrier while pressing the pin-into position.

(e) Remove the shim and install the second weight pin retainer.

(f) Install the second pair of weights in the carrier in the same manner as described above.

(4) Install the governor weight and shaft assem*bly* in the governor housing as follows:

(a) Slide the governor riser on the weight shaft and against the fingers of the high-speed weight.

(b) Place the governor riser thrust bearing over the weight shaft with the bearing race having the smaller inside diameter against the riser. Incorrect installation of the bearing will result in erratic operation of the governor.

(c) Insert the weight carrier and shaft assembly in the governor housing. Then support the splined end of the shaft and the governor housing on the bed of an

**Service Manual** SM1-63-37.0 Limiting Speed Mechanical Governor

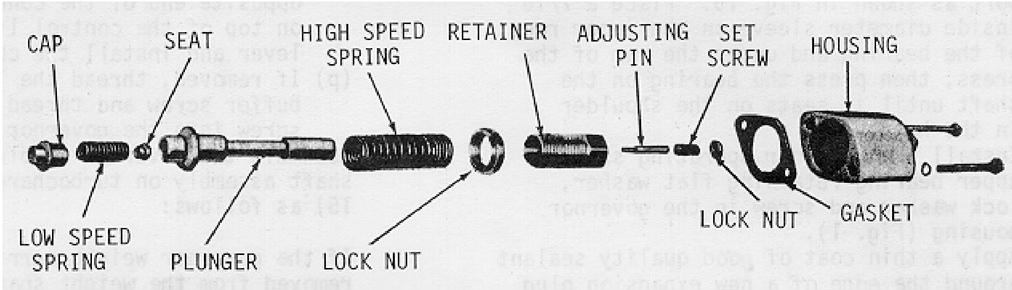



*Fig. 17*

*High and Low-Speed Springs and Plunger Details and Relative Location of Parts (other than Fuel Squeezer Engines)*

arbor press with the upper end of the shaft under the ram of the press.

(d) Place the weight shaft bearing in the governor housing (numbered side up) and start it straight on the end of the weight carrier shaft. Place a sleeve with a 1/2" inside diameter on top of the bearing inner race. Bring the ram of the press down on the sleeve and press the bearing into the housing and against the shoulder on the shaft.

(e) Place the special lock washer on the end of the weight carrier shaft with the tang on the inner diameter of the washer in the notch in the end of the shaft.

(f) Place the flat washer on the bearing retainer bolt and thread the bolt into the shaft. Clamp the splined end of the weight carrier shaft in the soft jaws of a bench vise and tighten the bearing retainer bolt to 15-19 ft/lb. (20-26 N.m) torque. Bend the tang on the lock washer against the head of the bolt.

(g) Place a gasket against the weight shaft bearing. Apply a sealant such as Loctite grade H, HV or HVW or equivalent on the threads of the governor housing and the plug and thread the plug into the housing. Tighten the plug to 45 ft/lb. (61 N.m) torque.

Note: Rotate the governor weight assembly to see that there is no bind. If bind exists, remove the housing plug and check to see if the weight shaft bearing is fully seated in the governor housing.

(5) Refer to Fig. 1 and Fig. 17 and assemble the high and low-speed spring, plunger and adjusting screw:

(a) If removed, thread the retainer lock nut on the high-speed spring retainer approximately 1-1/2". Place the high-speed spring on the high-speed spring plunger with the loosely wound end of the spring against the shoulder of the plunger.

(b) Insert the high-speed spring and plunger assembly in the high-speed spring retainer. Thread the idle speed adjusting screw into the threaded end of the plunger approximately 1/2". Then thread the lock nut on the idle speed adjusting screw.

(c) Place the low-speed spring in the low-speed spring cap and the small end of the low-speed spring seat in the opposite end of the spring.

(d) Insert the low-speed spring seat, spring and cap assembly into the high-speed spring plunger and over the idle speed adjusting screw.

(e) Affix a new high-speed spring retainer housing gasket to the governor housing.

(f) Insert the spring, plunger and retainer assembly into the opening in the governor housing and thread the retainer into the housing approximately one inch.

(g) Install the high-speed spring retainer housing after the governor assembly has been installed on the engine and the governor adjustment procedures performed as outlined in SM1-63-68.0.

(6) Assemble the governor cover (Fig. 3) as follows:

(a) If the speed control lever shatt needle bearing were removed from the cover, place the cover, inner face down, on two steel supports on the bed of an arbor press. Lubricate the outside diameter of a bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

(b) Place the correct end of the bearing Fig. 18 Installing Bearings in Governor Cover

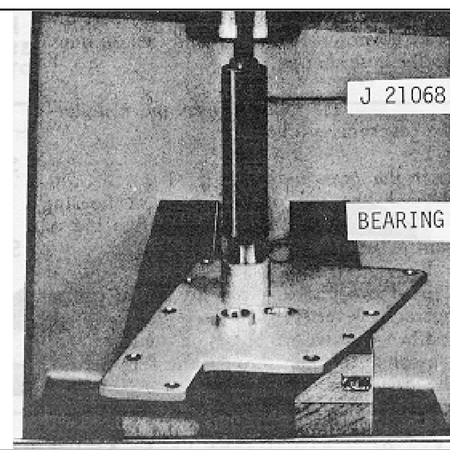



*Fig. 18*

*Installing Bearings in governor cover*

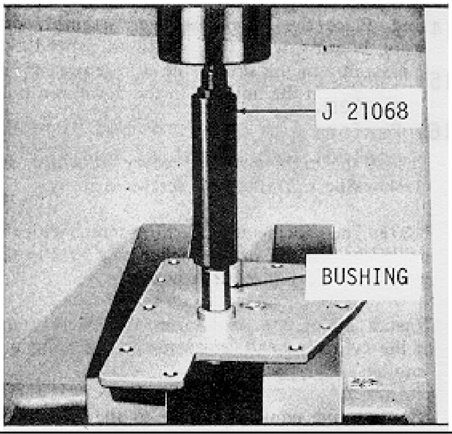



*Fig. I1*
*Installing Bushing in Governor Cover*

installer J 21068 in the bearing and under the ram of the press as shown in Fig. 18. Then press the bearing into the bore until the stop on the installer contacts the cover boss.

Note: Installer J 21068 has a pilot on each end; one end is for the speed control shaft upper bearing and the other is for the stop shaft bushing or upper bearing.

(c) Reverse the governor cover, inner face up, on the bed of the arbor press. Lubricate the outside diameter of the lower bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

(d) Place the bearing installer J 21068 in the bearing and under the ram of the press. Then press the bearing in the bore until it is flush with the face of the boss.

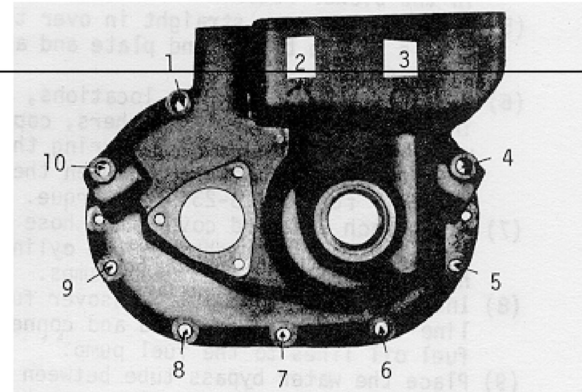
(e) On a governor equipped with a stop lever shaft bushing, install the bushing in the cover (Fig. 19) in the same manner as described in Steps a and b above. Use the small pilot end of installer J 21068 to install the bushing.

(f) Lubricate the stop lever shaft needle bearings or bushing with Shell Alvania No. 2 grease, or equivalent.

(g) Place the stop lever shaft return spring over the boss on the inner face of the cover as shown in Fig. 3. Insert the shaft part way through the bearings or bushing and hook the end of the return spring over the end of the lever, then push the shaft up in the cover. Position the end of the lever on the right side of the stop pin (Fig. 3).

(h) Place the seal ring over the shaft and push it into the bearing bore and against the bushing. Place the two seal ring retainer washers on the shaft and against the cover boss, then in- stall the snap ring in the groove in the shaft.

(i) Install the stop lever on the shaft and secure it in place with the




| Bolt Size: | Washer: | Position: |
|---|---|---|
| 5/16" .18 x 5 ¼" | Copper | 4 |
| 5/16" .18 x 4 | Copper | 10 |
| 5/16" .18 x 3 ¾" | Lock and plain | 1 |
| 5/16" .18 x 2 ¼" | Lock | 2-3-5-6-7-8-9 |

*Fig. 20*
*Location and Size of Governor Retaining Bolts*

retaining bolt and lock washer.

(j) Lubricate the speed control shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then insert the speed control shaft through the bearings.

(k) Place the seal ring over the shaft and push it into the bearing bore and against the bearing. Place the two seal ring retainer washers on the shaft and against the cover boss, then install the snap ring in the groove in the shaft.

(l) Install the spacer on the speed control shaft (slip fit) against the retaining washers and over the snap ring.

(m) Install the speed control lever on the shaft and secure it in place with the retaining bolt and lock washer. Be sure the lever contacts the spacer.

(n) Install the lubrication fitting in the speed control shaft.

37.7 Install Governor on Engine

(1) Affix a new gasket to the bolting flange of the fuel pump. Place the fuel pump against the governor housing in its original position and secure it in place with the three bolt and seal assemblies. Tighten the bolts to 13-17 ft/lb. (18-23 N.m) torque.

(2) If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing.

(3) Affix a new gasket to the forward face of the blower end plate.

(4) Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the prongs of the fork align with the slots in the drive disc. Rotate the weight shaft and align the splines on the shaft with the splines

in the blower rotor.

(5) Push the governor straight in over the dowels in the blower end plate and against the gasket.

(6) Refer to Fig. 20 for the locations, and install the bolts, lock washers, copper washers and plain washer securing the governor to the blower. Tighten the bolts to 13-17 ft/lb. (18-23 N.m) torque.

(7) Slide each fuel rod cover tube hose down on the cover tube attached to the cylinder heads and tighten the hose clamps.

(8) Install and connect the crossover fuel oil line to each cylinder head and connect the fuel oil lines to the fuel pump.

(9) Place the water bypass tube between the two thermostat housings and slide the hoses part way on the thermostat housings. Position the bypass tube so it clears the governor, fuel pump and fuel oil lines. Then tighten the hose clamps.

(10) Install the fuel rods between the cylinder heads and the governor as follows:

(a) Insert the lower end of the left-bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

(b) Raise the connecting pin up in the control link operating lever (Fig. 1). Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

(c) Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

(d) Insert the lower end of the right-bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

(e) Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

(f) Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

(11) Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the speed control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes in the cover.

(12) Install the eight governor cover attaching screws and lock washers. Tighten the screws securely.

Note: The short cover attaching screw, with the drilled head, goes in the corner hole next to the high-speed spring retainer housing.

(13) Install all of the accessories that were removed from the cylinder head, governor or front end of the engine.

(14) Connect the control linkage to the speed control and stop levers.

(15) Close the drain cocks and fill the cooling system.

(16) Perform the governor and injector rack control adjustment as outlined in SM1-63- 68.0.

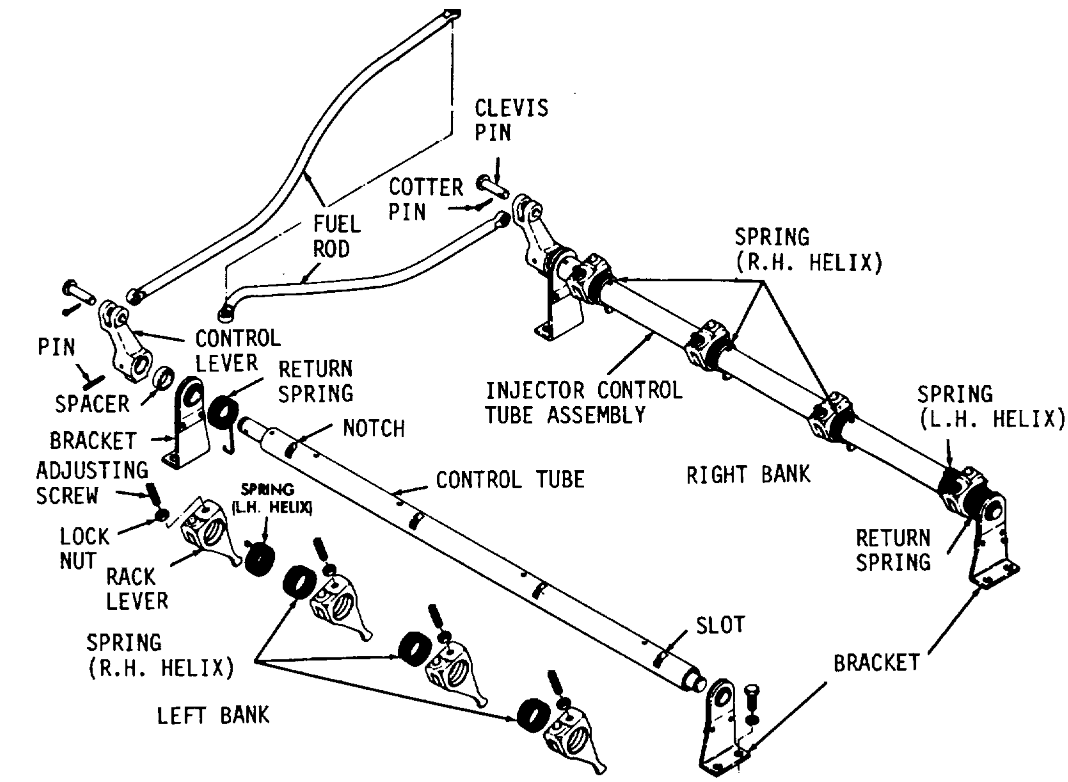



Fig. 1
Injector Control Tube Assemblies (Spring-Loaded)

The fuel injector control tube assemblies (Fig. 1) are mounted on the left and right bank cylinder heads of an engine and consist of a control tube, injector rack control levers, a return spring and injector control tube lever mounted in two bracket and bearing assemblies attached to each cylinder head.

The injector rack control levers connect with the fuel injector control racks and are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no-fuel position. The injector control tube lever is pinned to the end of the control tube and connects with the fuel rod which connects with the engine governor. Refer to SM1-63-68.O for positioning of the injector rack control levers.

This engine uses spring loaded injector control tube assemblies (Fig. 1) that have a yield spring at each injector rack control lever and only one crew and lock nut to keep each injector rack properly positioned. This enables an engine to be brought to a lesser fuel position if there is an inoperative fuel injector rack. The above also permits the use of an air inlet housing with no emergency air shut-off valve as is required in some applications.

Note: <u>Do not replace the spring-loaded fuel injector control tube and lever assembly with the two screw design control tube assembly without including an air inlet housing that incorporates an emergency air shut-off valve. However. when the spring-loaded fuel injector control tube and lever assembly is installed on an engine and the emergency shutdown mechanism is removed from the air inlet housing, the shaft holes at each end of the housing must be plugged. Ream the shaft holes to .6290" and install a 518" cup plug at each end of the housing.</u>

Engine shut down (normal or emergency) is accomplished on the spring-loaded fuel injector control tube (one screw design) by pulling the governor shut-down lever to the no-fuel position. Normal shutdown is accomplished by pulling the governor shutdown lever to the no-fuel position. Adjustment of the single screw and lock nut on each injector rack control lever is outlined in SM1-63-68.0.

38.1 Remove Injector Control Tube

(1) Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube control lever.

(2) Remove the two attaching bolts and lock washers at each bracket. Disengage the rack levers from the injector control racks and lift the control tube assembly from the cylinder head.

38.2 Disassemble Injector Control Tube

The injector control tube, one mounting bracket, a spacer and injector control tube lever are available as a service assembly. When any part of this assembly needs replacing, it is recommended the complete service assembly be replaced. Therefore, the disassembly and assembly procedure for these items is not included in the following:

(1) Remove the bracket from the injector control tube.
(2) Loosen the adjusting screw and lock nut at each injector rack control lever.
(3) With the spring-loaded injector control tube, disconnect the yield springs at each rack lever, then roll the yield springs out of the slots and notch of the control tube.
(4) Disconnect the return spring from the bracket and front or rear rack lever.
(5) Then remove the yield springs and return spring and rack levers from the control tube.

38.3 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wash all of the injector control tube parts in clean fuel oil and dry them with compressed air.

Examine the control tube, control lever, control tube rack control levers and brackets for excessive wear, cracks or damage and replace them if necessary. The bearing in the bracket isnot serviced separately. Examine the yield springs and return spring and replace them if worn or fractured.

38.4 Assemble Injector Control Tube

With all of the parts cleaned and inspected and the necessary new parts on hand, refer to Fig. 1 and assemble as follows:

Left Bank Cylinder Head:

(1) Install the return spring on the control tube and against the front bracket.

(2) Install a rack control lever, with the lever facing the rear bracket position, and the odd (L.H. helix) yield spring. Then install the R.H. helix yield springs and rack control levers with the levers facing the rear bracket.

(3) Attach the curled end of the yield springs to the rack control levers and roll the yield springs into the notch (odd spring) and slots (R.H. helix springs) in the control tube. Then turn the adjusting screws and lock nuts into the slots far enough to position the levers on the control tube.

(4) Attach the curled end of the control tube return spring to the rack control lever and the extended end of the spring behind the front bracket.

(5) Install the rear bracket on the end of the injector control tube.

Right Bank Cylinder Head:'

(1) Install the rack control levers, with the levers facing the front bracket position and the R.H. helix yield springs. Then install the odd (L.H. helix) yield spring and rack control lever, with the lever facing the front bracket position.
(2) Attach the curled end of the yield springs to the rack control levers and roll the springs into the notch (odd yield spring) and the slots (R.H. helix yield springs) in the control tube. Then turn the adjusting screws and lock nuts into the notch and slots far enough to position the levers on the control tube.
(3) Install the control tube return spring and rear bracket on the control tube. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the rear bracket.

38.5 Install Injector Control Tube

(1) Engage the injector rack control levers with the injector control racks and place the brackets over the mounting holes on the cylinder head.
(2) Install the two 1/4"-20 x 5/8" bolts and lock washers at each bracket to attach the injector control tube assembly to the cylinder head. Tighten the bolts to 10-12 ft/lb. (14-16 N-m) torque.
(3) Check the control tube to be sure it is free in the brackets. Tap the control tube lightly to align the bearings in the bracket, if necessary.
(4) Connect the fuel rod to the injector tube control lever with a clevis pin and a new cotter pin.
(5) Refer to SM1-63-68.0 and position the injector rack control levers.

Note: Be sure the injector rack control levers can be placed in a no-fuel position before restarting the engine.

**WARNING**

Loss Of Shut Down Control Could Result In A Runaway Engine Which Could Cause Personal Injury.

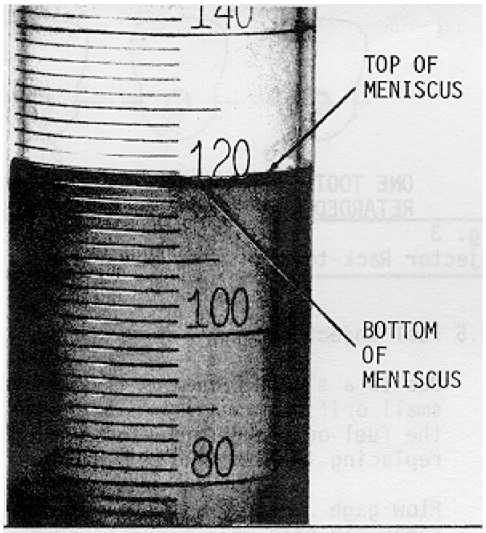



*Fig. 1*
*Check Fuel Output*

39.1 Injector Calibrator Readings

Several factors affect the injector calibrator output readings. The four major items are:

(1) Operator Errors: If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of 1 or 2 points will result. Refer to Fig. 1.

(2) Air In Lines: This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.

(3) Counter Improperly Set: The counter should be set to divert the injector output at 1,000 strokes. This should not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 1,000 strokes (if properly set) although the counter may overrun several digits.

(4) Test Oil: A special test oil is supplied with the calibrator and should always be used. If regular diesel fuel (or any other liquid) is used, variations are usually noted because of the affect of the oil on the solenoid valve and other parts. The fuel oil introduced into the test oil when the fuel injector is placed in the calibrator for a calibration check contaminates the test oil. Therefore, it is important that the test oil filter be changed very six months or sooner if required.

In addition, other malfunctions such as a slipping drive belt, low level of fuel oil, a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell-tale conditions.

39.2 Checking Injector Tester J9787

The injector tester J 9787 should be checked monthly to be sure that it is operating properly. The following check can be made very quickly using test block J 9787-49.

Fill the supply tank in the injector tester with clean injector test oil J 26400. Open the valve in the fuel supply line. Place the test block on the injector locating plate and secure the block in place with the fuel inlet connector clamp. Operate the pump handle until all of the air is out of the test block, then clamp the fuel outlet connector onto the test block. Break the connection at the gage and operate the pump handle until all of the air bubbles in the fuel system disappear. Tighten the connection at the gage. Operate the pump handle to pressurize the tester fuel system to 2400-
2500 psi. Close the valve on the fuel supply line. After a slight initial drop in pressure, the pressure should remain steady. This indicates that the injector tester is operating properly. Open the fuel valve and remove the test block.

If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected and the tester rechecked before checking an injector.

Occasionally dirt will get into the pump check valve in the tester, resulting in internal pump valve leakage and the inability to build up pressure in the tester fuel system. Pump valve leakage must be corrected before an injector can be properly tested.

When the above occurs, loosen the fuel inlet connector clamp and operate the tester pump handle in an attempt to purge the dirt from the pump check valve. A few quick strokes of the pump handle will usually correct a dirt condi tion. Otherwise, the pump check valve must be removed, lapped and cleaned, or replaced.

If an injector tester supply of gage line is damaged or broken, install a new replacement line (available from the tester manufacturer). Do not shorten the old lines or the volume of test oil will be altered sufficiently to give an inaccurate valve holding pressure test.

If it is suspected that the lines have been altered; i.e., by shortening or replacing with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

39.9 Refinish Lapping Blocks

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time. It is good practice, where considerable lapping work is done, to devote some time each day to

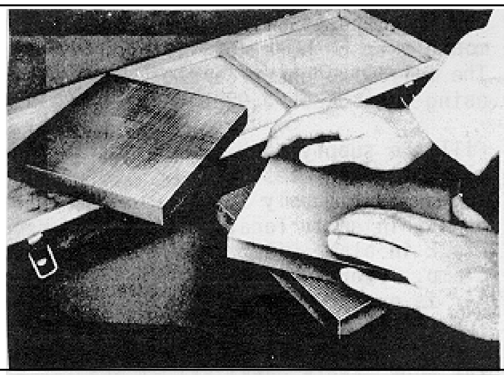


*Fig. 2*
*Refinishing Lapping Blocks*

refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the block.

To refinish the blocks, spread some 600 grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together as shown in Fig. 2. Alternate the blocks from time to time. For example, assuming the blocks are numbered 1, 2, and 3, work 1 and 2 together, then 1 and 3, and finish by working 2 and 3 together. Continue this procedure until all blocks are perfectly flat and free of imperfections.

Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory when the entire surface is a solid dark grey. Bright or exceptionally dark spots indicate defects and additional lapping is required.

After the surfaces have been refinished, remove all the powder by rinsing the lapping blocks in trichloroethylene and scribbing with a bristle brush.

When not in use, protect the lapping blocks against damage and dust by storing them in a close-fitting wooden container.

39.4 Injector Timing

If it is suspected that a fuel injector is "out of time", the injector rack-to-gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector
rack and gear are correctly timed. When the rack is all the way in (full-fuel position), the flat side of the plunger will be visible in the hole, indicating that the injector is "in time". If the flat side of the plunger does not come into full view (Fig. 3), and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack-to-gear timing.

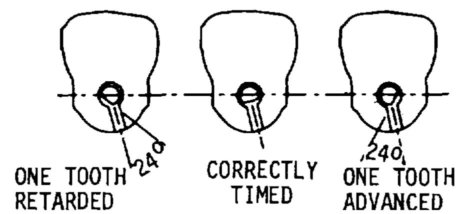



*Fig. 3*
*Injector Rack-to-Gear Timing*

39.5 Fuel Injector Spray Tips

Due to a slight variation in the size of the small orifices in the end of each spray tip, the fuel output of an injector *may* be varied by replacing the spray tip.

Flow gage J 25600 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

39.6 Effects of Pre-Ignition on Fuel Injector

Pre-ignition is due to ignition of fuel or lubricating oil in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures and may eventually cause burning of the injector spray tip and lead to failure of the injectors in other cylinders.

When pre-ignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of pre-ignition to avoid reoccurrence of the problem. Check for oil pull over from the oil bath air cleaners, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

39.7 Refinishing Injector Follower Face

When refinishing the face of an injector follower it is extremely important that the distance between the follower face and the plunger slot is not less than the 1.645" minimum shown in

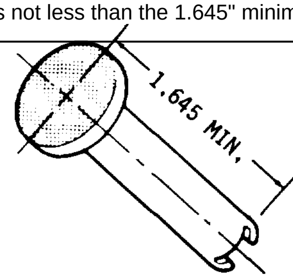



*Fig. 4*
*Injector Follower*

Fig. 4.

If this distance is less than specified, the height of the injector follower in relation to the injector body will be altered and proper injector timing cannot be realized.

**Note**: The maximum amount of metal that can be removed from the injector follower face and still ensure a sufficiently hardened surface for contact with the rocker arm is . 010".

39.8 Master Injector Calibrating Kit

Use Master Injector Calibrating Kit J 26298 to determine the accuracy of the injector calibrator.

With the test fluid temperature at 100° F (380C, + 1°) and each injector warm after several test cycles, run the three injectors contained in the kit. Several readings should be taken with each injector to check for accuracy and repeatability. If the output readings are within 2% of the values assigned to the calibrated masters, the calibrator can be considered accurate.

Injector testing can be carried out now without any adjustment of figures. However, when testing new injectors for output, any difference between the calibrator and the masters should be used to compute new injector calibration. If more than a 2% variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

39.9 Bluing Injector Body and Nut

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

The appearance of the injector body and nut of a rebuilt injector can be enhanced with an oxide finish obtained through a dipping process known as bluing. Pre-mixed compounds are available commercially for preparing the necessary solutions. Detailed instructions are usually provided with the commercial compounds. An effective bluing solution can be prepared in the service shop *by* mixing the following materials:

6 lbs. of sodium hydroxide per gallon of water; 3-1/2 lbs of sodium nitrite per gallon of water;
and
1 ounce of phosphoric acid per gallon of water.

The procedure usually follows five (5) steps in sequence:

(1) An alkaline solution bath (180-212° F or 82-1000 C) to preclean.
(2) A hot or cold water rinse.
(3) The bluing solution bath.
(4) A cold water rinse.
(5) An engine lubricating oil bath (180-212°F or 82-100° C) to rustproof the parts.The1 bluing tank should be a double walled, 1-1/2" insulated type of 10 gage steel.

The temperature of the bluing solution should be 295-305° F (146-152° C).The boiling point of the solution is directly related to its concentration. Therefore, when the boiling point is too high, the solution is too concentrated and the volume of water is probably low. When this occurs, the boiling point can be reduced to 300° F (1490 C) by adding water. The parts should be placed in the solution for 15 to 30 minutes.

It is extremely important that the parts be free of oil before placing them in the bluing bath. Oil will produce a varied color part.

There are several important safety precautions to be followed for preparing and using the solutions. Protective clothing such as rubber gloves, rubber arm covers, rubber apron and protective face shield contribute to the safety of personnel carrying out the procedures. When preparing the solutions, the compounds should be added to the water and not water added to the compounds. The dipping tanks should be properly vented and all fumes exhausted to the outside atmosphere. Since temperatures of the caustic solutions exceed the boiling point of water, any splashing encountered while adding make-up water can cause serious burns. Always add water slowly and with extreme care. When the parts to be dipped are cold, caution should be taken to avoid splashing that might occur when the cold parts come in contact with the hot solutions. A heavy wire-screen type basket, suitable for holding a quantity of injector bodies, is recommended for dipping the parts in the solution.

39.10 Fuel Lines

Flexible fuel lines are used to facilitate connection of the lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

Be sure a restricted fitting of the proper size is used to connect the fuel return line to the fuel return manifold. Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, it is recommended that the connections be tightened only sufficiently to prevent leakage of fuel; thus flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all of the fuel lines are installed, run the engine long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also check the filter cover bolts for tightness.

39.11 Locating Air Leaks in Fuel Lines

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or a loss of power. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return line in the fuel tank, which would cause the pump to draw air.

Presence of an air leak may be detected by observing the fuel filter contents after the filter is bled and the engine is operated for 15 to 20 minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

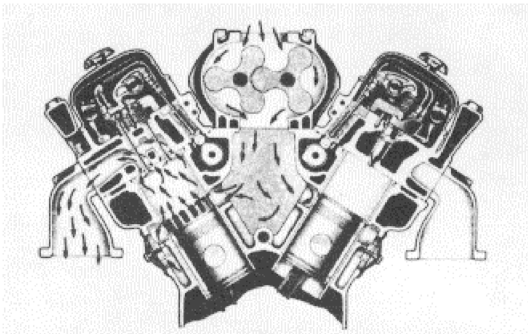


Fig.1
Air Flow Through Blower and Engine

In the scavenging process employed in the V-92 engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, therefore, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air, entering the blower from the air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows in Fig.1.The continuous discharge of fresh air from the blower enters the air chamber of the cylinder block and sweeps through the intake ports of the cylinder liners.

The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters. the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

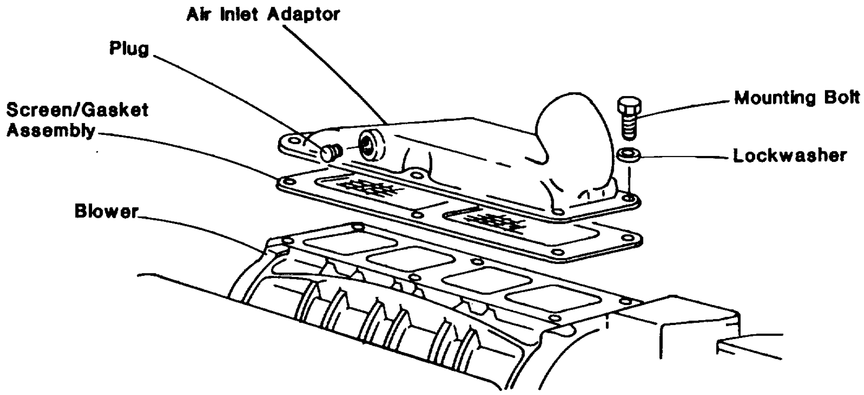



Fig.1
Air Inlet Adaptor

The air inlet adaptor is mounted on the blower as illustrated in Fig.1.

41.1 Remove Air Inlet Adaptor

(1) Loosen the hose clamp and slide the hose between the air inlet adaptor and the turbo-charger back on the turbocharger.
(2) Remove the bolts and washers which attach the adaptor to the blower. Then remove the adaptor and the blower screen.

41.2 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean all parts thoroughly, including the blower screen, with fuel oil and dry them with compressed air. Replace screen if worn or damaged.

41. 3 Install Air Inlet Adaptor

(1) Place the blower screen and gasket assembly in position and install the adaptor on the blower. Tighten attaching bolts to 16-20 ft/lbs (23-27 N-m) torque.

**IMPORTANT**: The current screen gasket consists of wire mesh secured between two sheets of gasket material.

(2) Slide the hose in place between the adaptor and turbocharger and tighten the clamps.

The large bearing blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow three-lobe rotors revolve with very close clearances in a housing bolted to the top deck of the cylinder block, between the two banks of cylinders. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form.

The OTM (optional turbocharger mounting) type blower has additional outboard holes for mounting the turbocharger adaptor. One of the end plates includes two oil drain holes with seal rings for the turbocharger return oil drain back (refer to "Lubrication", SM1-63-43. 0).

The blower used on turbo charged engines has a 2. 05:1 ratio blower-to-engine speed. Certain 6V turbo-charged aftercooled engines have a 1. 95:1 ratio blower-to-engine speed.

Two timing gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance. Therefore, as the lobes of the two rotors do not touch at any time, no lubrication is required.

Metal ring-type oil seals are incorporated in the blower. Each ring-type oil seal consists of a carrier pressed on the rotor shaft, a collar pressed into the end plate and a seal ring contained in a groove of the carrier. The outside diameter of the seal ring rides against the collar to prevent leakage of air or oil.

Each rotor is supported in the doweled end plates of the blower housing by a roller bearing at the front end and a double-row radial and thrust ball bearing at the gear end.

The right-hand helix rotor of the blower is driven by the blower drive shaft. The blower drive shaft is splined at one end to a drive hub attached to the blower drive gear and at the other end to a drive hub attached to the right-hand helix blower timing gear. The mating left-hand helix timing gear drives the left-hand helix rotor.

The blower rotors are timed by the two rotor gears at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance between the rotor lobes will not be maintained. A change in rotor timing is obtained by the use of shims between the gears and the bearings.

Normal gear wear causes a decrease of rotor-to-rotor clearance between the leading edge of the right-hand helix (drive) rotor and the trailing edge of the left-hand helix (driven) rotor. Clearance between the opposite sides of the rotor lobes is increased correspondingly. While the rotor lobe clearance may be corrected by adjustment, gear backlash cannot be corrected. When gears have worn to the point where the backlash exceeds . 004", replace the gears.

42. 1 Lubrication

The OTM (optional turbocharger mounting) blower bearings are lubricated by the drain oil from the turbocharger.

42. 2 Inspection

The blower may be inspected for any of the following conditions without being removed from the engine. However, the air shutdown housing adaptor, the turbocharger and adaptor must be removed on engines equipped with the OTM blower.

**WARNING**

When Inspecting A Blower On An Engine With The Engine Running, Keep Fingers And Clothing Away From Moving Parts Of The Blower And Run The Engine At Low Speeds Only.

(1) Dirt or chips, drawn through the blower, will make deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine and "dress" the parts to eliminate interference, or replace the rotors if they are badly scored.

(2) Leaky oil seals are usually manifest by the presence of oil on the blower rotors or inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals toward the inlet of the blower is indicative of leaking seal s.

(3) A worn blower drive may be detected by grasping the right-hand helix rotor firmly and attempting to rotate it. The rotors may move from 3/8" to 5/8", measured at the lobe crown, with a springing action. When released, the rotors should move back at least 1/4".

(4) Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates, or between the rotors and the housing. Generally, a combination of these conditions exists. Worn or damaged bearings will cause rubbing between mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing or the end plates. This condition will usually show up at the end where the bearings have failed. (5) Excessive backlash between the blower timing gears usually results in the rotor lobes rubbing throughout their entire length. This usually is on the trailing (close clearance) side.

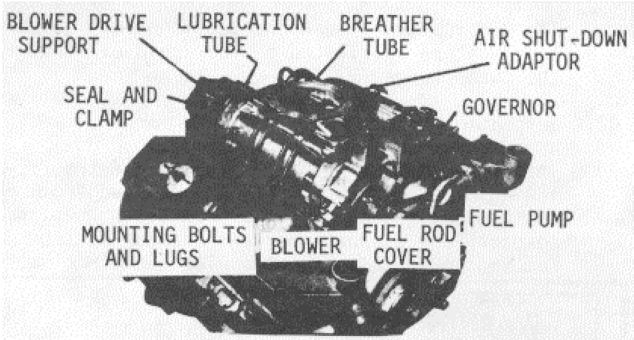



Fig.1
Typical Blower Mounting

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(6) Inspect the blower inlet screen, if used, periodically, as noted in the Operator's Manual, for an accumulation of dirt which, after prolonged operation, may affect the air flow. Servicing of the screen consists of thoroughly washing it in fuel oil and cleaning with a stiff brush until the screen is free of all dirt deposits. If broken wires are found in the blower screen, replace the screen.

(7) Check the lubricating oil connection between the blower and the blower drive support for excessive oil leakage. If oil leakage exists, retighten or replace the fittings or seal rings.

(8) Check the rubber seal ring used between the blower end plate cover and the blower drive support for oil leakage. If oil leakage exists, retighten the seal clamp or replace the seal ring. Current engines use a seal ring (. 740" wide) that incorporates two raised edges which provide a groove to retain the clamp. To replace a seal ring without removing the blower, refer to SM1-63-45. 0.

To correct any of the conditions cited in items 1 through 6, the blower must be removed from the engine and either repaired or replaced.

42.3 Remove Blower from Engine

The engine governor components are assembled in a combination governor housing and blower front end plate cover. The fuel pump is also attached to the front end of the blower. Therefore, when removing the blower assembly from the engine, the governor and fuel pump will also be removed at the same time. Refer to Fig.1 and proceed as follows:

(1) Disconnect the turbocharger tubing as required,

(2) Remove the turbocharger and attaching parts (SM1-63-43. 0).

(3) Remove the adaptor and blower screen.

(4) Loosen the oil pressure line fitting from the rear of the blower to the blower drive support and slide the fitting back on the tube.

(5) Loosen the hose clamp on the blower drive F support-to-blower seal .

(6) Disconnect the tachometer drive cable from the adaptor at the rear of the blower.

(7) Remove the flywheel housing cover at the blower drive support.

(8) Remove the snap ring and withdraw the blower drive shaft from the blower.

(9) Open the drain cocks and drain the engine cooling system.

(10) Loosen the hose clamps and slide the hoses back on the bypass tube between the thermostat housings. Remove the bypass tube.

(11) Remove the fuel inlet and outlet lines to the fuel pump. Also remove the fuel return crossover tube between the cylinder heads.

(12) Remove or disconnect the breather pipe at the top of the cylinder block.

(13) Remove the front engine lifter bracket, if necessary.

(14 Disconnect the throttle control rods from the governor.

(15) Clean and remove the rocker cover from each cylinder head.

(16) Remove the eight governor cover screws and lock washers and remove the governor cover.

(17) Disconnect the fuel rods from both the injector control tube levers and the governor and remove the fuel rods.

(18) Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head and slide each hose and clamp up on the tube in the governor housing.

(19) Remove the two bolts and washers through the top of each end plate which secures blower to the cylinder block.

(20) Remove the blower-to-block bolts and retaining washers on each side of the blower.

(21) Disconnect and remove any tubing or accessories which may interfere with removal of the blower.

(22) Thread eyebolts in the diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts.

(23) Lift the blower up slightly and move it forward to detach the blower from the seal at the drive end. Then lift the blower up and away from the engine. Remove the blower gasket.

With the blower, fuel pump and governor assembly removed from the engine, cover the air inlet and outlet openings of the blower housing and install the governor cover. Wash the exterior of the blower and governor housing with clean fuel oil and dry them with compressed air.

42.4 Remove Blower Rear End Plate Cover

Remove the blower rear end plate cover, governor and fuel pump assembly from the blower as follows:

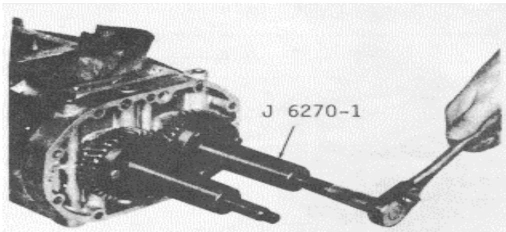



*Fig. 2*
*Removing Blower Gears*

(1) Remove the remaining bolts, lock washers and special washers securing the rear end plate cover to the end plate. Remove the cover and gasket from the end plate.

(2) Remove the three bolts and washers securing the spring plates to the right-hand blower rotor gear. Remove the drive coupling from the gear.

(3) Note the location of the two copper washers, one plain washer and eight lock washers on the governor-to-blower bolts before removing them. Then remove the ten bolts and washers (two inside and eight outside) securing the governor and fuel pump assembly to the blower.

(4) Tap the sides of the governor housing slightly with a plastic hammer to loosen the governor from the blower. Then pull the governor and fuel pump assembly from the dowels in the blower end plate. Remove the fuel pump drive coupling fork and the governor housing gasket.

42.5 Disassemble Blower

With the blower rear end plate cover, blower drive hub and governor assembly removed from the blower, refer to Fig.7 and disassemble the blower as follows:

(1) Place a clean folded cloth between the rotors, then remove the lock bolts and thick washers securing the timing gears to the blower rotor shafts.

(2) Remove the timing gears with pullers J 6270-1 (Fig.2).Both gears must be pulled at the same time as follows:

(a) Back out the center screws of both pullers and place the flanges against the gear faces, aligning the flange holes with the tapped holes in the gears. Secure the pullers to the gears with 5/16"-24 x 1-1/2" bolts (two bolts on the L. H.helix gear and three bolts on the R. H.helix gear).

(b) Turn the two puller screws uniformly clockwise and withdraw the gears from the rotor shafts as shown in Fig.2.

(3) Remove the shims form the rotor shafts, after the gears have been removed, and note the number and thickness of shims on each rotor shaft to ensure identical replacement when reassembling the blower.

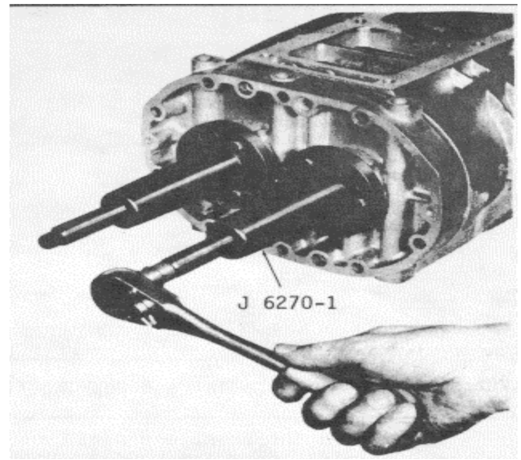



*Fig. 3*
*Removing Blower End Plate and Bearings from Housing and Rotors*

(4) Remove the self-locking screws securing the rotor shaft bearing retainers to the front and rear end plates. Remove the retainers.

(5) Remove the blower rear end plate and ball bearing assembly from the blower housing and rotors with the two pullers J 6270-1 as follows:

(a) Remove the two fillister head screws securing the rear end plate to the blower housing and loosen the two fillister head screws securing the front end plate to the housing approximately three turns.

(b) Back out the center screws of the pullers far enough to permit the flange of each puller to lay flat on the face of the end plate.

(c) Align the holes in each puller flange with the tapped holes in the end plate and secure the pullers to the end plate with six 1/4"-20 x 1-1/4" or longer bolts.

**Note**:<u>Be sure that the 1/4"-20 bolts are threaded all the way into the tapped holes in the end plate to provide maximum anchorage for the pullers and to eliminate possible damage to the end plate.</u>

(d) Turn the two puller screws uniformly clockwise and withdraw the end plate and bearings from the blower housing and rotors as shown in Fig.3.

(6) Remove the blower front end plate and roller bearing assembly from the blower housing and rotors as follows:

(a) Remove the fuel pump drive bolt, washer and spacer.

(b) Remove the two fillister head screws securing the front end plate to the blower housing.

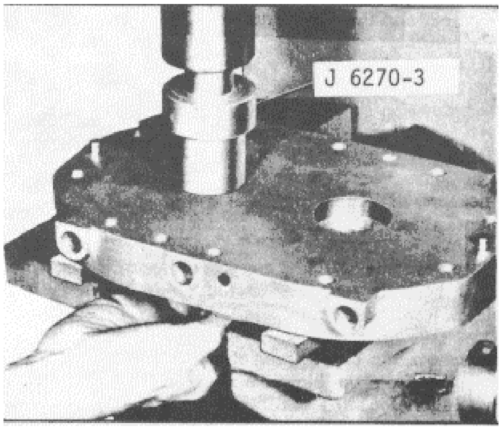



*Fig. 4*
*Removing Oil Seal Ring Collar and Bearing from End Plate*

(c) Remove the front end plate and roller bearings from the housing and rotors.

**Note**: The roller bearing inner races will remain on the shaft of the rotor and the lip type oil seals could be damaged.

(7) Withdraw the blower rotors from the housing.
(8) Remove the bearings and ring-type oil seals, carriers, roller bearing inner races and collars from the turbocharged engine blower rotor shafts and end plates as follows:
- (a) Clamp one lobe of the rotor in a bench vise equipped with soft jaws (Fig.5). Tighten the vise just enough to hold the rotor stationary.
- (b) Remove the oil seal ring from the seal ring carrier on each blower rotor shaft with a pair of snap ring pliers as shown in Fig.5.

Note: To avoid breakage or distortion, do not spread or twist the ring any more than necessary to remove it.

- (c) Refer to Fig.6 and place the seal ring carrier remover adaptor J 6270-2 over the carrier. Make sure the adaptor is seated in the groove of the carrier.

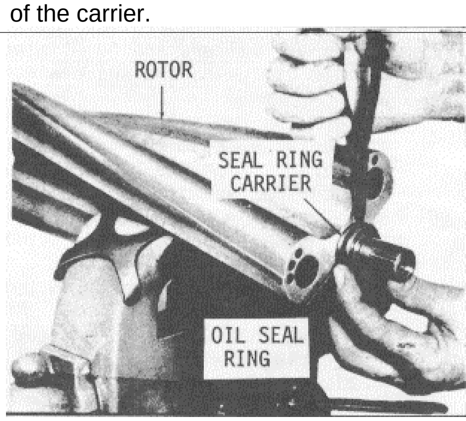



*Fig. 5*
*Removing Oil Seal Ring from Carrier*

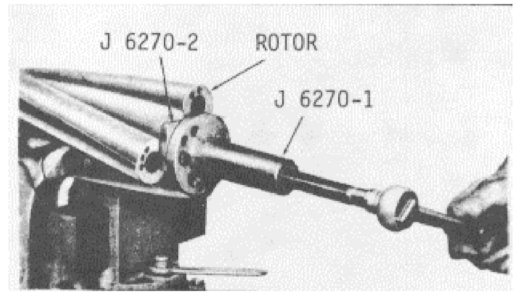



*Fig. 6*
*Removing Oil Seal Ring Carrier from Blower Rotor Shaft*

- (d) Back out the center screw of puller J 6270-1 far enough to permit the puller flange to lay flat against the adaptor J 6270-2.
- (e) Place the puller over the end of the rotor shaft and against the adaptor on the oil seal ring carrier. Align the holes in the puller flange with the tapped holes in the adaptor, then secure the puller to the adaptor with two bolts.
- (f) Turn the puller screw clockwise and pull the oil seal ring carrier and roller bearing inner race (front end of blower rotors only) from the rotor shaft (Fig. 6).
- (g) Remove the remaining oil seal ring carriers from the rotor shafts in the same manner.
- (h) Refer to Fig.4 and support the outer face of the blower end plate on wood blocks on the bed of an arbor press.
- (i) Place the long end of the oil seal remover and installer J 6270-3 down through the oil seal ring collar and into the bearing, with the opposite end of the remover under the ram of the press (Fig. 4).Then press the bearing and oil seal ring collar out of the end plate.
- (j) Remove the remaining bearings and oil seal ring collars from the end plates in the same manner.

The oil seal ring collar can be removed from he blower end plate with the bearing in ace as follows:
- a) Insert the two-piece collar remover (with he '0' ring) J 26221-15 in the collar with the lip of the remover on the inside edge of the collar.
- (b) Support the inner face of the blower end plate on wood blocks.
- (c) Insert the small end of the driver handle J 26270-17 through the bearing and into the collar remover, spreading it tight in the collar.
- (d) Press or tap on the driver handle to remove the collar.

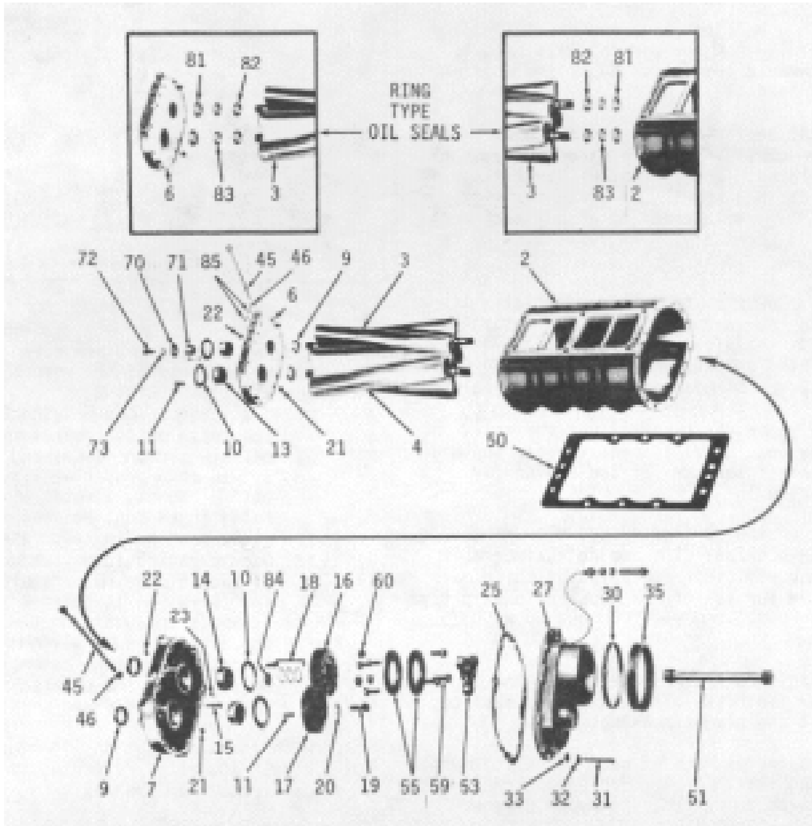



*Fig. 7*
*Blower Details and Relative Location of Parts*

(2) Housing - Blower (18) Shim - Blower Gear (50) Gasket
(3) Rotor Assembly - R.H. Helix (19) Bolt - Blower Gear (51) Shaft - Blower Drive
(4) Rotor Assembly - L.H. Helix (20) Washer (53) Coupling
(6) Plate - Blower Front End (21) Strainer - End Plate Oil Passage (55) Plate - Flexible
(7) Plate - Blower Rear End(22) Plug - Oil Passage (59) Bolt
(9) Seal - Oil (23) Orifice - Oil Passage (60) Spacer
(10)Retainer - Blower Bearing (25) Gasket - Cover (70) Disc - Fuel Pump Drive
(11)Lockscrew - Retainer (27) Cover - Rear End Plate (71) Spacer - Fuel Pump Drive Disc
(13)Bearing - Blower Rotor Front; Roller (30) Clamp - Hose (72) Bolt - Drive Disc
(31) Bolt - Cover (73) Lock Washer
(14)Bearing - Blower Rotor Rear; Ball (32) Lock Washer (81) Collar-Blower End Plate
(33) Washer - Special Flat (82) Carrier - Seal Ring
(15)Screw - Fillister Head (35) Hose - Blower Drive Cover (83) Ring - Seal (Piston Type)
(16)Gear - R.H. Helix Rotor (45) Bolt - Blower Mounting(84) Spacer
(17)Gear - L..H. Helix Rotor (46) Lock Washer (85) Seal Rings

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42.6 Inspection

Wash all of the blower parts in clean fuel oil and dry them with compressed air.

Examine the bearings for any indications of corrosion or pitting. Lubricate each ball bearing with light engine oil. Then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.

The double-row ball bearings are pre-loaded and have no end play. A new bearing will seem to have considerable resistance to motion when revolved by hand.

Check the oil seal rings, carriers and collars for wear or scoring.If worn excessively, they must be replaced. The current oil seal rings are chrome flashed and the carriers are liquid nitrided. When replacement of an oil seal ring or carrier is necessary, both parts must be replaced together.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs or scoring. Rotors must be smooth for satisfactory operation of the blower. If the rotors are slightly scored or burred, they may be cleaned up with emery cloth.

Examine the rotor shaft serrations for wear, burrs or peening. Also inspect the bearing and oil seal contact surfaces of the shafts for wear or scoring.

Inspect the inside surface of the blower housing for burrs or scoring. The inside surface must be smooth for efficient operation of the blower. If the inside surface of the housing is slightly scored or burred, it may be cleaned up with emery cloth.

Check the finished ends of the blower housing for burrs or flatness. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

**Note**: Be careful not to remove metal at the joint face between the end plates and the housing. Air or oil leaks could develop after assembly.

Examine the serrations in the blower timing gears for wear or peening. Also, check the gear teeth for wear, chipping or other damage. If the gears are worn to the point where the backlash between the gears exceeds . 004", or damaged sufficiently to require replacement, both gears must be replaced as a set.

Check the blower drive shaft serrations for wear or peening, Replace the shaft if it is bent, cracked or has excessive spline wear.

Replace all worn or excessively damaged blower parts.

Clean the oil strainer in the vertical oil passage at the bottom side of each blower end plate and blow out all oil passages with compressed air.

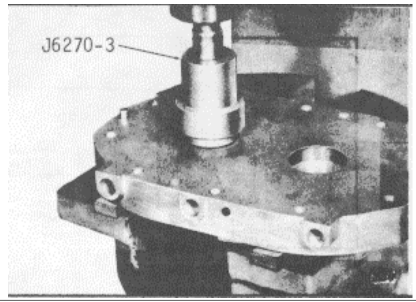



*Fig. 8*
*Installing Oil Seal Ring Collar in End Plate*

42.7 Assemble Blower

Several precautions are given below to assure proper assembly of the rotors and gears for correct blower timing.

(1) The lobes on the driving blower rotor and the teeth on its gear form a right-hand helix while the lobes and teeth of the driven rotor and gear form a left-hand helix. Hence, a rotor with right-hand helix lobes must be used with a gear having right-hand helix teeth and vice versa.
(2) One serration is omitted on the drive end of each blower rotor shaft and a corresponding serration is omitted in each gear. Assemble the gears on the rotor shafts with the serrations in alignment.
(3) The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig.19.

With these precautions in mind, proceed with the blower assembly, referring to Fig.7 through 19 as directed in the text.

(1) Install the ring-type oil seal carriers, collars, seal rings and roller bearing inner races (front end of blower rotors only) on the rotor shafts and in the end plates as follows:

(a) Support one of the rotor assemblies on wood blocks on the bed of an arbor press as shown in Fig.10.
(b) Lubricate the inside diameter of the oil seal ring carrier with engine oil. Then start the carrier straight over the

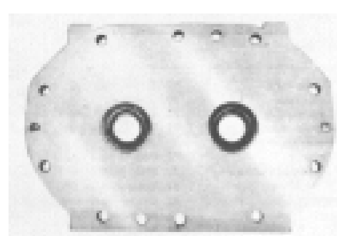


*Fig.9*
*Location of Oil Seals in End Plate*

end of the rotor shaft with the chamfered inside diameter end facing the rotor.

(c) Place the oil seal ring carrier installer J 6270-13 over the end of the rotor shaft and against the carrier with the end of the installer under the ram of the press. Then press the carrier down tight against the rotor.

(d) Install the remaining oil seal ring carriers on the rotor shafts in the same manner.

(e) Install an oil seal ring in the ring groove of each carrier with a pair of snap ring pliers in the same manner as shown in Fig.5.

**Note**: To avoid breaking the oil seal rings, do not spread them any more than necessary to place them over the end of the carrier. Do not twist the rings or possible distortion may result in loss of side contact area.

(f) Support one of the blower end plates, inner face up, on wood blocks on the bed of an arbor press as shown in Fig.8.

(g) Lubricate the outside diameter of a seal ring collar with engine oil. Then start the chamfered outside diameter end of the collar straight into the bore in the end plate.

(h) Place the oil seal ring collar installer J 6270-3 on top of the seal ring collar and under the ram of the press (Fig.8)

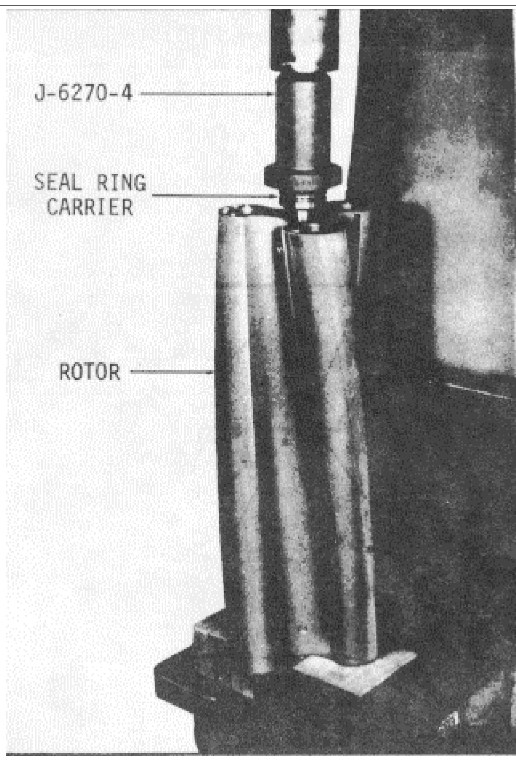



*Fig. 10*
*Installing Oil Seal Ring Carrier on Blower Rotor Shaft (V-92T Blowers)*

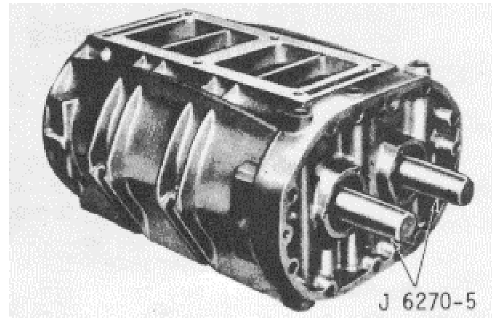



*Fig. 11*
*Assembling Blower Rotors in Housing and Front End Plate with Oil Seal Pilots*

Then press the collar into the end plate until the shoulder on the installer contacts the end plate.

**Note**: A step under the shoulder of the installer will position the collar approximately .005" below the finished face of the end plate. This is within the .002" to .008" specified.

(i) Install the remaining oil seal ring collars in the end plates in the same manner.

42.8 Assemble Rotors and End Plates (Blower with Ring Type Oil Seals - Regular and OTM Blowers)

(1) Install the blower rotors in the blower front end plate as outlined below.

(a) Check the dowel pins, The dowel pins must project . 320" from the flat inner

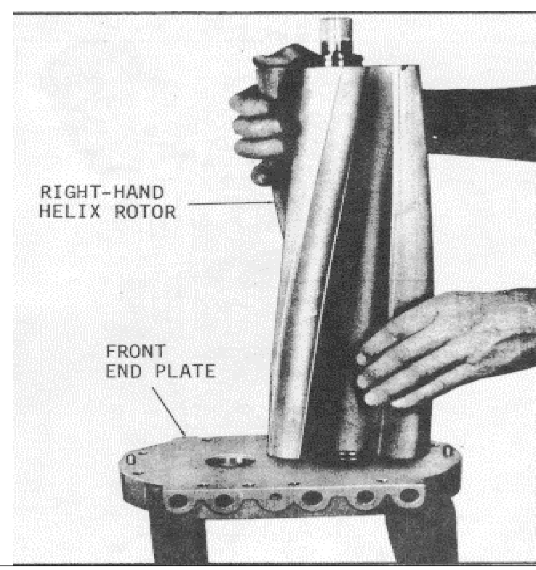



*Fig.12*
*Installing Blower Rotor in Front End Plate (V-92T Blowers)*

face of the front end plate to assure proper alignment of the end plate with the housing.

(b) If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005" below the surface of the end plate.

**Note**: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

(c) Support the front end plate on two wood blocks approximately 4" high, with the inner face of the end plate facing up and the TOP side of the plate facing the serviceman's right (Fig.12).

(d) Lubricate the oil seal ring in the carrier on the front end of the right-hand helix rotor shaft with engine oil.

(e) Hold the right-hand helix rotor in a vertical position (gear end up) and position the seal ring in the carrier so the ring protrudes from its groove the same amount on each side and the gap is facing away from the serviceman.

(f) With the omitted serration in the splines of the shaft facing toward the top side of the end plate, start the end of the rotor shaft into the right-hand shaft opening in the end plate so that the gap portion of the seal ring is started into the ring collar (Fig.12).Continue to lower the rotor and very carefully apply pressure to the seal ring approximately 180° from the gap while gently working the seal ring Into the collar until the rotor contacts the end plate.

(g) Perform steps (d) and (e) above on the left-hand helix rotor.

(h) Position the rotors so the lobes are in mesh and the omitted serrations in the splines of both rotor shafts are facing toward the top side of the end plate. Then install the left-hand helix rotor as in step (f).

(2) Install the blower housing over the rotors and attach it to the front end plate as follows:

**Note**: When assembling an OTM 6V blower, it must be determined which is the front end of the housing. For front mounted OTM vehicle engines, the housing must be installed with the stamped triangle end toward the front of the engine. With the rear mounted OTM vehicle engines, the housing is installed with the stamped triangle end toward the rear.

(a) Position the blower housing over the top of the rotors so the bottom face of the housing faces the bottom side of the front end plate. Then lower the housing over the rotors until it contacts the dowel pins in the end plate.

(b) Align the dowel pin holes in the housing with the dowel pins in the end plate. Then push the housing tight against the end plate. If necessary, tap the housing lightly with a plastic hammer.

(c) Insert the two fillister head screws

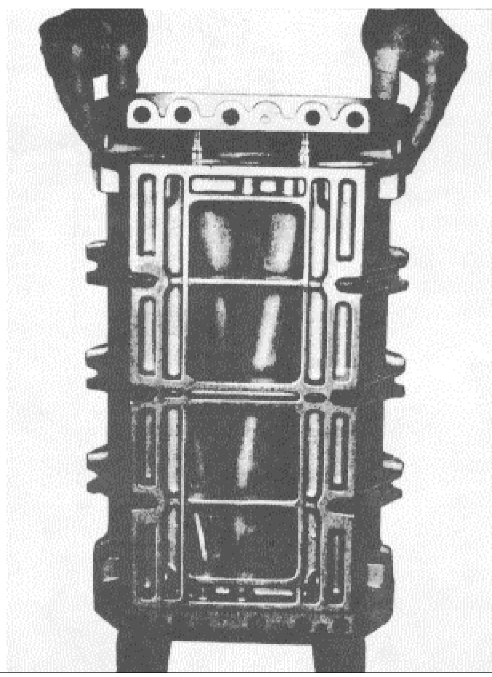


Fig. 13
Installing Rear End Plate on Blower Rotors and Housing

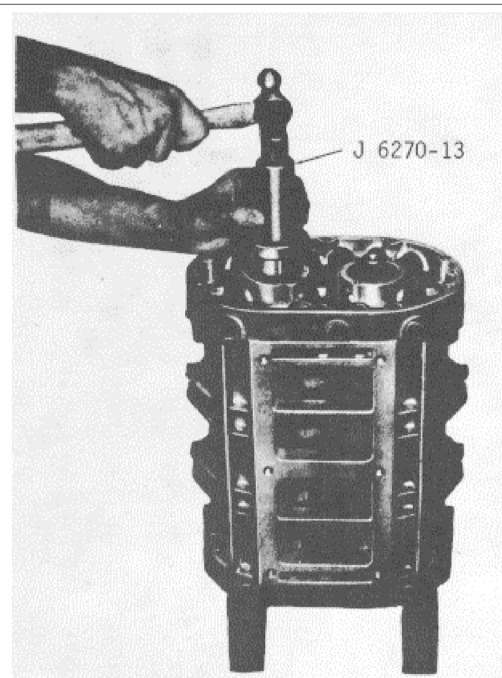




*Fig. 14*
*Installing Ball Bearings on Rotor Shaft and in Rear End Plate*

through the front end plate and thread them into the housing. Tighten the screws to 5-10 ft/lb.(7-14 N-m) torque. Do not use lock washers on these screws.

(3) Install the blower rear end plate on the rotor shafts and housing as follows:

(a) Check the dowel pins. They must project .320" from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

(b) If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to . 005"below the surface of the end plate.

**Note**: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

(c) Lubricate the oil seal rings in the carriers on the rotor shaft with engine oil.

(d) Position the oil seal rings in the carriers so the ring protrudes from its groove the same amount on each side.

(e) Position the rear end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors and the top side of the end plate facing the top side of the blower housing.

(f) Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing (Fig.13).Then carefully work the dowel pins into the dowel pin holes in the housing and the oil seal rings into the collars. Push the end plate tight against the housing. If necessary, tap the end plate lightly with a plastic hammer.

(g) Insert the two fillister head screws through the rear end plate and thread them into the housing. Tighten the screws to 5-10 ft/lb.(7-14 N-m) torque. Do not use lock washers on these screws.

(4) Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than . 0005" above to . 0065" below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor to housing interference.

42.9 Install Blower Rotor Shaft Bearings and Gears

(1) With the blower housing, rotors and end plates still supported in a vertical position on the two wood blocks, install the ball bearings on the rotor shafts and in the rear end plate as follows:

(a) Lubricate one of the ball bearings with light engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

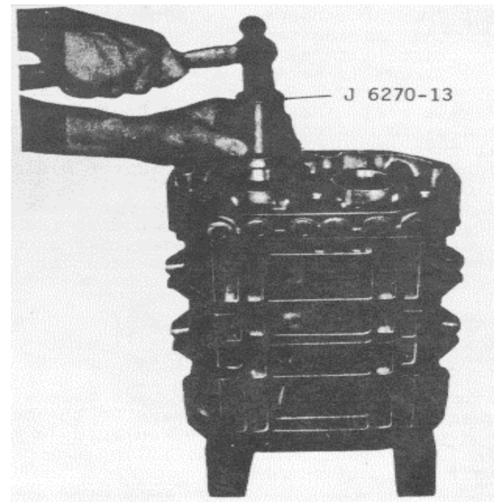



*Fig.15*
*Installing Roller Bearings on Rotor Shafts and in Front End Plate*

(b) Place installer J 6270-13 on top of the bearing and tap the bearing straight on the shaft and into the rear end plate as shown in Fig.14.

(c) Install the second ball bearing on the remaining rotor shaft in the same manner.

(d) Place the bearing retainers on top of the bearings and the end plate. Then install the self-locking screws. Tighten the screws to 7-9 ft/lb.(9-12 N-m) torque.

(2) Install the roller bearing inner races on the rotor shafts at the front end plate as follows:

(a) Reverse the position of the blower housing on the two wood blocks (Fig.15).

(b) Position the roller bearing inner race over the front end of the rotor shaft and press the race on the shaft with tool J 6270-13 until the bearing contacts the shoulder on the shaft.

(c) Install the bearing inner race on the front end of the other rotor in the same manner.

(3) Install the roller bearing outer race assemblies in the front end plate as follows:

(a) Lubricate one of the roller bearings with light engine oil. Start the bearing (shoulder side up) over the rotor shaft and bearing inner race and into the end plate.

(b) Place installer J 6270-13 on top of the bearing and tap the bearing straight on the inner race and into the front end plate as shown in Fig.15.

(c) Install the second roller bearing on the remaining rotor shaft in the same manner.

d) Place the bearing retainers on top of the bearings and the end plate. Then install three self-locking retainer screws in each retainer. Tighten the screws to 7-9 ft/lb.9-12 N-m) torque.

(4) Make a preliminary check of the rotor-to-end plate and rotor-to-housing clearances at this time with a feeler gage as shown in Fig.20.Refer to Fig.18 for minimum blower clearances.

(5) Before installing the blower rotor timing gears on the rotor shafts, observe precautions '2' and '3' relative to the rotor shaft and timing gear alignment under 47. 2 "Assemble Blower".

The center punch mark in the end of each rotor shaft at the omitted serration will assist in aligning the gears on the shafts.

If shims were removed from the back side of the gears (between the inner race of the bearing and the gear), they should be replaced in their original positions before installing the gears on their respective shafts.

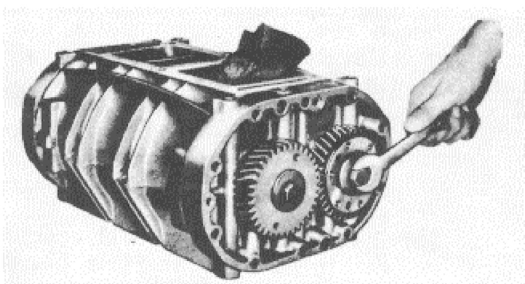


*Fig. 16*
*Installing Blower Rotor Timing Gears*

Install the blower timing gears as follows:

(a) Place the blower assembly on the bench, with the top of the housing up and the rear end (serrated end of the rotor shafts of the blower facing the outside of the bench.

(b) Rotate the rotors to bring the omitted serrations on the shafts in alignment ana facing to the left.

(c) Install a .140" thick gear spacer and the same number and thickness of shims on each rotor shaft that were removed at the time of disassembly.

(d) Lubricate the serrations of the rotor shafts with light engine-oil.

(e) Place the teeth of the rotor gears in mesh so that the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts.

(f) Start both rotor gears straight on the rotor shafts with the right-hand helix gear on the right-hand helix rotor and the left-hand helix gear on the left-hand helix rotor, with the omitted serrations in the gears in line with the omitted serrations on the rotor shafts.

(g) Thread a 1/2"-20 x 1-1/4" bolt with a thick washer into the end of each rotor shaft. Place a clean folded cloth between the lobes of the rotors (Fig.16) to prevent the gears from turning. Draw the gears into position tight against the spacers and shims and the bearing inner races as shown in Fig.16.

(h) Remove the two bolts and washers that were used to draw the gears into position on the rotor shafts.

(i) Lubricate the threads of the 1/2"-20 x 1-1/2" gear retaining bolts with engine oil. Place a spacer (. 340" thick) on each of the bolts and thread the bolts into the rotor shafts. Tighten the bolts to 100-110 ft/lb.(136-150 N. m) torque. Remove the cloth from the blower rotors.

42.10 Timing Blower Rotors

After the blower rotors and timing gears are installed, the blower rotors must be timed.

**Note**: <u>Before timing the blower, install four 5/16"-18 x 1-7/8" bolts with flat washers through four bolt holes in each end plate (top and bottom) and thread them into the blower housing (Fig.9).Tighten the bolts to 13-17 ft/lb.(18-23 N-m) torque. This will hold the end plates against the blower housing so the proper clearance between the rotors and the</u>

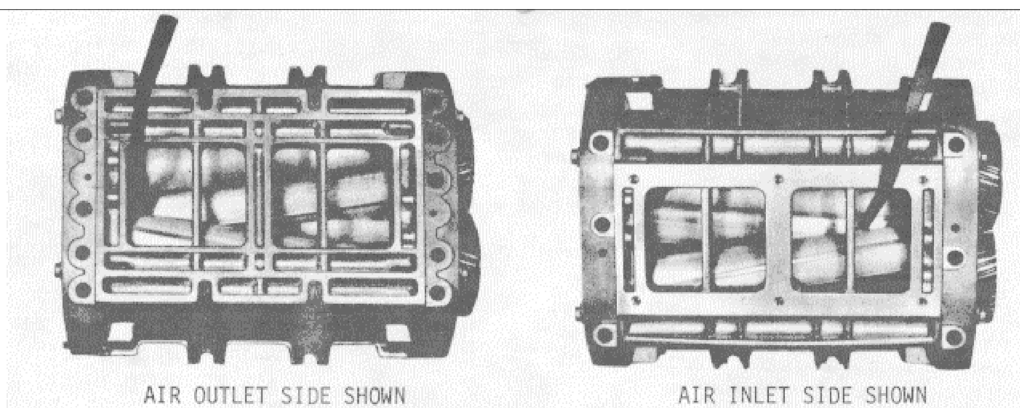
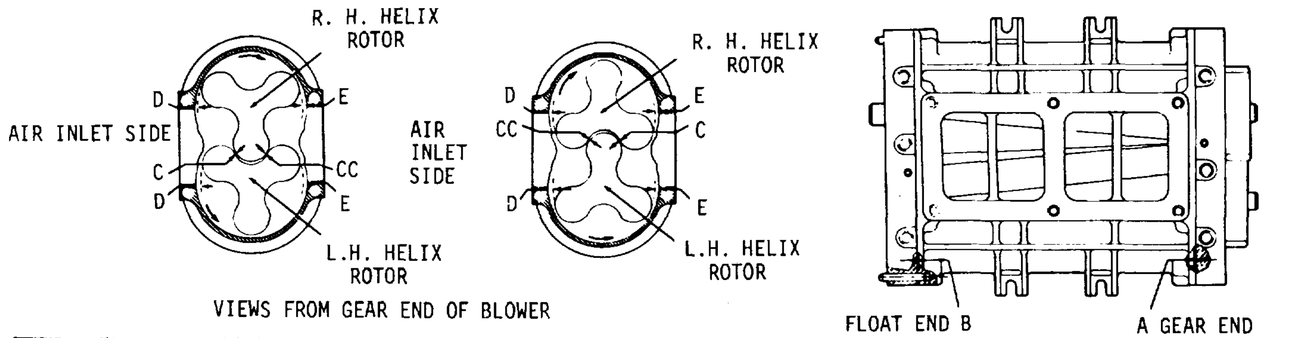



*Fig. 17*
*Measuring 'CC' and 'C' Clearance Between Blower Rotor Lobes*




| ENGINE | BLOWER | IDENT. | A | B | C | CC | D | E |
|---|---|---|---|---|---|---|---|---|
| 6 CYL. | TURBO | T | .007" | .012" | .010" | .004" TO .008" | .015" | .004" |

*IDENTIFICATION STAMPED ON BLOWER HOUSING

NOTE: TIME ROTORS TO DIMENSIONS ON CHART FOR CLEARANCE BETWEEN TRAILING SIDE OF R.H. HELIX ROTOR AND LEADING SIDE OF L.H. HELIX ROTOR (CC) FROM BOTH INLET AND OUTLET SIDE OF BLOWER.

*Fig. 18*
*Chart of Minimum Blower Clearances*

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end plate can be obtained

(1) The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

(2) If the right-hand helix gear is moved out, the right-hand helix rotor will turn counterclockwise when viewed from the gear end. If the left-hand helix gear is moved out, the left-hand helix rotor will turn clockwise when viewed from the gear end. This positioning of the gears, to obtain the proper clearance between the rotor lobes, is known as blower timing.

(3) Moving the gears OUT or IN on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

(4) The clearance between the rotor lobes may be checked with 1/2" wide feeler gages in the manner shown in Fig.17.When measuring clearances of more than . 005", laminated feeler gages that are made up of . 002", . 003" or . 005" feeler stock are more practical and suitable than a single feeler gage. A specially designed feeler gage set J 1698-02 for the blower clearance operation is available. Clearances should be measured from both the inlet and outlet sides of the blower.

(5) Refer to Fig.17 and Fig.18 and time the rotors to the specified clearance between the trailing edge of the right-hand helix rotor and the leading edge of the left-hand helix rotor ('CC' clearance) measured from both the inlet and outlet sides. Then check the clearance between the leading edge of the right-hand helix rotor and the trailing edge of the left-hand helix rotor ('C' clearance) for the minimum clearance. Rotor-to-rotor measurements should be taken 1" from each end and at the center of the blower.

(6) After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear as shown

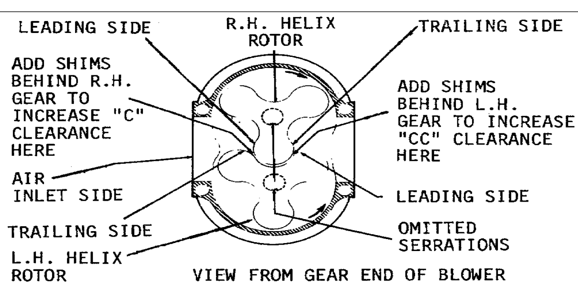


*Fig. 19*
*Diagram Showing Proper Location of Shims Correct Rotor Lobe Clearance*

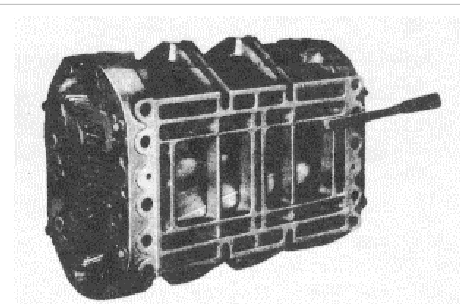

*Fig. 20*
*Measuring End Clearance Between Blower Rotors and End Plate*

in Fig.19 to produce the desired result. When more or less shims are required, both gears must be removed from the rotors. Placing a . 003" shim in back of a rotor gear will revolve the rotor . 001".

(7) Install the required thickness of shims back of the proper gear and next to the . 140" thick gear spacer which is against the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.

(8) Determine the minimum clearances at points 'A' and 'B' shown in Fig.18.Insert the feeler gages, as shown in Fig.20, between the end plates and the ends of the rotors. This operation must be performed at the ends of each lobe, making 12 measurements in all. Refer to Fig.18 for minimum clearances.

(9) Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side -- 12 measurements in all. Refer to Fig.18 for the minimum clearances.

After the blower rotors are timed, complete assembly of the blower as outlined below.

(1) Place the fuel pump drive disc spacer over the forward end of the right-hand helix rotor shaft. Then place the special lock washer and the drive disc on the retaining bolt and thread the bolt into the rotor shaft against the spacer. Tighten the bolt to 55-65 ft/lb.(75-88 N. m) torque. Bend one tang of the lock washer over into the slot in the drive disc and two tangs over against the flat sides of the bolt head.

(2) Attach two spring plates to the drive hub with three bolts, flat washers and lock washers. Tighten the bolts to 25-30 ft/lb. (34-41 N. m) torque.

(3) Attach the drive hub and spring plate assembly to the right-hand helix blower rotor timing gear with three spacers, bolts, flat washers and lock washers. Tighten the bolts to 25-30 ft/lb.(34-41 N-m) torque.

(4) Affix a new gasket to the blower rear end plate cover. Place the cover over the gears and against the end plate, with the opening in the cover over the blower drive hub attached to the right-hand helix gear. Install the rear cover using ten 5/16"-18 x 2-1/2" bolts and lock washers. Tighten the bolts to 13-17 ft/lb.(18-23 N. m) torque.

Note: The tab on the gasket is to assure the gasket is in place.

(5) Attach the adaptor and dry seal connector to the rear blower end plate when installing the blower on an engine.

(6) Attach the governor and fuel pump assembly to the blower as follows:

(a) Affix a new gasket to the forward face of the blower end plate.

(b) Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the prongs of the fork align with the slots in the drive disc. Rotate the weight shaft and align the splines on the shaft with the splines in the blower rotor.

(c) Push the governor straight on the dowel pins in the blower end plate and against the gasket.

(d) Refer to SM1-63-37. 0 for the location and install the bolts, lock washers, copper washers and plain washer which secure the governor to the blower. Tighten the bolts to 13-17 ft/lb (18- 23 N. m) torque.

42.11 Install Blower on Engine

Refer to Fig.1 and install the blower assembly on the engine as follows:

(1) Affix a new blower housing gasket to the cylinder block with Scotch Grip rubber adhesive No.4300, or equivalent, to prevent the gasket from shifting when the blower is lowered into position.

(2) If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing and tighten the clamps.

(3) Place the blower end plate cover seal ring and clamp on the end of the blower drive support.

(4) Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts.

(5) Lift the blower assembly at a slight angle and position it on top of the cylinder block with the flange of the rear end plate cover inside the seal ring or hose.

(6) Install loose the 7/16"-14 x 8-1/4" blower end plate bolts and special washers. Install loose the 3/8"-16 x 5-1/2" bolts and retaining washers at each side of the blower housing. Install the blower alignment tool J 24619 and position the blower so that the tool can be easily removed and reinstalled. The blower will then be properly aligned.

**Note**: <u>The lip at the bevelled end of the bolt retaining washer goes in the small recess in the blower housing just above the bolt slot.</u>

(7) With the alignment tool in place and the blower properly aligned, tighten the bolts as follows:

(a) Tighten the blower-to-block end plate bolts to 40-45 ft/lb.(54-61 N-m) torque.

(b) Tighten the blower housing-to-block side angle bolts uniformly to 30-35 ft/lb.(41-47 N. m) torque in 5 ft/lb. (7 N. m) increments. Remove the alignment tool.

(c) Recheck the blower-to-block end plate bolts.

(8) Place the blower rear end plate cover seal ring and hose clamp in position and tighten it.

**Note**: <u>Current engines use a seal ring. 740" wide) that incorporates two raised edges which</u>

provide a groove to retain the clamp.

(9) Connect the lubricating oil tube to the fitting in the blower drive support.

(10) Insert the blower drive shaft through the blower drive hub and into the blower drive coupling and install the snap ring in the coupling. Then attach the flywheel housing cover to the flywheel housing.

(11) Attach the tachometer drive adapter to the blower. Then connect the tachometer drive cable to the drive adapter.

(12) Slide each fuel rod cover tube hose down on the cover tubes attached to the cylinder heads and tighten the hose clamps.

(13) Install the fuel rods between the cylinder heads and governor as follows:

(a) Insert the end of the left-bank fuel rod through the hole in the cylinder head and up through the fuel rod cover tube to the control link operating lever.

(b) Raise the connecting pin up in the connecting link lever. Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

(c) Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

(d) Insert the end of the right-bank fuel rod through the hole in the cylinder head and up through the fuel rod cover tube to the control link operating lever.

(e) Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

(f) Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

(14) Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the speed control or stop lever shaft assembly in the slot in the differential lever and the dowel pins in the housing in the dowel pin holes in the cover. Install the eight cover attaching screws and lock washers. Tighten the screws securely.

(15) Attach the alternator and support bracket to the cylinder head and connect the wires to the alternator.

(16) Install and connect the crossover fuel oil line to each cylinder head and connect the fuel oil lines to the fuel pump.

(17) If removed, install the front engine lifter bracket.

(18) Place the water bypass tube between the two thermostat housings and slide the hoses part way on the thermostat housings. Position the bypass tube so it clears the governor, fuel pump and fuel oil lines. Then tighten the hose clamps.

(19) Attach the air shutdown adapter to the blower as outlined in SM1-63-41.0.

(20) Install the turbocharger and attaching parts (SM1-63-43.0).

(21) Connect the turbocharger tubing as required (SMI-63-43.0).

(22) Connect the throttle control rods to the speed control and stop levers on the governor

(23) Attach any other accessories to the engine that were removed.

(24) Close the drain cocks and fill the engine cooling system.

(25) Perform the governor and injector rack control adjustment as outlined in SM1-63-68.0. Check for and correct any coolant or oil leaks detected.

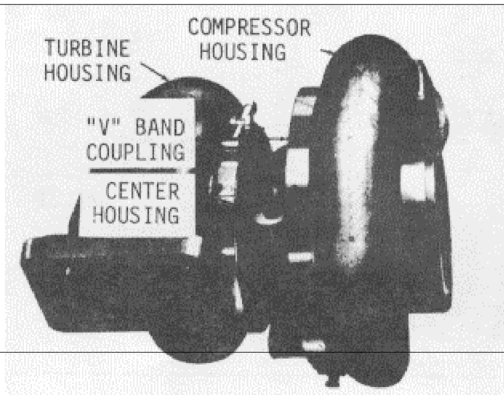


*Fig. 1*
*Typical Turbocharger Assembly*

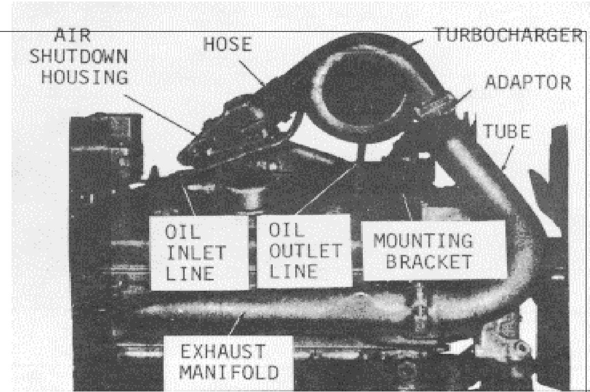


*Fig. 2*
*Typical Turbocharger Mounting*

The turbocharger (Fig. 1 and 2) is designed to increase the over-all efficiency of the engine. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

The turbocharger consists of a radial inward flow turbine wheel and shaft, a centrifugal compressor wheel, and a center housing which serves to support the rotating assembly, bearings, seals, turbine housing and compressor housing. The center housing has connections for oil inlet and oil outlet fittings.

The turbine wheel is located in the turbine housing and is mounted on one end of the turbine shaft. The compressor wheel is located in the compressor housing and is mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly.

The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer or thrust collar, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings which are retained in the center housing by snap rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings and the thrust bearing.

The turbine housing is a heat-resistant alloy casting which encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially located turbocharger exhaust gas outlet. The turbine housing is secured to the turbine end of the center housing with a "V" band coupling, thus providing a compact and vibration-free assembly.

The compressor housing which encloses the compressor wheel provides an ambient air inlet and a compressed air discharge outlet. The compressor housing is secured to the backplate assembly with a "V" band coupling.

## 43.1 Operation

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 3). The gases are discharged into the atmosphere after passing through the turbine housing.

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft, rotates with the turbine wheel. The compressor wheel draws in fresh air, compresses it and delivers high-pressure air through the engine blower to the engine cylinders.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the engine power output increases or decreases, the turbocharger responds to the engine's demand to deliver the required amount of air under all conditions.

Certain engines are equipped with an aftercooler to cool the air going into the engine after it passes through both the turbocharger and the engine blower (refer to SM1-63-44.0).

## 43.2 Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings and thrust bearings (Fig. 4). The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

Note: <u>On OTM (optional turbocharger mounting) vehicle engines, the oil returns by gravity directly from the turbocharger through two drain holes in the blower end plate (front end plate for front mounted turbocharger or rear end plate for rear mounted turbocharger) to lubricate the blower bearings and either the timing gears or the governor drive and fuel pump drive (refer to Lubrication in SMl-63-42.0T.</u>

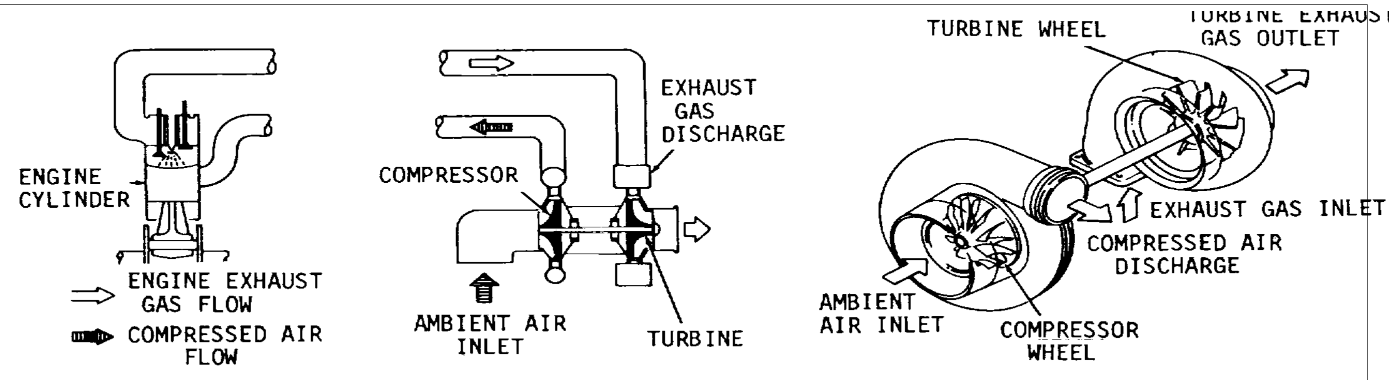


*Fig. 3*
*Schematic Air Flow Diagram*

Before the initial start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under 43.9, "Install Turbocharger".

## 43.3 Periodic Inspection

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to SM1-63-66.0).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

**CAUTION**

Do Not Operate The Engine If Leaks Are Found In The Turbocharger Ducting Or If The Air Cleaner Is Not Filtering Efficiently. Dust Leaking Into The Air Ducting Can Damage The Turbocharger And The Engine.

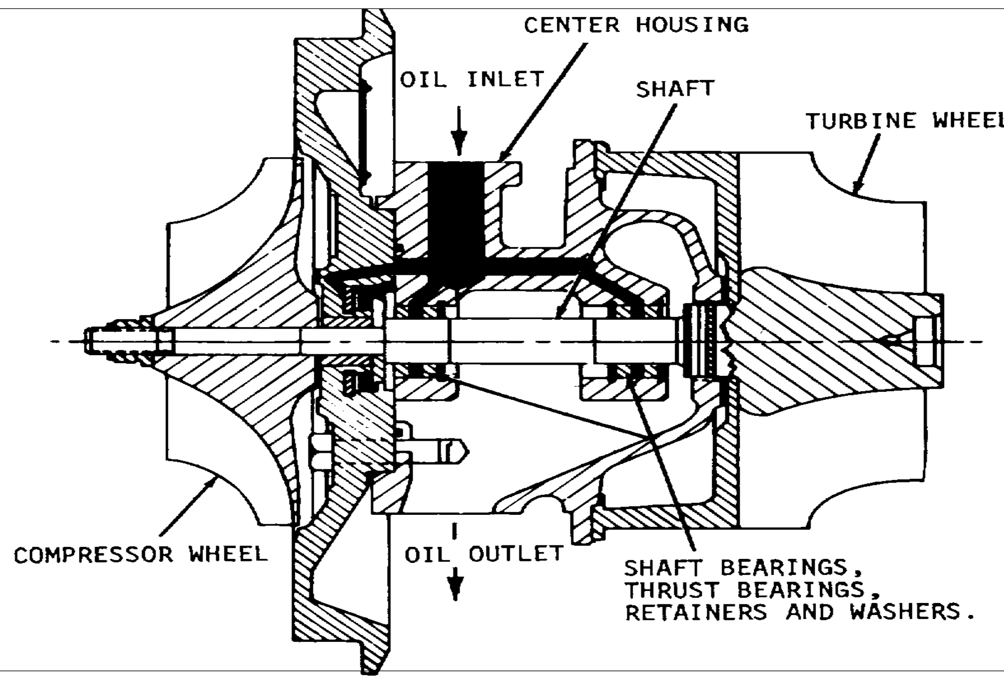


*Fig. 4*
*Typical Turbocharger Oil Flow Diagram*

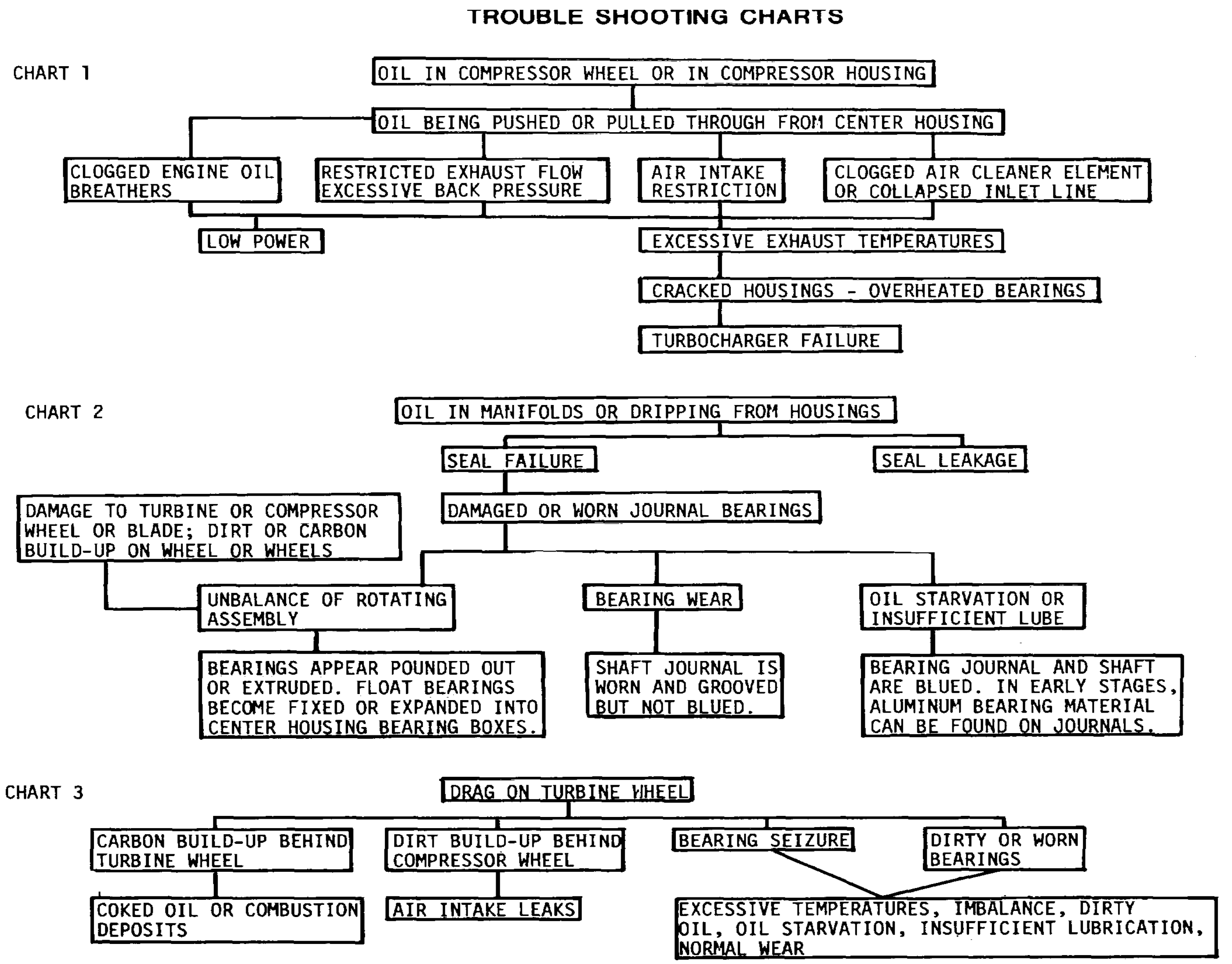


*Fig. 5*
*Inspection Checks for Turbocharger*

Remove the air inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to "Trouble Shooting Charts" (Fig. 5). Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

**CAUTION**

Do Not Attempt To Remove Carbon Or Dirt Buildup On The Compressor Or Turbine Wheels Without Removing The Turbocharger From The Engine. The Blades On The Wheels Must Be Thoroughly Cleaned. If Chunks Of Carbon Are Left On The Blades, An Unbalanced Condition Would Exist And Subsequent Failure Of The Bearings Would Result If The Turbocharger Is Operated. However, It Is Not Necessary To Dis-Assemble The Turbocharger To Remove Dirt And Dust Buildup.

For proper operation, the turbocharger rotating assembly must turn free. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1 of Fig. 5. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine.

**CAUTION**

Be Sure The Oil Inlet Lines Are Filled With Oil And That They Are Clear Of The Turbine Housings.

Check for signs of oil leaking from the turbocharger housings.

Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2 of Fig. 5.

Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pullover. Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3 of Fig. 5.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal.

(1) A worn or defective oil seal, which must be replaced.
(2) High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.
(3) Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil, it indicates leakage.

If this test does not show leakage patterns, the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in al cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure.

(1) Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to SM1-63-66.0.
(2) Be certain that the turbocharger oil drain line is unrestricted.
(3) Be certain that the turbocharger has not obviously been damaged and in need of major repair.
(4) Remove the air intake ducting. Inspect the inside of the ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with the compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.
(5) Remove the compressor housing from the turbocharger.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(6) Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the backplate annulus with suitable solvent spray and then dry completely with shop air.
(7) Spray the backplate annulus with a light coating of Spot-Check developer type SKD-MF, or equivalent.
(8) Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.
(9) Warm up the engine to normal operating temperature.
(10) Operate engine at no load at the governor limited high speed for approximately five minutes.
(11) Return the engine to low idle and then stop it.
(12) Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the Spot-Check developer on the backplate annulus. This surface should be completely free of oil streaks after the test.
(13) If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

### 43.4 Remove Turbocharger

(1) Disconnect the exhaust manifold adapter attached to the turbine housing.

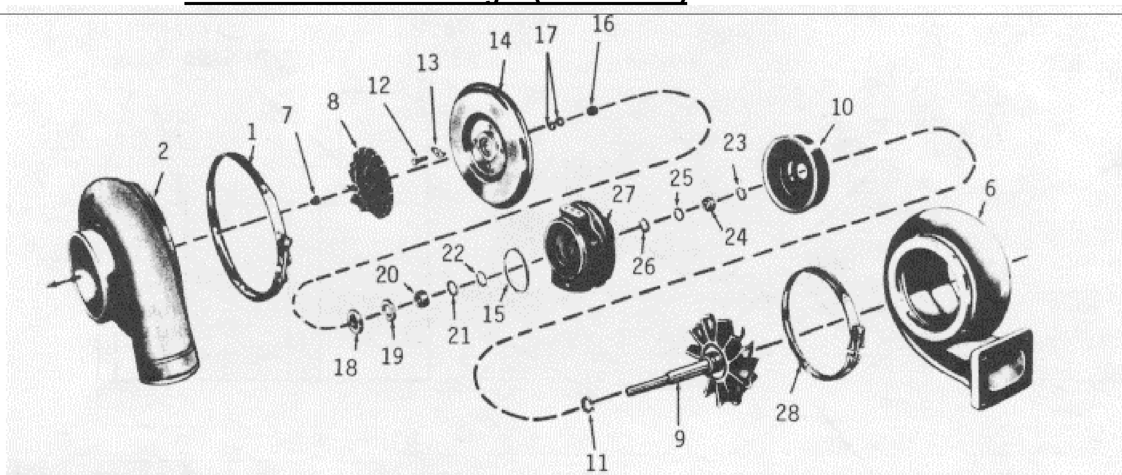


Fig. 6
Turbocharger Details and Relative Location of Parts

(20) Bearing
(1) Coupling - "V" Band (12) Screw (21) Washer - Bearing
(2) Housing - Compressor (13) Lockplate (22) Ring - Snap
(6) Housing - Turbine (14) Backplate Assembly (23) Ring - Snap
(7) Nut - Self Locking (15) Ring - Seal (24) Bearing
(8) Wheel - Compressor (16) Spacer - Thrust (25) Washer - Bearing
(9) Shaft - Turbine Wheel Assembly (17) Ring - Piston (26) Ring - Snap
(10) Shroud - Turbine Wheel (18) Collar - Thrust (27) Housing - Center
(11) Ring - Turbine Piston (19) Washer - Inboard Thrust (28) Coupling - "V" Band

Note: When removing the left bank exhaust manifold to turbocharger tube on the blower mounted turbochargers, matchmark one end of the tube for ease of identification when reinstalling the tube.

(2) Disconnect the air inlet hose attached to the compressor housing.
(3) Remove the oil inlet line from the top of the center housing.
(4) Remove the oil outlet line from the bottom of the center housing.
(5) Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
(6) Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket. Then lift the turbo-charger assembly away from the engine and place it on a bench.
(7) Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entry of foreign material.

### 43.5 Disassemble Turbocharger

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well ’Ventilated Area, Away From Flame.

Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly and proceed as follows:

Note: Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly to assure re-assembly in the same relative position.

(1) Refer to Fig. 6 and loosen the "V" band coupling (1) securing the compressor housing
(2) to the backplate assembly (14) and remove the compressor housing and "V" band.

**CAUTION**

Exercise Care When Removing The Compressor Housing And Turbine Housing To Prevent Damage To The Compressor And Turbine Wheels.

(2) Loosen the "V" band coupling (28) securing the turbine housing (6) to the center housing (27). Remove the turbine housing from the center housing.

Note: Tap the housing with a soft hammer if force is needed for removal.

(3) Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture (Fig. 7). Remove the wheel nut (7) from the shaft.

Note: If a holding fixture is not available, clamp a suitable socket or b6x end wrench in a vise and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright and remove the wheel nut from the shaft.

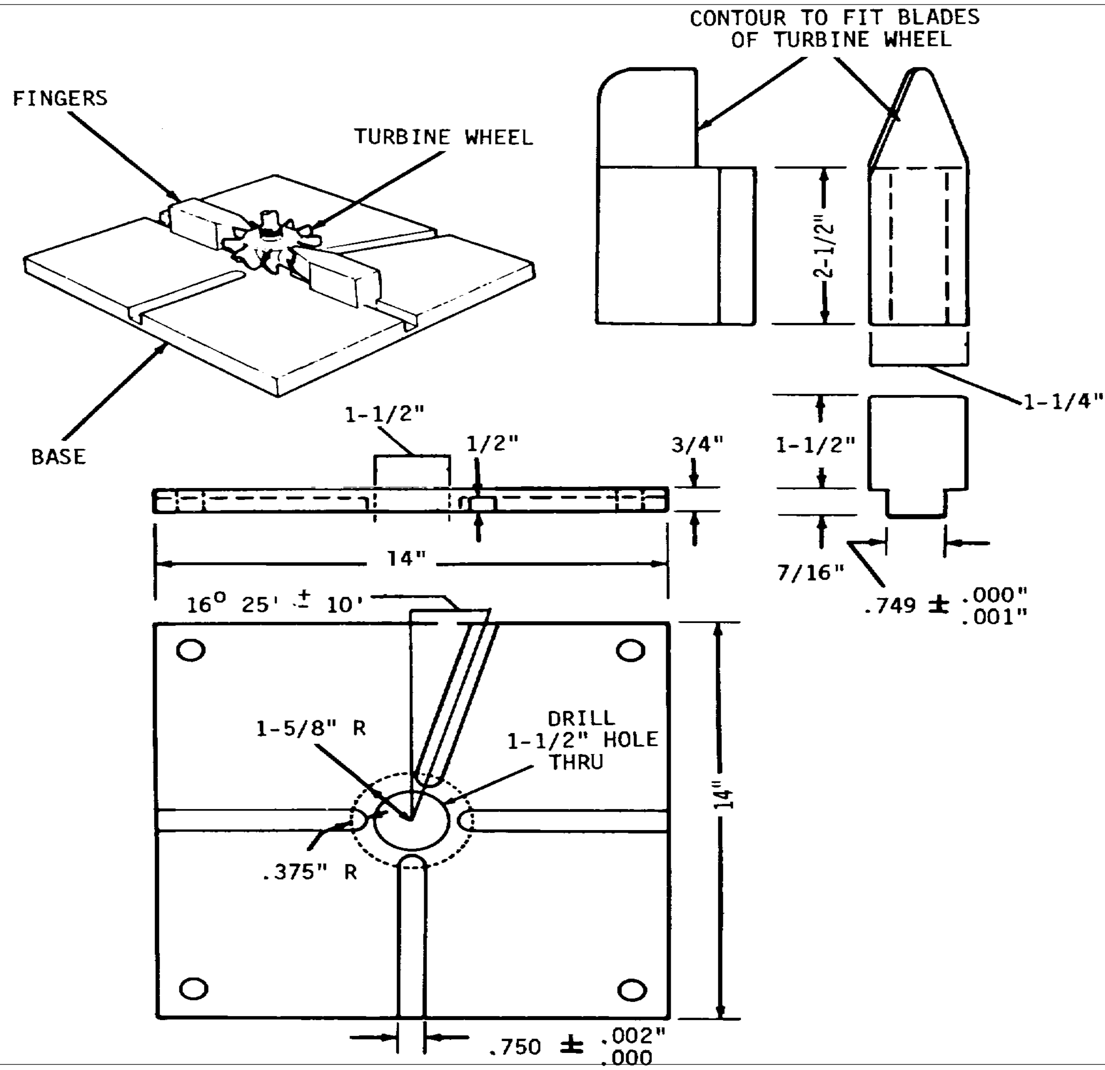


*Fig. 7*
*Turbocharger Holding Fixture*

**CAUTION**

To Prevent The Possibility Of Bending The Turbine Wheel Shaft, Remove The Compressor Wheel Nut From The Shaft With A Double Universal Socket And Tee Handle.

(4) Lift or press the compressor wheel (8) from the wheel shaft assembly (9).
(5) Withdraw the wheel shaft assembly (9) from the center housing. The wheel shroud (10), which is not retained, will fall free when the wheel shaft is removed.
(6) Remove and discard the turbine piston ring (11) from the wheel shaft.
(7) Bend down the lock tabs and remove the four bolts (12) and lockplates (13) securing the backplate assembly (14) to the center housing (27) and remove the backplate assembly. Also, do not remove the pins from the center housing, unless it is necessary to replace the pins.

Note: Tap the backplate lightly to remove it from the center housing recess.

(8) Remove and discard the seal ring (15) from the groove in the center housing.
(9) Remove the thrust spacer (16) and piston rings (17) from the backplate assembly. Discard the piston ring(s).
(10) Remove the thrust collar (18), inboard thrust bearing (19) if used, bearing (20), bearing washer (21) if used, and snap ring

thrust bearing, bearing, washer and snap ring.

(11) Remove the snap ring (23), bearing (24), bearing washer (25) if used, and snap ring (26) from the opposite end of the center housing. Discard the snap rings, bearing and washer.

## 43.6 Cleaning

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Before cleaning, inspect the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all parts in a non-caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all of the parts thoroughly.

**WARNING**

Never Use A Caustic Cleaning Solution For Cleaning As This Will Damage Certain Parts. Use The Cleaning Solution In An Open Or Well-Ventilated Area. Avoid Breathing The Fumes To Avoid The Possible Toxic Effect Of The Cleaning Solvent. Keep Away From Open Flames To Avoid The Possibility Of A Fire. Do Not Use A Wire Brush Or A Steel Blade Scraper To Clean The Parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

Clean the oil passage in the backplate assembly and the housing thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.

## 43.7 Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel shroud and turbine wheel for signs of rubbing. For shaft bearing journal dimensions and wear limits, refer to SM1-63-40.0.

Inspect the shaft for signs of scoring, scratches or bearing seizure.

Check the compressor wheel for signs of rubbing, or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

Inspect the seal parts for signs of rubbing or scoring of the running faces.

Inspect the backplate assembly for wear or damaged bore (piston ring groove).

Inspect the housing for contact with the rotating parts. The oil and air passages must be clean and free of obstructions.

Inspect the exhaust outlet elbow seal ring for signs of wear or breakage.

Minor surface damage may be burnished or polished. Use a Silicone Carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts.

It is recommended that the seal ring, piston rings, thrust bearings, bearing washers, snap rings, lockplates and bolts be replaced at time of disassembly. The backplate must be replaced if the thrust bearing is excessively worn.

## 43.8 Assembly Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

Refer to Fig. 6 for parts orientation and proceed as follows:

(1) Lubricate the new bearings (20 and 24) with clean engine oil.

(2) Install a new snap ring (26), bearing washer (25), bearing (24) and snap ring (23) in the turbine end of the center housing (27).

(3) Install a new snap ring (22), bearing washer (21) and bearing in the compressor end of the center housing.

(4) Install a new piston ring(s) (17) on the thrust spacer (16) and gently insert the spacer into the backplate assembly (14).

**CAUTION**

Do Not Force The Piston Ring(s) Into Place.

(5) Make sure the compressor bearing is in place, then position the new inboard thrust washer (19) flat against the center housing with the hole and cutout in the thrust washer in alignment with the pins in the center housing.

(6) Install the thrust collar (18) snugly against the thrust washer. Lubricate the thrust collar and thrust washer with clean engine oil.

(7) Install a new seal ring (15) in the groove at the compressor end of the center housing.

(8) Align the oil feed holes in the center housing (27) and the backplate assembly (14) and attach the backplate to the center housing with four bolts (12) and new lockplates (13). Tighten the bolts to 80-100 in/lb. or 9-11 N•m torque and bend the lockplate tangs up against the side of the bolt heads.

**CAUTION**

If A New Backplate With A Warning Plate Is Inadvertently Installed, The Warning Plate Must Be Removed And The Three Drive Screw Holes Plugged To Prevent Air Leakage.

(9) Install a new turbine piston ring (11) on the wheel shaft assembly.

Note: Before installing the piston ring, fill the piston ring groove with Dow Corning High Vacuum Silicone grease, or equivalent.

(10) Position the wheel shroud (10) against the center housing (27) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing. Lubricate the wheel shaft assembly journal prior to assembly.

**CAUTION**

Be Careful Not To Scuff Or Scratch The Bearings When Installing The Shaft.

(11) Place the turbine wheel shaft assembly, shroud, center housing and backplate up right in a suitable holding fixture as shown in Fig. 7.

Note: If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.

(12) With the compressor wheel at room temperature, position it over the shaft.

(13) Lightly lubricate the shaft threads and wheel face that will be under the nut with the engine oil and install the retaining nut. Tighten the nut to 125-150 in/lb. (14-17 N•m) torque to seat the compressor wheel against the thrust spacer.

(14) Loosen the nut and inspect the nut face and the front face of the compressor wheel to be sure they are smooth and clean.

(15) Re-tighten the nut to 35-55 in/lb. (4-6 N•m) torque.

(16) Continue to tighten the retaining nut until the shaft increases .007" to .008" in length (T18A40) or .009" to .010" in length (T18-A90, TV81).
at assembly against the center housing (27) and secure it in place.

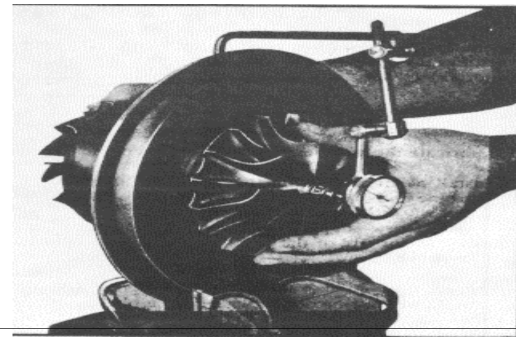

*Fig. 8*
*Checking Bearing Axial End Play*

**CAUTION**

Tighten The Retaining Nut In Such A Manner As Not To Impose Bending Load On The Shaft.

Note: If equipment is not available to measure the shaft stretch, tighten the wheel retaining nut to 35-55 in/lb.74-6 N•m) torque. Then continue to tighten the nut through an angle of .120-1300 turn (900 = 1/4 turn).

(17) Check the bearing axial end play:
- (a) Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 8.
- (b) Fasten the dial indicator and magnetic base (J 7872-2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 8).
- (c) Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be .003" to .010". If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

(18) Position the turbine housing (6) as marked at disassembly against the center housing (27) and secure it in place.
- (a) Secure turbine housing with the "V" band coupling (28). Tighten the toggle nut as follows:
  - (1) Lubricate the toggle bolt threads with a high temperature anti-seize compound such as Jet Lube (Mil Spec A-907D, or equivalent.
  - (2) Tighten the nut on the "V" band toggle bolt to approximately 160 in/lb. (18 N•m) torque.

**CAUTION**

Do Not Pull A Misaligned Turbine Housing Into Alignment With The "V" Band Coupling. The Parts Must Be Aligned And Seated First.

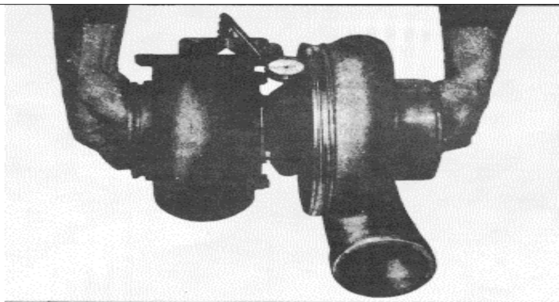

*Fig. 9*
*Checking Shaft Radial Movement*

(3) Loosen the "V" band coupling nut to approximately 50 in/lb. (6 N•m) torque, then re-torque the nut to 110-130 in/lb. (12-15 N•m) torque.

(19) Position the compressor housing (2) as marked at disassembly against the backplate assembly (14) and secure it in place with the "V" band coupling (1). Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 110-130 in/lb. (12-15 N•m) torque.

(20) Check the shaft radial movement:

(a) Position the magnetic base J 7872-2 with the swivel adapter J 7872-3 on the flat surface of the turbine housing inlet flange as shown in Fig. 9.

(b) Fasten the dial indicator extension rod J 7872-1 to the dial indicator J 8001-3 and attach the dial indicator to the swivel adapter.

(c) Insert the extension rod J 7872-1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

**CAUTION**

Make Sure The Extension Rod Does Not Make Contact With The Sides Of The Center Housing, Otherwise It Will Be Impossible To Obtain An Accurate Reading.

(d) Grasp each end of the rotating assembly (Fig. 9) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003" and .007". If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

(21) If it is to be stored, lubricate the unit internally and install protective covers on all openings.

(22) Stamp the letter "R" in the lower left-hand corner of the name plate to identify that the turbocharger has been reworked.

## 43.9 Install Turbocharger

If a turbocharger is to be installed on a new or overhauled engine, operate the engine for approximately one hour before the turbocharger is installed. This must be done to ensure that no foreign material is carried from the engine into the turbocharger lubrication system.

(1) Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

(2) Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed.

Note: Be sure gaskets are installed at the three mounting bracket to flywheel housing attaching bolts.

(3) Place the turbocharger assembly into position on the mounting bracket. Use a new gasket between the exhaust manifold adapter and the turbine housing flange.

**CAUTION**

When Attaching The Exhaust Flange Or Adapter To The Turbine Housing, Be Sure The Inner Diameter Of The Flange Or Adapter Is The Same As The Turbine Housing Inner Diameter. The Turbine Opening Is 3.892".

(4) Secure the turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbo-charier tight against the bracket.

Important: When self-locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is full thread engagement (at least one full thread above the nut) of the self-locking nuts on the bolts.

(5) Slide the blower air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

(6) When installing the left bank exhaust manifold to turbocharger tube on a blower mounted turbocharger, it is very important that the tube is installed correctly. If the tube is installed incorrectly, it can crack in the flange area and adversely affect performance. The solid left bank tube is almost symmetrical, thus it is difficult to identify which end goes where. Therefore, position the tube between the exhaust manifold and the turbocharger and check to determine that the conical seat at each end of the tube is a flush fit with the openings. If not, reverse the position of the tube and recheck to be sure each end of the tube is a flush fit with the openings. To help in the installation of the tube, loosen the exhaust manifold mounting bolts and then tighten them alter-

nately while tightening the tube clamps.

Note: Be sure the exhaust manifold remains seated on the locating pads on the cylinder head.

(7) Tighten the turbocharger to exhaust manifold adapter bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.
(8) Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.
(9) Attach the oil inlet line to the cylinder block.
(10) After installing a rebuilt or new turbocharger, it is very important that all moving parts of the turbocharger center housing be lubricated as follows:
    (a) Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 4).
    (b) Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.
    (c) Add additional clean engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.
    (d) Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig or 60 kPa at idle speed).

**WARNING**

Do Not Hold The Compressor Wheel, For Any Reason, While The Engine Is Running. This Could Result In Personal Injury.

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure before the turbocharger reaches its maximum operating speed which is produced by high engine speeds. Starting any turbo-charged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

(11) Check all connections, ducts and gaskets or leaks.
(12) Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

Note: <u>After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated</u>

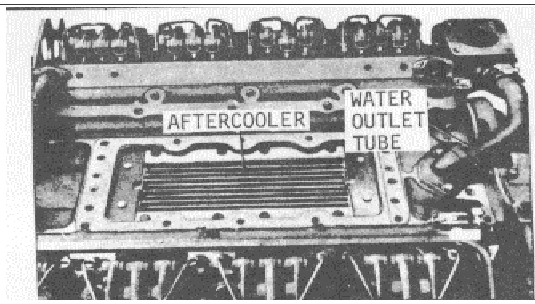


*Fig. 1*
*Aftercooler Mounted in Cylinder Block*

The aftercooler mounts in the cylinder block opening between the cylinders, beneath the blower assembly (Fig. 1). The aftercooler (Fig. 2) cools the air going into the engine after it passes through both the turbocharger and the blower. The air flows downward through the aftercooler and the coolant flows from rear to front through the aftercooler and returns through the left bank thermostat housing.

The top deck of the cylinder block has been revised to accept the aftercooler. A water inlet adapter plug replaces the rear 2-1/2" core plug in the bottom of the cylinder block opening (Fig. 4) to supply water to the aftercooler. Tool J 25275 should be used to install or remove this adapter plug.

### 44.1 Remove Aftercooler

(1) Loosen the two 7/16"-14 x 5-1/4" attaching bolts and lift the turbocharger from the air inlet adapter (refer to SM1-63-43.0).
(2) Remove the air inlet adapter from the blower.
(3) Remove the blower and any accessories attached to the blower from the cylinder block (refer to SMI-6342.0).
(4) Loosen the hose clamps and slide the cylinder block water outlet tube hose back against the thermostat housing.
(5) Remove the water outlet tube from the front of the cylinder block. Discard the gasket.
(6) Remove and discard the 5/16"-18 x 9/16" attaching bolts with nylon locking patch and lift the aftercooler from the cylinder block opening between the cylinders. Do not remove the four bolts in the top face

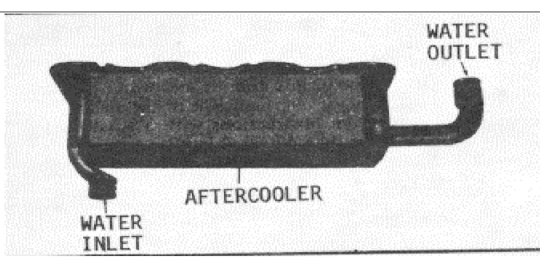


*Fig. 2*
*Aftercooler*

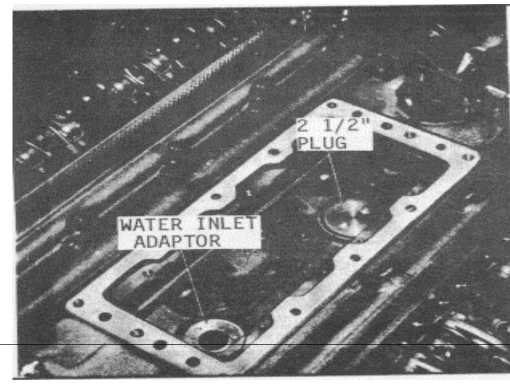


*Fig. 3*
*Location of Water Inlet Adapter Plug in Cylinder Block*

of the aftercooler (Fig. 1). They are part of the aftercooler assembly and need not be removed for any reason.

Note: Be careful not to damage the cooler fins when lifting the aftercooler from the cylinder block.

(7) Remove and discard the seal rings from the grooves in the water inlet and outlet tube ends of the aftercooler.

### 44.2 Clean Aftercooler

The length of time an aftercooler will function satisfactorily before cleaning will be governed largely by the kind of coolant and coolant additive used in the engine.

Check all of the cooler fins and air and water passages for plugging at major overhaul. Clean the fins of dirt or any other foreign obstructions with a small brush. Do not apply more than 40 psi (276 kPa) air pressure.

### 44.3 Install Aftercooler

(1) Install new seal rings in the two grooves on the water inlet and outlet tube ends of the aftercooler. Coat the seal rings lightly with engine oil or vegetable shortening. Do not scratch or nick the sealing edge of the seal rings.
(2) Place the aftercooler, water outlet end first, into the cylinder block opening between the cylinders. The water inlet end of the cooler seats in the water inlet adapter plug (Fig. 3). Install new 5/16"-18 x 9/16" attaching bolts with nylon locking patch (six - 6V-92, eight - 8V-92). Do not tighten the bolts until the water outlet tube to thermostat housing hose and clamps are aligned and tightened.

(3) Use a new gasket and attach the water outlet tube with two 5/16" bolts and lock washers to the cylinder block. Do not tighten the attaching bolts.

(4) Align the water outlet tube to the thermostat housing with the hose and clamps in position. Tighten the clamps.

(5) Tighten the two 5/16" water outlet tube bolts, then tighten the aftercooler attaching bolts.

(6) Use a new blower to cylinder block gasket and install the blower and any accessories attached to the blower (refer to SM1-63-42.0).

(7) Attach the air inlet adapter to the blower with the 7/16"-14 x 1-1/2" attaching bolts and lock washers. Tighten the bolts to 46-50 ft/lb (62-68 N-m) torque.

(8) Install the turbocharger (refer to SM1-63-43.0). Tighten the two 7/16"-14 x 5-1/4" bolts to 46-50 ft/lb (62-68 N•m) torque.

## 45.1 Blower Drive Seal Ring

The rubber seal ring used between the blower end plate and the blower drive support can be replaced without removing the blower as follows:

(1) Remove the clamp and cut and remove the old seal ring.

(2) After thoroughly cleaning the blower drive groove area, make a square cut on a new seal ring and install the seal ring around the groove, with the cut at the top. Attach the two ends of the seal ring together with Loctite No. 06, or equivalent, as follows:

(a) The cutting blade to be used must be clean and free of contaminants. If a razor edge is to be used, remove the protective oil film by wiping with solvent.

(b) Make a square cut in the replacement seal. The cut ends must remain clean to achieve a satisfactory bond.

(c) Apply a thin film of Loctite Super Bonder Adhesive to one of the cut ends. Use adhesive sparingly and avoid contact with skin.

(d) Position the seal in the blower drive groove, locating the adhesive treated end first. Place the other end of the seal in the groove and slide it into the adhesive end to make the joint. Apply light pressure to the joint and hold firmly for 30 seconds. (e) To remove excess adhesive around the joint, apply a chlorinated solvent (Acetone, MEK or Methylene Chloride) to a cloth and wipe the joint.

**WARNING**

This Adhesive Contains Cyanoacrylate. Keep Away From Children. Irritating Liquid And Vapor. Hazardous If Swallowed. Use With Adequate Ventilation. In Case Of Skin Contact, Flush With Plenty Of Water. For Eye Or Mouth Contact, Get Medical Attention.

(3) Install the plain clamp between the raised edges of the seal ring and tighten.

Note: <u>If a former seal ring (without groove) is used, it should be replaced with the current molded (two raised edges) type seal ring.</u>

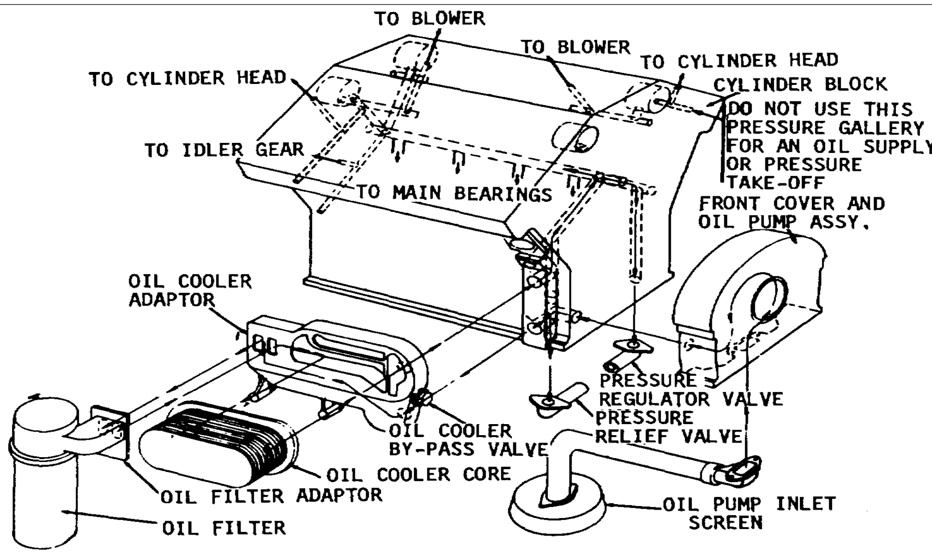


*Fig. 1*
*Schematic Diagram of Typical 6V Lubrication System*

Figure 1 schematically illustrates the flow of oil through a typical 6V engine lubrication system including the various components such as the oil pump full-flow oil filter, oil cooler, and pressure regulator.

The oil pump is placed in the crankshaft front cover and consists of a pair of spur gears, one large and one small, which mesh together and ride in a cavity inside the crankshaft cover. The large gear is concentric with and splined to a pump drive hub on the front end of the crankshaft. The pump idler gear is much smaller and runs on a bushing and hardened steel shaft pressed into the crankshaft cover.

The oil is drawn by suction from the oil pan through the intake screen and pipe to the oil pump where it is pressurized. The oil then passes from the pump into a short gallery in the cylinder block to the oil cooler adapter plate. At the same time, oil from the pump is directed to a spring-loaded pressure relief valve mounted on the cylinder block. This valve discharges excess oil directly to the oil sump when the pump pressure exceeds 105 psi (724 kPa).

From the oil cooler adapter plate, the oil passes into the full-flow filter, through the oil cooler and then back into the cylinder block where a short vertical oil gallery and a short diagonal oil gallery carry the oil to the main longitudinal oil gallery through the middle of the block. Valves are also provided to bypass the oil filter and oil cooler should either one become plugged.

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a pressure regulator valve located at the end of a vertical oil gallery connected to the main oil gallery. This vertical gallery is located at the front of the cylinder block on the side opposite the cooler (Fig. 1). When the oil pressure at the valve exceeds 50 psi (345 kPa), the regulator valve opens, discharging oil back into the sump.

From the main oil gallery, the pressurized oil flows through drilled passages to each main bearing then passes to an adjacent pair of connecting rods by means of grooves in the unloaded halves of the main and connecting rod bearings and drilled passages in the crankshaft. The rifle drilled connecting rods carry oil from the rod bearings to the piston pin bushing.

At the rear of the block, two diagonally drilled oil passages, which intersect the main oil gallery, carry oil to the two rear camshaft end bearings. Oil is then conducted through the rifle drilled camshaft to the intermediate and front end bearings. Oil from the camshaft intermediate bearings is directed against the camshaft lobes and cam rollers which run in an oil bath. This oil from the intermediate bearings provides lubrication of the cam lobes immediately after starting the engine when the oil is cold and before camshaft bearing oil flow and oil drainage from the cylinder head have had time to build up.

The diagonally drilled oil passage on the right side at the rear of the block intersects with a vertical passage to carry oil to the right bank cylinder head. A short gallery also intersects with this diagonal passage to lubricate the idler gear bearing. Another gallery intersecting the diagonal passage from the camshaft at the front of the block supplies oil to the left bank cylinder head.

Note: Do not use the oil gallery on the upper front left bank of the cylinder block (Fig. 1) for an oil supply or pressure take-off. This gallery intersects 'the cylinder head oil supply gallery. If used, it will reduce oil pressure to the rocker arm assemblies.

Drilled passages, intersecting longitudinal galleries which parallel the camshafts, lead to the blower and supply oil for the blower drive gears and bearings. Oil from the right-bank camshaft front end bearing lubricates the water pump drive gear and bearings and the front camshaft gear.

The gear train is lubricated by the overflow of oil from the camshaft pocket spilling into the gear train compartment and by splash from the oil pan. A certain amount of oil also spills into the gear train compartment from both camshaft rear end bearings, the blower drive gear bearing and the idler gear bearing. The blower drive gear bearing is lubricated through an external pipe from the blower rear end plate to the blower drive support.

The valve and injector operating mechanism is lubricated from a longitudinal oil passage, on the camshaft side of each cylinder head, which connects to the main oil gallery in the cylinder block. Oil from this passage enters the drilled rocker arm shafts through the lower end of the rocker shaft bolts and rocker shaft brackets. 'Excess oil from the rocker arms lubricates the exhaust valves and cam followers.

## 46.1 Lubrication System Maintenance

Use the proper viscosity grade and type of heavy duty oil as outlined in the Lubricating Oil Specifications in Operator's Manual. Change the oil and replace the oil filter elements at the periods recommended by the oil supplier (based on his analysis of the drained engine oil) to ensure trouble-free lubrication and longer engine life.

The oil level should never be allowed to drop below the low mark on the dipstick. Overfilling the crankcase may contribute to abnormal oil consumption, high oil temperature, and also result in oil leaking past the crankshaft rear oil seal.

To obtain the true oil level, the engine should be stopped and sufficient time (approximately twenty minutes) allowed for the oil to drain back from the various parts of the engine. If more oil is required, add only enough to bring the level to the full mark on the dipstick.

## 46.2 Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by ethylene glycol antifreeze solution or other soluble material, refer to SM1-63-54.0 for the recommended cleaning procedures.

The gear type lubricating oil pump is mounted in the crankshaft front cover, which also functions as the oil pump body (Fig. 1). The pump consists of two spur gears which mesh and rotate in a cavity inside the crankshaft cover. The pump drive gear is concentric with and splined to a pump drive hub on the front end of the crankshaft. The pump driven gear and bushing assembly rotates on a hardened steel shaft. One end of the driven gear shaft is pressed into the crankshaft front cover and the other end is supported in the oil pump gear retaining plate.

### 47.1 Operation

As the gears revolve, a vacuum is created on the inlet side of the pump and oil is drawn from the oil pan through the intake screen and pipe assembly into a passage, in the crankshaft front cover, which leads to the inlet port in the pump. The oil then enters the cavities between the gears and the crankshaft front cover and is then forced out under pressure through the discharge port into a short gallery in the cylinder block which leads to the oil filter, oil cooler and cylinder block main oil gallery. At the same time, the oil is directed through a short vertical gallery to the pressure relief valve which opens at approximately 105 psi (724 kPa) to return excess oil to the oil pan.

### 47.2 Remove Oil Pump

(1) Drain the oil and remove the oil pan.
(2) Remove the oil pan gasket and clean all traces of the gasket from both the oil pan and the cylinder block.
(3) Remove the bolts and lockwashers which secure the oil inlet pipe and screen support to the crankshaft front cover and to the main bearing cap. Then remove the oil inlet pipe and screen support as an assembly.
(4) Remove the crankshaft front cover from the engine as outlined in SM1-63-12.0.
(5) Remove the oil pump drive hub and key from the crankshaft.

### 47.3 Disassemble Oil Pump

(1) Remove the self-locking bolts that secure the oil pump gear retaining plate to the crankshaft front cover. Then remove the retaining plate.
(2) Remove the oil pump drive and driven gears from the crankshaft front cover.

### 47.4 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean all of the metal parts with fuel oil and dry them with compressed air.

Examine the oil pump gear cavity in the crankshaft front cover. Replace the cover if the surfaces are worn or scored excessively. If necessary, replace the crankshaft front oil seal as outlined in SM1-62-10.0.

Replace the driven gear shaft if it is worn or scored excessively. When a new shaft is pressed in place, the shoulder on the shaft must be flush to .020" below the finished face of the crankshaft front cover.

The clearance between the driven gear bushing and the shaft is .001" to .0025" when new parts are used, or a maximum of .0035" with used parts.

Inspect the teeth on the oil pump gears and the pump drive hub. Also examine the bushing in the driven gear for wear. The bushing is not serviced separately. Therefore, if the bushing is worn, it will be necessary to replace both the drive and driven gears as they are only serviced as a set. The use of excessively worn parts will result in low oil pressure which may cause serious damage throughout the engine.

Inspect the inner face of the oil pump gear retaining plate. Replace the retaining plate if it is scored or worn.

Remove the screen and cover from the oil inlet pipe assembly. Then clean the parts with fuel oil and dry them with compressed air. Reassemble the screen, cover and oil intake pipe.

Whenever the oil pump is removed for service, remove and inspect the oil pressure regulator and oil pressure relief valves as outlined in SM1-63-48.0.

### 47.5 Assemble Oil Pump

Refer to Fig. 2 and assemble the oil pump as follows:

(1) Lubricate the oil pump gears and the driven gear shaft with engine oil. Then install the gears in the crankshaft front cover.
(2) Install the gear retaining plate and secure it to the crankshaft front cover with eight 5/16"-18 x 3/4" self-locking bolts. Tighten the bolts to 13-17 ft-lbs (18-23 N•m) torque.

Note: Self-locking bolts must be used due to the close clearance between the oil pump and the crankshaft.

(3) Install the key in the crankshaft and slide the oil pump drive hub in place.

### 47.6 Install Oil Pump

(1) Install the crankshaft front cover on the engine as outlined in SM1-63-12.0.

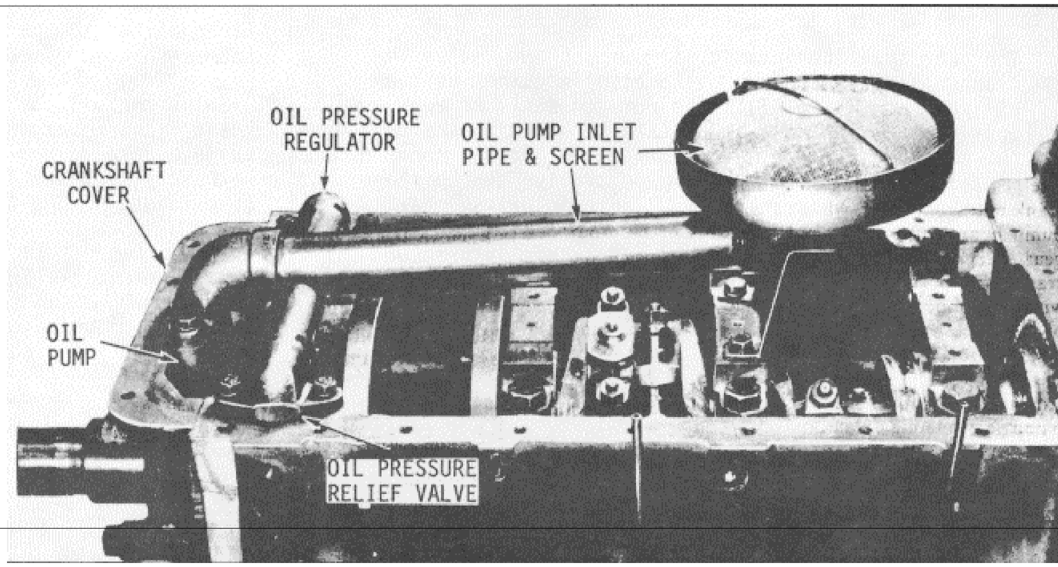


*Fig. 1*
*Typical Lubricating Oil Pump Mounting*

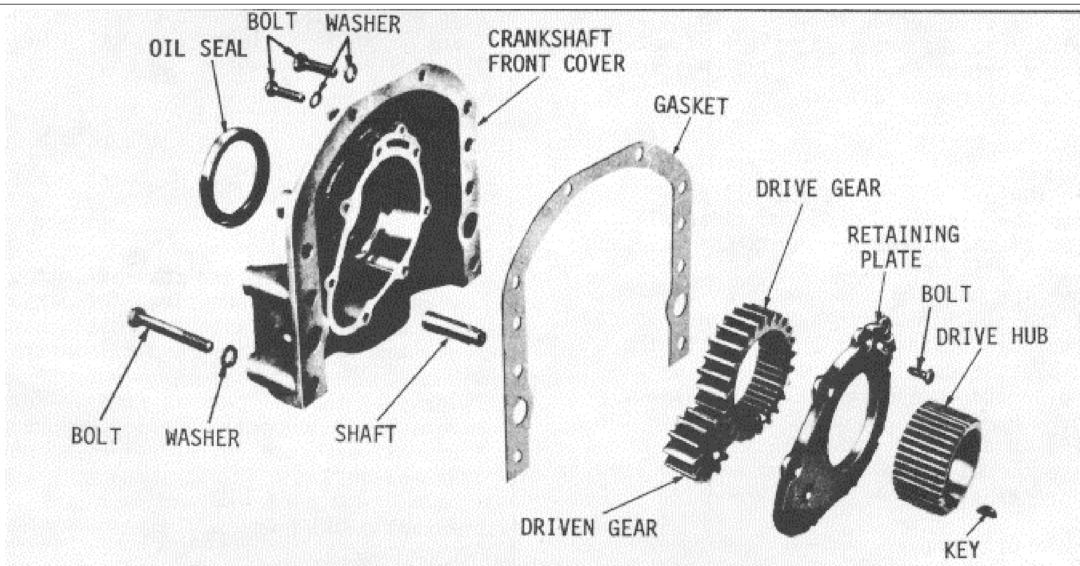


*Fig. 2*
*Lubricating Oil Pump Details and Relative Locations of Parts*

(2) Refer to Fig. 1 and install the oil inlet pipe and screen assembly. Use a new gasket between the oil inlet pipe and the crankshaft front cover.

(3) Install the oil pan, using the new gasket. Starting with the center bolt on each side and working toward each end of the oil pan, tighten the 3/8"-16 bolts to 10-20 ft-lbs (14-27 N•m) torque.

(4) Fill the oil pan, to the proper level on the dipstick, with the lubricating oil recommended in the Lubricating Oil Specifications in Operator's Manual.

## 48.1 Oil Pressure Regulator Valve

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator valve. The valve is installed at the end of the vertical oil gallery near the front of the cylinder block on the side opposite the oil cooler (Fig. 1).

The oil pressure regulator consists of a valve body, a hollow piston-type valve, a spring, a spring seat and a pin to retain the valve assembly within the valve body (Fig. 2).

The valve is held on its seat by the spring, which is compressed by the pin in back of the spring seat. The entire assembly is bolted to the lower flange of the cylinder block and sealed against leaks by a gasket between the block and the valve body. When conditions are such that the oil pressure at the valve exceeds 50 psi (345 kPa), the valve is forced from its seat and oil from the engine gallery is bypassed to the engine oil pan. Thus stabilized lubricating oil pressure is maintained at all times.

Under normal conditions, the oil pressure regulator should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

Whenever the lubricating oil pump is removed for inspection, remove the regulator valve and spring and thoroughly clean and inspect them.

## 48.2 Remove Oil Pressure Regulator

(1) Remove the two regulator-to-cylinder block attaching bolts and lockwashers.

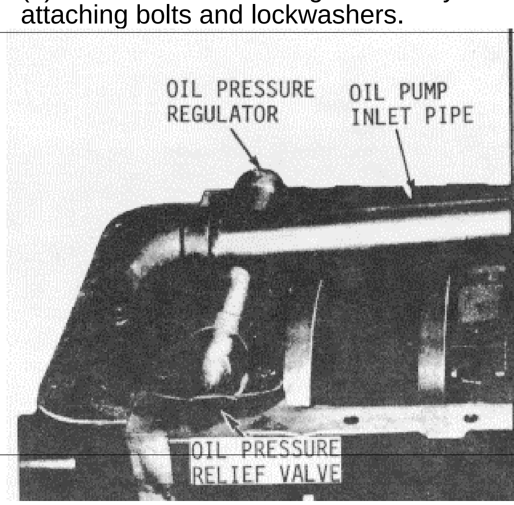


*Fig. 1*
*Oil Pressure Regulator Valve and Relief Valve Mounting*

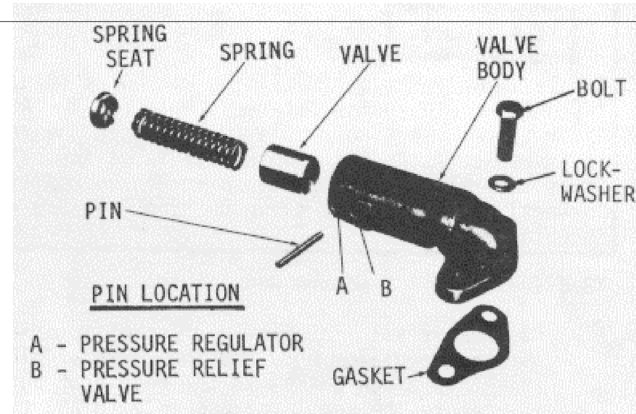


*Fig. 2*
*Oil Pressure Regulator Valve and Relief Valve Details and Relative Location of Parts*

(2) Tap the regulator body lightly to loosen it from the gasket and the cylinder block. Remove the regulator and the gasket.

## 48.3 Disassemble Oil Pressure Regulator

(1) Clamp the regulator assembly in the soft jaws of a bench vise and remove the spring seat retaining pin from the regulator body.
(2) Remove the spring seat, spring and valve from regulator body.

## 48.4 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean all of the regulator components in fuel oil and dry them with compressed air. Then inspect them for wear or damage.

The regulator valve must move freely in the valve body. If the valve or the valve body is scored and cannot be cleaned up with crocus cloth, replace them.

Replace a pitted or fractured spring.

## 48.5 Assemble Oil Pressure Regulator

After the parts have been cleaned and inspected, refer to Fig. 2 and assemble the regulator as follows:
(1) Apply clean engine oil to the outer face of the valve and slide it into the regulator body, closed end first.
(2) Insert the spring in the valve and install the spring seat. While compressing the spring, install the retaining pin behind the spring seat. Press the pin flush to .010" below the surface of the valve body.

**CAUTION**

The Valve Body Has Two Retaining Pin Holes (Fig. 2). Install The Pin In The Outermost Hole For The Regulator Valve. The Inner Hole Is Used When The Valve Is Assembled As An Oil Pump Relief Valve Assembly. It Is Important That The Retaining Pin Be Positioned Correctly So The Proper Valve Opening Pressure Will Be Obtained.

### 48.6 Install Oil Pressure Regulator

(1) Remove all traces of old gasket material from the regulator body and the cylinder block.
(2) Affix a new gasket to the regulator body and secure the regulator assembly to the cylinder block with two bolts and lockwashers.

### 48.7 Oil Pressure Relief Valve

Oil leaving the pump under pressure passes into the pressure relief valve body. The spring loaded valve opens when the pressure exceeds approximately 105 psi or 724 kPa and directs the excess oil to the oil pan. The pressure relief valve is located at the lower end of the vertical oil gallery near the front of the cylinder block on the oil cooler side (Fig. 1).

The pressure relief valve consists of a valve body-, a hollow piston-type valve, a spring, spring seat and a pin to retain the valve assembly within the valve body.

The relief valve assembly is composed of the same parts as the regulator valve assembly (Fig. 2).

However, the retaining pin is located in the inner pin hole in the valve body to provide the necessary tension on the spring.

Service operations for the pressure relief valve are similar to those of the regulator valve.

The spring in the relief valve assemblies is the same as used in the oil pressure regulator assemblies.

Replace the springs when they are pitted or fractured.

The V-92 engines are equipped with a full-flow type lubricating oil filter.

## 49.1 Full-Flow Oil Filter

The full-flow type lubricating oil filter is installed ahead of the oil cooler in the lubrication system. The engine is equipped with a single filter (Fig. 1). The filter is mounted directly to the oil cooler adapter.

The filter assembly consists of a replaceable spin-on element which is mounted on the adapter.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adapter to the space surrounding the filter element. Impurities are filtered out as the oil is forced through the element to a central passage surrounding the center stud and out through another passage in the filter adapter and then to the oil cooler.

A valve which opens at approximately 18-21 psi (124-145 kPa), is located in the filter adapter or base and will bypass the oil directly to the oil cooler should the filter become clogged.

## 49.2 Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action. Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found on the filter elements at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles and carbon must be ensured by replacement of the oil filter elements at the time the engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations and proper filter maintenance will ensure trouble-free lubrication and longer engine life.

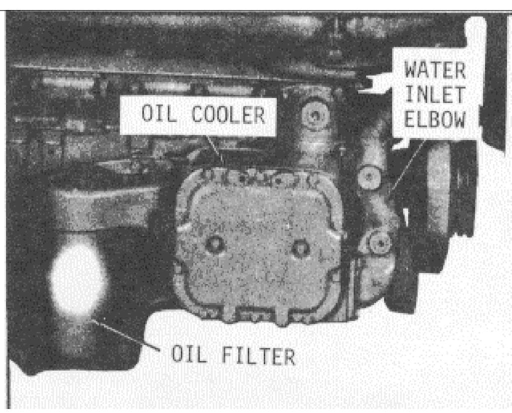


*Fig. 1*
*Typical Full-Flow Oil Filter Mounting*

In order to perform its functions satisfactorily, the lubricating oil must be kept within the proper temperature limits. If the oil is too cold, it will not flow freely. If the oil is too hot, it cannot support the bearing loads, it cannot carry away enough heat, and it may result in too great an oil flow. As a consequence, oil pressure may drop below acceptable limits and oil consumption may become excessive.

In performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat and this heat must be dissipated by an oil cooler.

Each engine is provided with an oil cooler mounted on the right-hand side of the cylinder block at the lower front corner (Fig. 1) as viewed from the flywheel end of the engine.

Oil from the lubricating oil pump flows through a passage in the oil cooler adapter to the oil filter, then through the oil cooler, and finally through the outlet passage in the cooler adapter which leads to the cylinder block oil galleries. The engine coolant is pumped through the oil cooler and completely surrounds the oil cooler core.

To ensure continuing engine lubrication should the oil cooler become plugged, a bypass valve is installed in the oil cooler adapter (Fig. 2).

### 50.1 Remove Oil Cooler Assembly

(1) Drain the cooling system by opening the drain cock at the bottom of the oil cooler housing or water inlet elbow.
(2) Remove any accessories or equipment necessary, such as the full flow oil filter, to provide access to the oil cooler.
(3) Loosen the clamps and slide the hose down on the water inlet elbow.
(4) Remove the bolts and lockwashers which retain the water inlet elbow to the oil cooler housing. Then remove the elbow and gasket.
(5) Remove the bolts, nuts and lockwashers and withdraw the water outlet flange and seal.

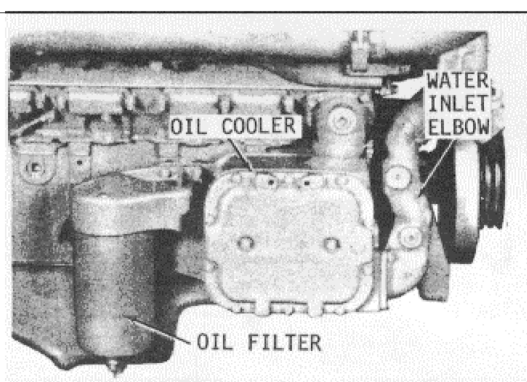


*Fig. 1*
*Typical Oil Cooler Mounting*

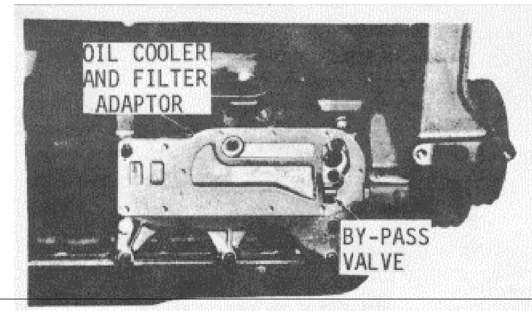


*Fig. 2*
*Oil Cooler Adapter and Bypass Valve Mounting*

(6) Remove the bolts and lockwashers and withdraw the oil cooler housing and oil cooler core as an assembly, using care to avoid dropping the oil cooler core.
(7) If the oil cooler adapter is to be removed, first remove the oil filter. Then remove the bolts and lockwashers which attach the adapter to the cylinder block and withdraw the adapter and gaskets.
(8) Clean all traces of gasket material from the cylinder block and the oil cooler components.
(9) Inspect the vertical oil passage in the cylinder block for the presence of the cup plug which directs the flow of oil through the oil cooler (Fig. 3). Absence of this plug will result in high oil temperature or low oil pressure (resulting from high oil temperature).

### 50.2 Clean Oil Cooler Core

(1) Clean the oil passages in the oil cooler core by circulating a solution of trichloroethylene through the passages with a force pump.

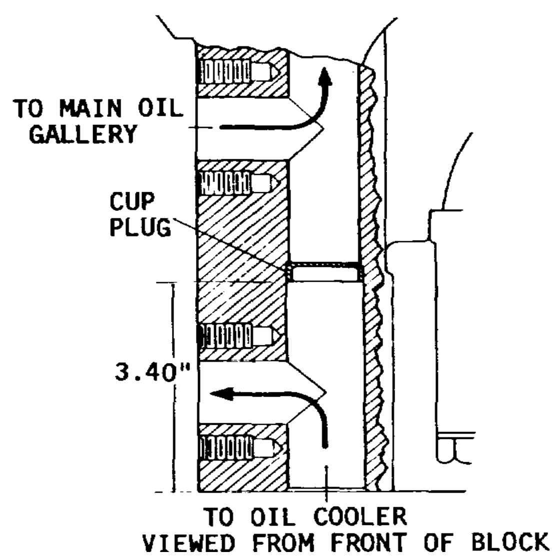


*Fig. 3*
*Location of Cylinder Block Oil Gallery Cup Plug*

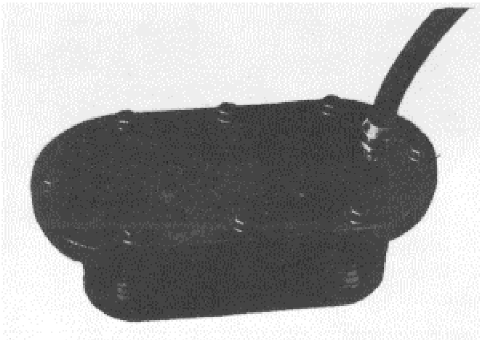

*Fig. 4*
*Oil Cooler Core Prepared for Pressure Check*

**WARNING**

Perform This Operation In The Open Or In A Well Ventilated Room. Avoid Breathing The Fumes Or Direct Contact Of The Chemicals With Your Skin.

Clean the oil cooler core before the sludge hardens. If the oil passages are badly clogged, circulate an Oakite or alkaline solution through the oil cooler core and flush it thoroughly with clean, hot water.

Note: Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. In this instance, replace the oil cooler core.

(2) After cleaning the oil passages, clean the water side of the oil cooler core by immersing it in a solution made as follows: add 1/2 pound of oxalic acid to each 2-1/2 gallons of a solution composed of 1/3 muriatic acid and 2/3 water. The cleaning action is evident by the bubbling and foaming. Carefully observe the process and remove the oil cooler core from the solution when the bubbling stops (this usually takes from 30 to 60 seconds). Then thoroughly flush the oil cooler core with clean, hot water. After cleaning, dip the oil cooler core in light oil.

**WARNING**

Protect Your Eyes And Avoid Breathing The Fumes Or Direct Contact Of The Acid With Your Skin.

### 50.3 Pressure Check Oil Cooler Core

(1) Make a suitable plate and attach it to the flanged side of the oil cooler core. Use a gasket made from rubber to ensure a tight seal. Drill and tap the plate to permit an air hose fitting to be attached at the inlet side of the oil cooler core (Fig. 4).

(2) Attach an air hose and apply approximately 75-150 psi (517-1,034 kPa) air pressure. Then submerge the oil cooler core and plate assembly in a tank of water heated to 180°F (82°C). Any leaks will be indicated by air bubbles in the water.

**WARNING**

When Making This Pressure Test Be Sure That Personnel Are Adequately Protected Against Any Stream Of Pressurized Water From A Leak Or Rupture Of A Fitting, Hose Or The Oil Cooler Core.

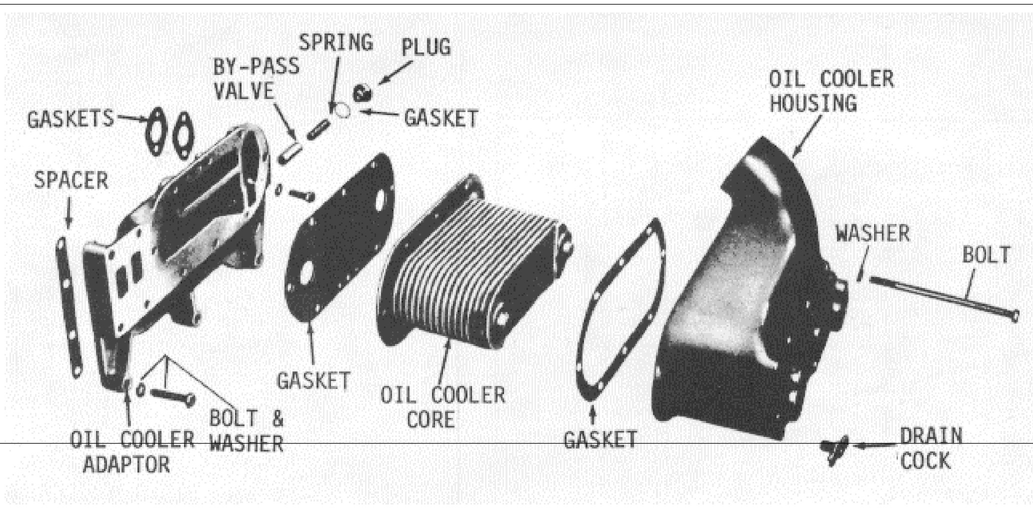


*Fig. 5*
*Oil Cooler Details and Relative Location of Parts*

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(3) After the pressure check is completed, remove the plate and air hose and dry the oil cooler core with compressed air. Replace the oil cooler core if leaks were indicated.

**CAUTION**

In Cases Where A Leaking Oil Cooler Core Has Caused Contamination Of The Engine, The Engine Must Be Flushed Immediately To Prevent Serious Damage (Refer To SM1-63-54.0).

## 50.4 Install Oil Cooler Assembly

Refer to Fig. 5 and install the oil cooler as follows:

(1) If the oil cooler adapter was removed, use new gaskets and attach the adapter to the cylinder block with bolts and lockwashers.
(2) Affix new gaskets to the inner and outer faces of the flange and insert the oil cooler core in the oil cooler housing.

**CAUTION**

The Inlet And Outlet Openings In The Oil Cooler Core Are Marked "IN" And "OUT". Make Sure The Oil Cooler Core Is Reinstalled In Its Original Position, Otherwise The Oil Flow Will Be Reversed And Could Result In Foreign Particles That May Not Have Been Removed To Be Loosened And Circulated Through The Engine. If The Openings Are Unidentified, It Is Suggested That They Be Marked Before Reinstalling The Oil Cooler Core.

(3) Place the housing and oil cooler core against the adapter and secure them with bolts and lockwashers.
(4) Install the water outlet flange and seal, or water outlet elbow, seal and gasket. Secure the flange to the cylinder block with bolts, nuts and lockwashers.
(5) Affix a new gasket to the oil cooler housing at the water inlet opening and secure the water inlet elbow to the housing with bolts and lockwashers.
(6) Slide the water inlet elbow hose in position and tighten the clamps.
(7) Install any accessories which were removed to provide access to the oil cooler.
(8) Close the drain cock in the oil cooler housing and fill the cooling system to the proper level.
(9) Add sufficient oil to the crankcase to bring the oil level to the proper level on the dipstick.
(10) Start and run the engine for a short period and check for oil and water leaks. After any leaks have been corrected and the engine has been stopped long enough (approximately twenty minutes) for the oil from various parts of the engine to drain back to the crankcase, bring the oil level up to the proper level on the dipstick.

## 50.5 Lubricating Oil Cooler Bypass Valve

To ensure engine lubrication should the oil cooler become plugged, a bypass valve is installed in the inlet passage of the oil cooler adapter (Fig. 2). The valve opens and allows the oil to bypass the oil cooler when the pressure at the inlet side exceeds the pressure at the outlet side by 40 psi (276 kPa).

The bypass valve assembly, which consists of a valve, spring, retaining plug and gasket, should be removed, cleaned and reassembled whenever the oil cooler core is cleaned or replaced. However, the bypass valve can be disassembled without removing the oil cooler on most models.

## 50.6 Remove Oil Cooler Bypass Valve

Remove the retaining plug and withdraw the gasket, spring and valve from the oil cooler adapter.

## 50.7 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean the bypass valve components with fuel oil and dry them with compressed air. Inspect the valve and spring for wear and replace them if necessary. The bypass valve spring has a free length of approximately 2-1/64". Use spring tester J 22738-02 to check the spring load. When a force of 12 pounds or less will compress the spring to 1.793", replace the springs.

## 50.8 Install Oil Cooler Bypass Valve

Refer to Fig. 5 and install the bypass valve as follows:

(1) Apply clean engine oil to the outside surface of the valve and place it in the oil cooler adapter valve cavity, closed end first.
(2) Place the spring inside of the valve and place a new gasket on the retaining plug. Install and tighten the plug to 30-40 ft-lbs (41-54 N•m) torque.

Note: A slotted bypass valve plug is used with the oil cooler adapter plug on some engines. Tighten this plug to 25-30 ft-lbs (34-41 N•m) torque.

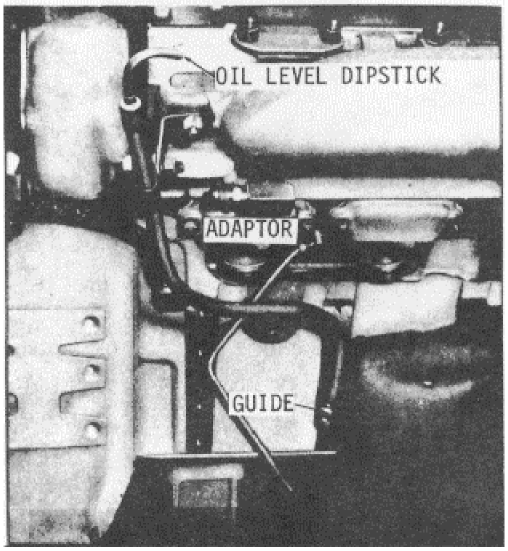


*Fig. 1*
*Typical Dipstick Mounting*

A steel ribbon type oil level dipstick is used to check the quantity of oil in the engine oil pan. The dipstick is located in the side of the cylinder block or the oil pan (Fig. 1).

Maintain the oil level between the full and low marks on the dipstick and never allow it to drop below the low mark. No advantage is gained by having the oil level above the. full mark. Overfilling will cause the oil to be churned by the crankshaft throws causing foaming or aeration of the oil. Operation below the low mark will expose the pump pick-up causing aeration and/or loss of pressure.

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various parts of the engine to drain back into the oil pan.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade.

Fill the crankcase with oil as follows:
(1) Fill the oil pan to the full mark on the dipstick.
(2) Start and run the engine for approximately ten minutes.
(3) Stop the engine and wait a minimum of twenty minutes. Then add the required amount of oil to reach the full mark on the dipstick.

Note: <u>Each engine oil filter will require approximately two additional quarts (1.9 liters) of oil.</u>

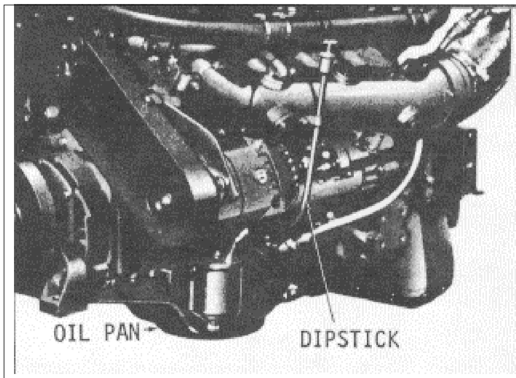


*Fig. 1 Typical One-Piece Oil Pan*

The oil pan is provided with an oil level dipstick adaptor and oil filler adapter mounting holes. A sectional oil pan gasket, consisting of two side sections and two end sections, incorporate all the necessary bolt holes.

52.1 Remove and Install Oil Pan

(1) Remove the drain plug and drain the oil.

(2) Remove the bolt and washer assemblies and detach the oil pan, being careful not to damage the oil pump piping and inlet screen.

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(3) Clean all of the old gasket material from the cylinder block and the oil pan. Clean the oil pan with fuel oil and dry it thoroughly with compressed air.

(4) Inspect a cast oil pan for porosity or cracks, a stamped oil pan for dents or other damage which may necessitate repair or replacement. Check for misaligned flanges or raised sur- faces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.

(5) When installing the oil pan, use a new gas- ket(s) and, starting with the center bolt on each side and working alternately toward each end of the pan, tighten the bolts to 10-20 ft-lbs (14-27 Nm) torque. Do not overtighten the bolts. Once the bolts are tightened to the specified torque, do not retighten them as it could be detrimental to the current type oil pan gasket. If a leak should de- velop at the oil pan, check if the lockwasher is compressed. If not, the bolt may be tightened. However, if the lockwasher is compressed and leaking occurs, remove the oil pan and determine the cause of the leakage. Note: Current oil pan bolts (stamped metal pans) are coated with a locking material. To reactivate the locking ability of the bolts, apply a drop or two of Loctite J 26558-242, or equivalent, to the threads of the bolts at reassembly.

(6) Install and tighten the drain plug to 25-35 ft-lbs (34-47 Nm) torque.

(7) Fill the oil pan with new oil (refer to SM1-63-51.0 and Operator's Manual) to the full mark on the dipstick. Then start and run the engine for a short period to check for oil leaks.

(8) Stop the engine and, after approximately twenty minutes, check the oil level. Add oil, if necessary.

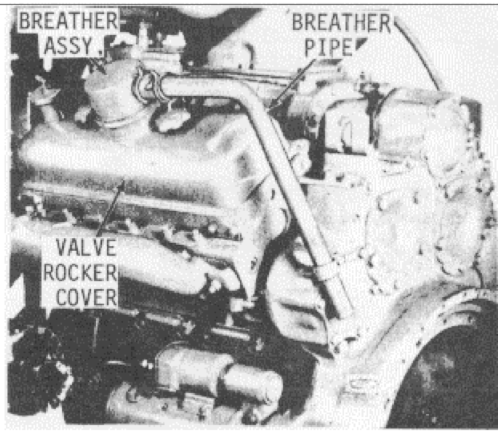


*Fig. 1 Typical Mounting of Breather Assembly on Valve Rocker Cover*

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system.

Breathing is through two openings in the rear main bearing bulkhead of the crankcase and one large hole in the cylinder block rear end plate. They connect to a central chamber (separated from chambers on each side which carry oil draining back from the cylinder heads) that leads to an exit at the top of the cylin- der block.

An external tube(s) connects the cylinder block exit hole at the rear of the cylinder head(s).

The left bank cylinder head to cylinder block breather system (Fig. 2) consist of an elbow bolted to the

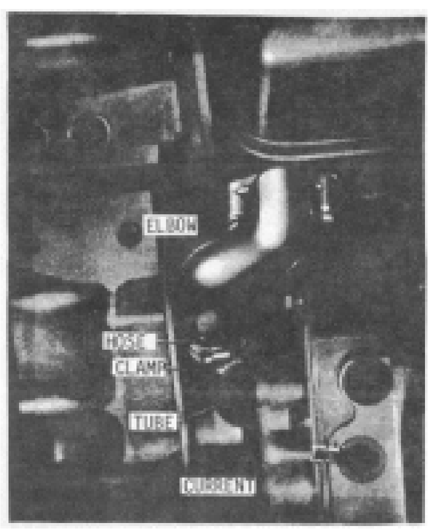


*Fig. 2 Cylinder Block to Cylinder Head Breather Systems for 6V Engines*

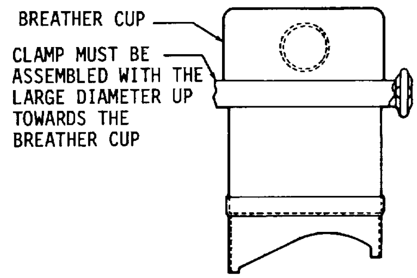


*Fig. 3 Correct Installation of Breather Clamp*

side of the cylinder head and a tube pressed in the opening at the top rear end of the cylinder block. They are joined with a rubber hose and clamps. The former breather system continues for the right bank cylinder head to cylinder block breather system, and will continue to be used on both banks for certain engine applications, because of clearance considerations.

The rocker cover(s) provides a large cross-sectional air flow area at maximum height for efficient breath- ing and oil separation. A breather assembly(s) is mounted at the openings in the rocker cover(s).

To index the breather assembly exhaust outlet on the aluminum die cast valve rocker covers, no disassembly is required. Insert a 1-1/8" outer diameter pipe or wood dowel into the exhaust outlet, apply pressure and rotate the outlet to the desired location.

53.1 Service

The element in the breather assembly mounted on the valve rocker cover (Fig. 1) should be cleaned if excessive crankcase pressure occurs. Also clean the breather pipe.

Note: Dirt can collect around the breather clamp. Clean out the dirt thoroughly before disassembling the breather.

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Wash the element in fuel oil and dry it with compressed air.

When reassembling the breather on the rocker cover, be sure the clamp is installed with the large (open) diameter facing up as illustrated in Fig. 3. If the clamp is improperly installed it could eventually loosen.

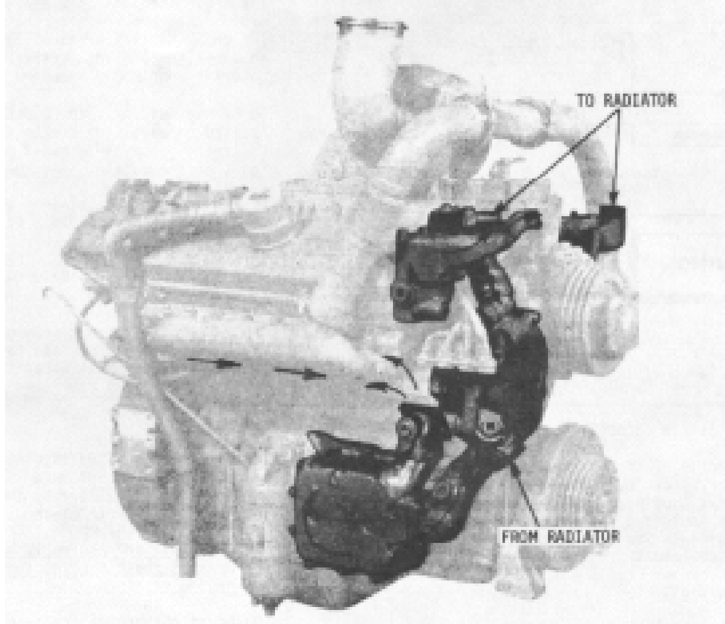


*Fig. 1 Cooling System*

To effectively dissipate the heat generated by the engine, the radiator and fan cooling system is used. The system is provided with a centrifugal type water pump that circulates the engine coolant. The system incorporates thermostats to maintain a normal engine operating temperature (refer to SM1-63-66.0).

Upon starting a cold engine or when the coolant is below operating temperature, the coolant flow to the radiator is blocked or restricted by the thermostats in the thermostat housings. A bypass provides cool- ant circulation within the engine during the warm-up period.

Coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler housing and into the cylinder block (Fig. 1).

From the cylinder block, the coolant passes up through the cylinder heads and, when the engine is at normal operating temperature, through the thermostats into the upper portion of the radiator. The coolant passes down a series of tubes where its temperature is lowered by the air stream created by the revolving fan.

54.1 Engine Cooling System Maintenance The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from components of the engine such as exhaust valves, pistons and cyl- inder liners which are surrounded by water jack- ets. In addition, heat absorbed by the oil is also removed by the engine coolant in the oil- to-water oil cooler. When operating within the proper temperature range and not exceeding the recommended horsepower output of the unit, all engine parts will be within their design oper- ating temperature range and at their proper operating clearances. Coolant must be properly selected and maintained (refer to Operator's Manual for coolant recommendations).

A pressurized cooling system, which normally operates at temperatures higher than a non-pres- surized system, is used. It is essential that the cooling system is kept clean and leakproof, that the filler cap and pressure relief mechanism be correctly installed and that the coolant level be properly maintained.

| ENGINE | COOLING SYSTEM | CAPACITY |
|---|---|---|
| | GALLONS | LITRES |
| AFTERCOOLER CAPACITY | | |
| 6V-92TA | .200 | .76 |

*Table 1*

**WARNING**

Use Extreme Care When Removing A Coolant Pressure Control Cap. The Sudden Release Of Pressure From A Heated Cooling System Can Result In Loss Of Coolant And Possible Personal Injury (Scalding) From The Hot Liquid.

54.2 Cooling System Capacity

The capacity of the basic engine cooling system, (cylinder block, cylinder heads, water manifolds, thermostat housings and oil cooler housing) is shown in Table 1. These quantities do not include the capacity of the radiator, hoses or related equipment.

54.3 Fill Cooling System

Before starting the engine, close all of the drain cocks and fill the cooling system with coolant (Operator's Manual). The raw water pump should be primed, since operation without water may cause impeller failure.

Start the engine and, after the normal operating temperature has been reached, check the coolant level. The coolant level should be within two inches of the top of the filler neck.

Should a daily loss of coolant be observed, and there are no apparent leaks, there is a possibility that gases are leaking past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube between the overflow pipe and a container of water. Bubbling of the water in the container during engine operation will indicate leakage. Another method for observing air in the cooling system is by inserting a transparent tube in the engine coolant outlet line.

54.4 Drain Cooling System

To ensure that all of the coolant is drained completely from a unit, all cooling system drains should be opened. Should any entrapped water in the cylinder block or radiator freeze, it will expand and may cause damage. When freezing weather is expected, drain all units not adequately protected by antifreeze. Leave all drain cocks open until refilling the cooling system.

The engine coolant is drained by opening the drain cocks and removing the cooling system filler cap. Removal of the filler cap permits air to enter the cooling passages and the coolant to drain completely from the system.

On 6V engines, cylinder block drain cocks are located on each side of the cylinder block at the rear, below the exhaust manifolds and at the front of the engine.

In addition to the cylinder block drains, the oil cooler housing has a drain cock at the extreme bottom.

Radiators are drained by opening a drain cock in the bottom tank.

Raw water pumps are drained by loosening the cover attaching screws and tapping the cover gently to loosen it. After the water has drained tighten the screws.

54.5 Flushing

If the cooling system is contaminated, flush the cooling system as follows:

(1) Drain the coolant from the engine.
(2) Refill with soft clean water.

Note: <u>If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.</u>

(3) Start the engine and operate it for fifteen minutes to thoroughly circulate the water.
(4) Drain the engine completely.
(5) Refill with the solution required (refer to Operator's Manual).

54.6 Cooling System Cleaners

**WARNING**

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If the engine overheats, and the fan belt tension and coolant level have been found to be satisfactory, it may be necessary to clean and flush the entire cooling system. Remove scale formation by using a reputable and safe descaling solvent. Immediately after using the descaling solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the descaler be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse-flush, as outlined below, before filling the system.

54.7 Reverse-Flushing

After the engine and radiator have been thoroughly cleaned, they should be reverse-flushed. The water pump should be removed and the radi- ator and engine reverse-flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump. Reverse-flushing is accomplished by hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, loosening and forcing scale deposits out.

The radiator is reverse-flushed as follows:

(1) Remove the radiator inlet and outlet hoses and replace the radiator cap.
(2) Attach a hose at top of the radiator to lead water away from the engine.
(3) Attach a hose to the bottom of the radiator and insert the flushing gun in the hose.
(4) Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.
(5) Turn on the water and, when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between air blasts.

Note: Apply air gradually. Do not exert more than 30 psi (207 kPa) air pressure. Too great a pressure may rupture a radiator tube.

(6) Continue flushing until only clean water is expelled from the radiator.

The cylinder block and cylinder head water passages are reverse-flushed as follows:

(1) Remove the thermostats and the water pump.
(2) Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.
(3) Attach a hose to the water outlet at top of the engine and insert the flushing gun in the hose.
(4) Turn on the water and, when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water be- tween air blasts.
(5) Continue flushing until the water from the engine runs clean.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse-flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

54.8 Miscellaneous Cooling System Checks

In addition to the above cleaning procedures, the other components of the cooling system should be checked periodically to keep the engine oper- ating at peak efficiency. The cooling system hoses, thermostats and radiator pressure cap should be checked and replaced if found to be defective.

When water connection seals and hoses are in stalled, be sure the connecting parts are prop-erly aligned and the seal or hose is in its proper position before tightening the clamps.

All external leaks should be corrected as soon as detected.

The fan belts must be checked and adjusted, if necessary, to provide the proper tension. The fan shroud must be tight against the radiator core to prevent recirculation of air which may lower the cooling efficiency.

54.9 Contaminated Engines

When the engine cooling or lubricating system becomes contaminated, it should be flushed thoroughly to remove the contaminants before the en- gine is seriously damaged. One possible cause of such contamination is a cracked oil cooler core. With a cracked oil cooler core, oil will be forced into the cooling system while the engine is operating and, where it is stopped, coolant will leak into the lubricating system.

Coolant contamination of the lubrication system is especially harmful to engines when the cooling system is filled with an ethylene glycol antifreeze solution. When mixed with the oil in the crankcase, this antifreeze forms a varnish which can cause the engine to seize or result in severe bearing wear.

Make certain that the cause of the internal cool-ant leak has been corrected before flushing the contaminated system(s).

Contaminants may be flushed from the engine systems as follows:

COOLING SYSTEM: If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, this flushing procedure is recommended.

(1) Prepare a mixture of Calgon, or equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.
(2) Remove the engine thermostats to permit the Calgon and water mixture to circulate through the engine and the radiator or heat exchanger.
(3) Fill the cooling system with the Calgon solution.
(4) Run the engine for five minutes.
(5) Drain the cooling system.
(6) Repeat Steps 1 through 5.
(7) Fill the cooling system with clean water.
(8) Let the engine run five minutes.
(9) Drain the cooling system completely.
(10) Install the engine thermostats.
(11) Close all of the drains and refill the cooling system with fresh coolant (refer to Operator's Manual).

LUBRICATION SYSTEM: When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution, or other water sol- uble material, the following cleaning procedure, using Butyl Cellosolve, or equivalent, is recommended.

**WARNING**

Use Extreme Care In The Handling Of These Chemicals To Prevent Serious Injury To The Person Or Damage To Finished Surfaces. Wash Off Spilled Fluid Immediately With Clean Water.

(1) Drain all of the lubricating oil.
(2) Remove and discard the oil filter elements. Clean and dry the filter shells and replace the elements.
(3) Mix two parts of Butyl Cellosolve, or equivalent, with one part SAE 10 engine oil. Fill the engine crankcase to the proper operating level with the mixture.
(4) Start and run the engine at a fast idle (1,000 to 1,200 rpm) for thirty minutes to one hour. Check the oil pressure frequently.
(5) After the specified time, stop the engine and immediately drain the crankcase and the filters. Sufficient time must be allowed to drain all of the fluid.
(6) Replace the drain plugs and refill the crank- case with SAE 10 oil and run the engine at the same fast idle for ten or fifteen min- utes and again drain the oil thoroughly.
(7) Remove and discard the oil filter elements, clean the filter shells and install new elements.
(8) Replace the drains and fill the crankcase to the proper level with the oil recommended for normal engine operation.
(9) To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1,000 to 1,200 rpm) for approximately thirty minutes. Then stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.
(10) If the procedure for cleaning the lubricating oil system was not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

The centrifugal-type water pump (Fig. 1) circulates the engine coolant through the cylinder block, cylinder heads, radiator or heat exchanger and the oil cooler.

The pump is mounted on the engine front cover and is driven by the 66 tooth front camshaft gear (water pump drive). The water pump gear has 42 teeth and meshes with the water pump drive gear.

A bronze impeller is secured to one end of a stain- less steel shaft by a locknut. The water pump gear is pressed on the opposite end of the shaft. Two ball bearings are used to carry the shaft. The larger bearing is used at the drive gear end of the shaft to accommodate the thrust load (Fig. 8).

An oil seal is located in front of the smaller bear- ing and a spring-loaded face type water seal is used behind the impeller.

55.1 Lubrication

The pump ball bearings are lubricated with oil splashed by the camshaft gear and the water pump gear.

55.2 Replace Water Seal

The water seal can be replaced without removing the pump if the radiator, fan and fan shroud or heat exchanger have been removed. (1) Remove the pump cover retaining ring (Fig. 7), from the groove in the pump body, with a screwdriver.

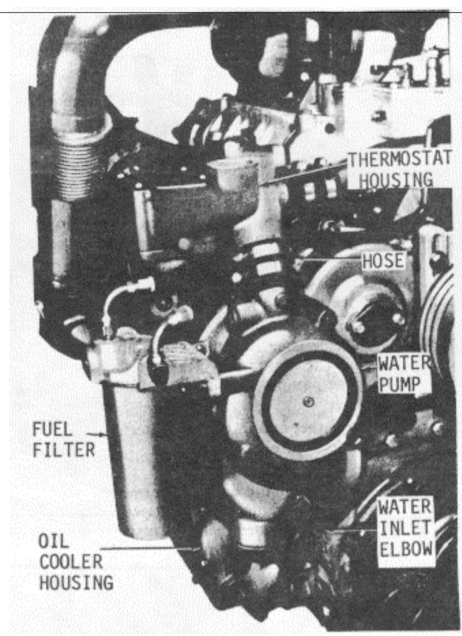


*Fig. 1 Water Pump Mounting*

(1) Remove the pump cover and discard the seal ring. The 1/4"-20 nut attached to the front cover is provided to facilitate removal of the cover.
(2) Remove the locknut and washer and withdraw the impeller with puller J 24420.

Note: <u>Use care to prevent damage to the ceramic impeller insert. Place the impeller on the bench with the insert up.</u>

(3) Use water pump seal remover set J 22150-01 to remove the seal with the pump on or off of the engine.
  (a) Place the seal puller over the seal and into the two slots in the pump body casting.
  (b) Remove the seal by turning the screw in a clockwise direction.
(4) To reduce possible coolant leakage, apply a light coat of non-hardening sealant on the outside diameter of a new water seal. Then tap the seal into the seal cavity with a suitable sleeve which has an inside diameter large enough to fit around the seal and rest on the brass cartridge lip.
(5) Inspect the ceramic impeller insert for cracks, scratches and bond to the impeller. If the insert is damaged, replace as follows:
  (a) Bake the insert and impeller assem bly at 5000F (2600C) for one hour. The insert can be removed easily while the adhesive is hot. After removing the insert, clean the insert area on the impeller with sandpaper, wire brush or a buffing wheel to remove the old adhesive, oxide, scale, etc.

**WARNING**

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  (b) Wet a clean cloth with a suitable solvent such as alcohol and thoroughly clean the impeller insert area and the grooved side of the new ceramic insert. Then wipe the parts clean with a dry cloth.
  (c) Place the adhesive washer in the impeller bond area with the ceramic insert on top. The polished face of the ceramic insert should be visible to the assembler (Fig. 2).

Clamp the ceramic insert and impeller together with a 3/8" bolt and nut and two smooth .125" thick washers. Tighten the bolt to 10 ft-lbs (14 Nm) torque.

Note: <u>Do not mar the polished surface of the ceramic insert.</u>

Important: <u>The face of the ceramic insert must be square with the axis of the tapered bore within .004". The pump shaft may be used as a mandrel for this inspection.</u>

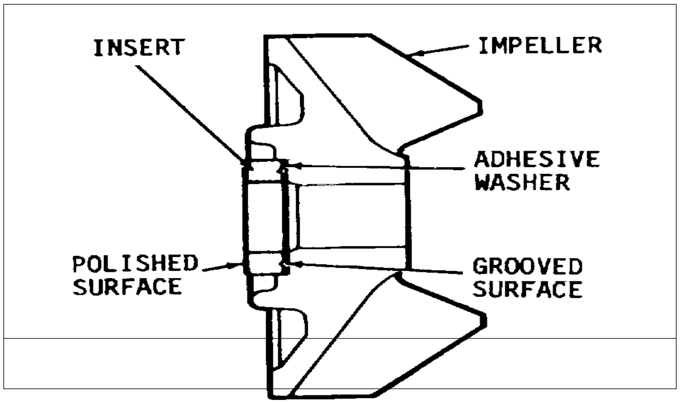


*Fig. 2 Impeller with Ceramic Insert*

(d) Place the impeller assembly in a level position, with the ceramic insert up, in an oven preheated to 3500F (1770C) for one hour to cure the adhesive.
(e) Remove the impeller from the oven and, after it has cooled to room temperature, install it in the pump. Do not loosen or remove the clamping bolt and washers until the assembly cools.

(6) Make sure the mating surfaces of the water seal and the ceramic insert (Fig. 8) are free of dirt, metal particles and oil film.
(7) Apply a small quantity of International Compound No. 2, or equivalent, to the threads of the pump shaft.
(8) Place the impeller and washer on the shaft and start a new locknut on the shaft. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the locknut. Tighten the nut to 45-50 ft-lbs (61-68 Nm) torque.
(9) Loosen the clamps and remove the hose from the water outlet opening of the pump.
(10) Insert a feeler gauge into the water outlet opening of the pump. The minimum clearance between the impeller and the pump body must be .015".
(11) Use a new seal ring when installing the pump cover. Install the cover retaining ring by hand. Tap the cover lightly to be sure the ring is completely seated in the groove.
(12) Install and secure the hose on the water outlet opening with the clamps.

55.3 Remove Pump

(1) Refer to SM1-63-54.0 and drain the cooling system.
(2) Remove the radiator, fan shroud and fan.
(3) Loosen the hose clamps and remove the hoses from the pump body.

(4) Remove the pump body-to-engine front cover mounting bolts and detach the pump. Use care to prevent damage to the gear teeth when disengaging the pump gear from the front cam-shaft gear (water pump drive gear).

55.4 Disassemble Pump

(1) Turn the pump gear so the slot is over the ends of the bearing retaining ring, insert pliers J 4646 into the slot and, with the aid of a small screwdriver, remove the ring from the groove (Fig. 3).
(2) Remove the attaching bolts and remove the pump cover and gasket.
(3) Hold the gear securely and remove the impeller locknut and washer.

Note: While holding the gear, use care to prevent damage to the gear teeth.

(4) Use puller J 24420 to remove the impeller.
(5) Press the shaft, bearings and pump gear assembly out of the pump body.
(6) Place the gear on the bed of an arbor press with the shaft extending downward, then place a short piece of .625" diameter bar stock between the shaft and the ram of the press and press the shaft out of the gear as shown in Fig. 4.
(7) Support the shaft assembly on the inner race of the larger bearing with the threaded end down. Place flat stock between the ram of the press and the shaft and press the pump shaft out of the large bearing.

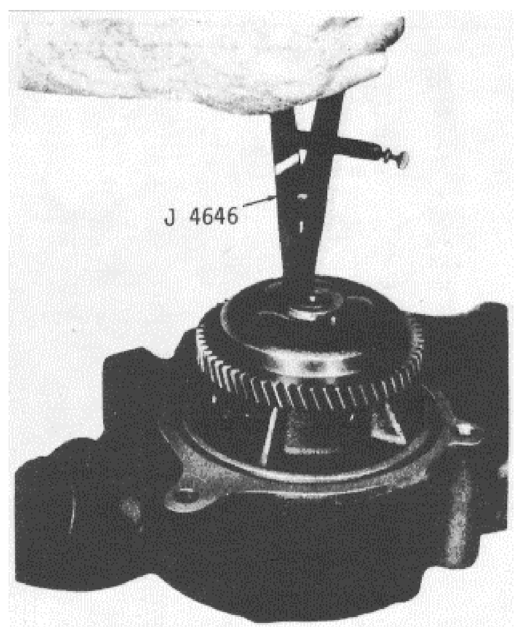


*Fig. 3 Removing Retaining Ring*

(8) Invert the shaft, support it on the inner race of the small bearing and repeat the process described in Step 6.

(9) If necessary, remove the water seal as described under 55.2 Replace Water Seal.

(10) Push the oil seal out of the pump body. Note: New seals must be used as replacements each time the water and oil seals are removed.

55.5 Inspection

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Wash all of the pump parts in clean fuel oil and dry them with compressed air. Inspect them for cracks, wear or damage. Replace damaged or worn parts.

Make sure the drilled "Y" passage in the pump body is clear of any obstruction.

Inspect the ceramic impeller insert for cracks, scratches and bond to the impeller. The insert may be replaced, if necessary, as noted under 55.2 Replace Water Seal.

The bearings should be examined for corrosion, pitting, wear and freedom of movement. Apply engine oil to the bearings, hold the inner race and slowly revolve the outer race to check for roughness. Replace the bearings if necessary.

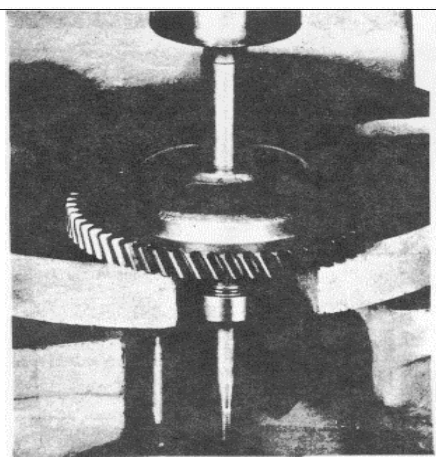


*Fig. 4 Pressing Shaft Out of Gear*

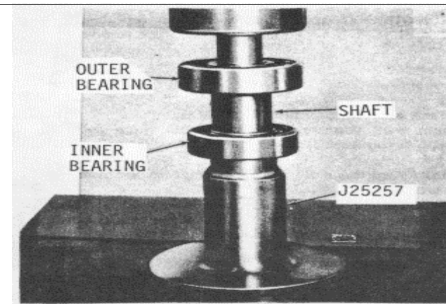



*Fig. 5 Pressing Bearing on Pump Shaft*

55.6 Assemble Pump

(1) Lubricate the bearing bores and shaft bearing surfaces. Use bearing and gear installer J 25257 and install the bearings on the shaft (Fig. 5).

Note: <u>Apply pressure to the inner races of the bearings only during assembly on the shaft.</u>

(2) Support the pump body on the bed of an arbor press with the cover side down. Then press the shaft and bearing assembly in place by applying pressure on the outer race of the large bearing.

(3) Install the bearing retaining ring.

(4) With gear installer J 25257 (Fig. 6) positioned on the impeller end of the shaft, place the gear between the shaft and the ram of the press. Press the gear on the shaft so it is flush with the end of the shaft. Important: Tool J 25257 will hold the shaft vertically to ensure the gear is pressed squarely on the shaft.

(5) Apply a film of engine oil to the sealing lip of the oil seal and the lip contact surface of the shaft, Then insert the seal into the pump body. With a suitable sleeve, tap the seal into place.

Note: <u>The oil seal must be flush with the water seal counterbore in the pump body.</u>

(6) Place the pump body on the bed of an arbor press. To prevent possible coolant leakage, apply a light coat of non-hardening sealant on the outside diameter of a new water seal. Then insert the seal in the cavity in the pump body and, with a sleeve large enough to fit around the seal and resting on the brass cartridge lip, press the seal into place.

(7) Make sure the mating surfaces of the water seal and the ceramic insert are free of dirt, metal particles and oil film.

(8) Apply a small quantity of International Compound No. 2, or equivalent, to the threads of the pump shaft.

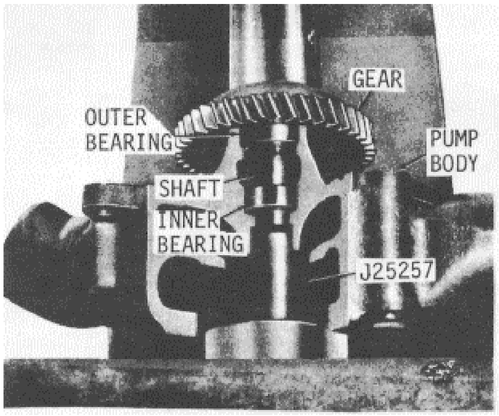



*Fig. 6 Pressing Gear on Pump Shaft*

(9) Place the impeller washer and new locknut on the shaft. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the locknut. Tighten the nut to 45-50 ft-lbs (61-68 Nm) torque.

Note: Do not damage the gear teeth while holding the gear.

(10) Insert a feeler gauge into the water outlet opening of the pump. The clearance between the impeller and the water pump body must be .015" minimum.

(11) Install the hose on the water outlet opening and secure it with clamps.

55.7 Install Pump on Engine

(1) Affix the seal ring to the pump body. Mount the pump on the engine so the pump gear meshes with the camshaft gear. Install and tighten the mounting bolts.

(2) Check the gear lash by installing bolts, or equivalent, in the impeller puller holes. Measure the lash with an indicator at that point. The gear lash setting should be .002" to .012". A .0015" movement of the pump directly away from the camshaft will increase the lash .001". Likewise, moving the pump toward the camshaft .0015" will decrease the lash .001".

Note: When the specified gear lash cannot be obtained, loosen the pump attaching bolts and move the pump up as required to obtain the correct gear lash. Retighten the mounting bolts.

(3) Use a new gasket and install the pump cover. Tighten the bolts securely.

Note: The pump cover is secured by cadmium plated bolts with nylon inserts to prevent water leakage. Inspect them carefully to make sure the nylon inserts are in place and protrude sufficiently beyond the threads. Under no circumstances should a standard bolt be used.

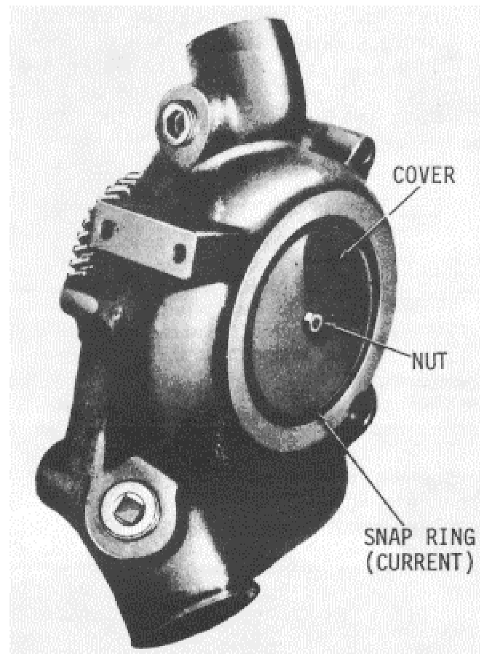



*Fig. 7 High Capacity Water Pump*

(4) Slide the hoses into position and tighten the hose clamps.

(5) Fill the cooling system as recommended in SM1-63-54.0 and Operator's Manual.

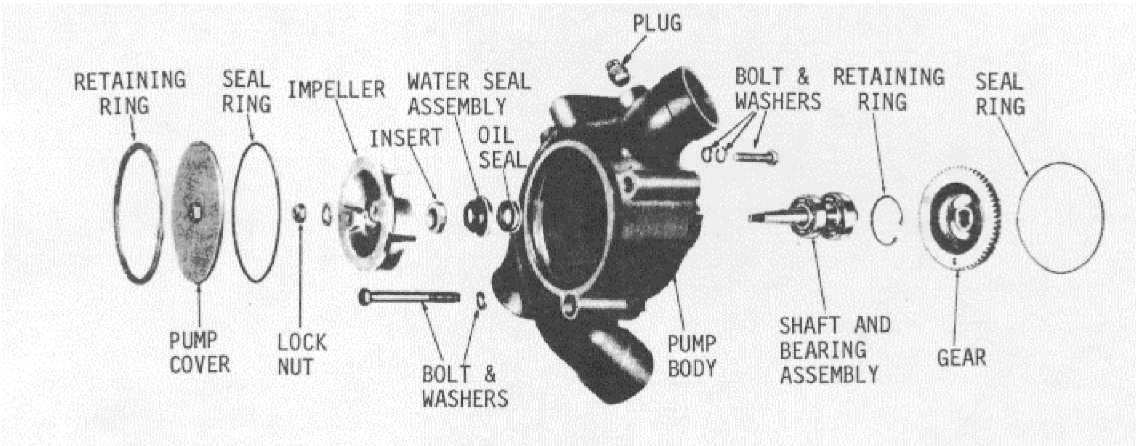



*Fig. 8 High Capacity Water Pump Details and Relative Location of Parts*

The temperature of the engine coolant is automatically controlled by a thermostat located in a housing attached to the water outlet end of each cylinder head. Blocking type thermostats (Fig. 1) are used. Two thermostats are employed.

At coolant temperatures below approximately 1700F, the thermostat valves remain closed and block the flow of coolant to the radiator. During this period. all of the coolant in the standard system is circulated through the engine and is directed back to the suction side of the water pump via the bypass tube. As the coolant temperature rises above 1700F, the thermostat valves start to open, restricting the by- pass system, and permit a portion of the coolant to circulate through the radiator. When the coolant temperature reaches approximately 1850F, the thermostat valves are fully open, the bypass system is completely blocked off, and all of the coolant is directed through the radiator.

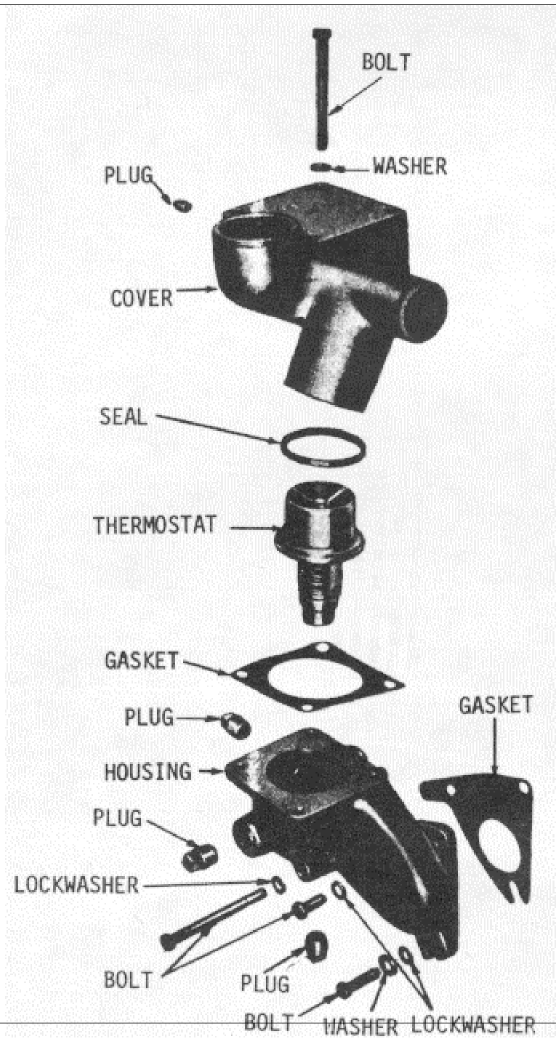



*Fig. 1 Typical Thermostat Housing and Relative Location of Parts*

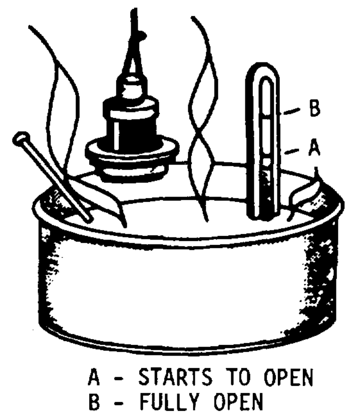



*Fig. 2 Method of Checking Thermostat Operation*

A defective thermostat which remains closed, or only partially open, will restrict the flow of coolant and cause the engine to overheat. A thermostat which is stuck in a full open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold engine operation will result in excessive carbon deposits on the pistons, rings and valves.

Properly operating thermostats are essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 160°F to 185°F, the thermostats should be removed and checked.

56.1 Remove Thermostat

Refer to Fig. 1 and remove the thermostats as fol lows:

(1) Drain the cooling system to the necessary level by opening the drain cocks. or removing the drain plugs on the cylinder block.
(2) Loosen the hose connections and remove the bypass (cross-over) tube. Then loosen the hose connections between the water pump and the right bank thermostat housing cover.
(3) Remove the bolts and lockwashers securing the covers to the thermostat housings. Then remove the thermostat housing covers and gaskets.
(4) Remove the thermostats.
(5) Clean the thermostat seating surfaces in the thermostat housings and covers.
(6) Remove the seals from the thermostat covers and discard the seals.

56.2 Inspect Thermostat

Check the operation of a thermostat by immersing it in a container of hot water (see Fig. 2). Place a thermometer in the container, but do not allow it to touch the bottom of the container. Agitate the water to maintain an even temperature throughout the container. As the water is heated, the thermostat should begin to open when the water temperature is approximately 1700 or 1750F (the opening temperature is usually stamped on the thermostat). The thermostat should be fully open at approximately 185°F. Allow at least 10 minutes for thermostat to react.

56.3 Install Thermostat

(1) Install a new seal(s) in the thermostat housing cover with installer J 8550 and driver handle J 7079-2. Position the seal so that the lip of the seal faces up (away from the thermostat) when the cover is installed on the thermostat housing. The seal installing tool assures that the seal is positioned the correct distance from the bottom face of the cover and parallel with the cover face.
(2) Place a new gasket on the thermostat housing.
(3) Set the thermostat(s) in the thermostat housing.
(4) Attach the covers to the thermostat housings with bolts and lockwashers. Tighten the 3/8"-16 bolts to 30-35 ft-lbs torque.
(5) Slide the hose in place between the water pump and the right bank thermostat housing cover. Tighten the clamps.
(6) Install the bypass (cross-over) tube and tighten the hose clamps.
(7) Close the drain cocks in the cylinder block. Then fill the cooling system.
(8) Start the engine and check for leaks.

The engine cooling fan (Fig. 1) is belt driven from the crankshaft pulley.

A three groove pulley hub turns on a front ball bearing and a rear roller bearing and also includes a hub cap (with relief valve), a dust cup and a grease fitting (Fig. 2).

Spacers provide a means for setting the proper clearance between the fan blades and the front groove of the crankshaft pulley.

57.1 Lubrication

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to Operator's Manual for the maintenance schedule.

57.2 Fan Belt Adjustment

Adjust the fan belts periodically as outlined in Operator's Manual.

57.3 Remove Fan, Hub and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core. Before removing the fan, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

(1) Remove the attaching bolts, lockwashers and nuts, then remove the fan and spacer.

Note: If insufficient clearance exists between the fan and the radiator, remove the fan, hub and adjusting bracket as an assembly.

(2) Loosen the fan hub adjusting bracket bolts and remove the drive belts. Then withdraw the bolts and washers and remove the hub and bracket assembly from the engine.

57.4 Disassemble Fan, Three Groove Pulley Hub and Bracket (Fig. 2)

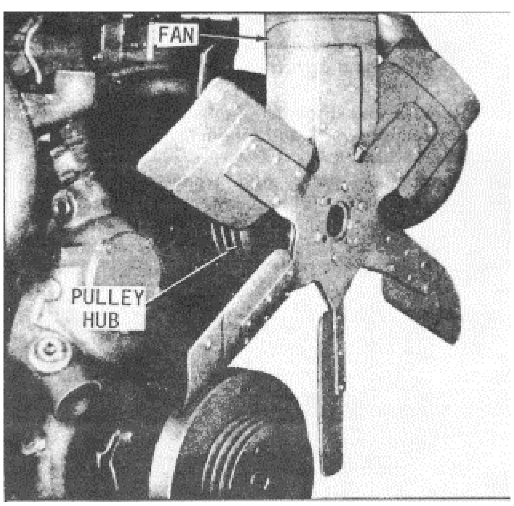



*Fig. 1 Typical Fan Mounting*

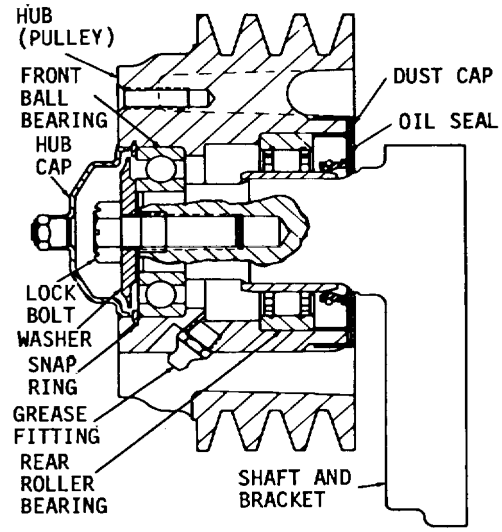



*Fig. 2 Three Groove Pulley Hub*

(1) Remove the fan to hub mounting bolts, nuts and lockwashers and detach the fan and spacer.
(2) Remove and discard the hub cap. If the bearings are to be removed, take out the retaining ring.
(3) Support the hub, front face up, on wood blocks high enough to allow the bracket to be removed. Tap the fan shaft with a plastic hammer to free the fan shaft and bracket assembly from the bearings in the hub.
(4) Remove the ball bearings from the pulley hub as follows:
(a) Support the pulley hub, rear face up, on two wood blocks spaced far enough apart to permit removal of the bearing from the hub.
(b) Tap the front bearing out of the hub by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.
(c) Reverse the pulley hub on the wood blocks and remove the rear bearing from the hub in the same manner.

57.5 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean the fan and related parts with clean fuel oil and dry them with compressed air. Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing.

Examine the bearings for any indications of corrosion or pitting. Hold the inner race or cone so it does not turn and revolve the outer race or cup slowly by hand. If rough spots are found, replace the bearings.

Check the fan blades for cracks. Replace the fan if the blades are badly bent, since straightening may weaken the blades, particularly in the hub area.

Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severely worn, replace the pulleys.

Examine and measure the fan hub shaft front and rear journals (industrial engines). The front journal diameter of a new shaft is .7866" - .7871" and the rear journal is 1.7705" - 1.7713". If the journals are worn excessively, replace the fan shaft.

Look for cracks in the adjusting and support bracket castings. When replacement of either the fan shaft or adjusting bracket is necessary, a new fan shaft and bracket assembly must be used.

The current fan shaft rear bearing inner race should be inspected for any measurable wear. Replace the inner race if the outer diameter is less-than 1.7297" or 2.6333" (Heavy Duty).

Note: The inner and outer races are only serviced as a rear roller bearing assembly.

When installing the rear bearing inner race, press it on the shaft and position it 1.92" to 1.94" or 2.31" to 2.33" (Heavy Duty) from the end of the shaft.

57.6 Assemble Three Groove Hub and Bracket (Fig. 2)

(1) Apply Texaco Premium RB grease or an equivalent Lithium base multipurpose grease to the front ball bearing and the rollers of the rear bearing, before installing them in the pulley hub.

Note: Do not overgrease.

(2) Install the front ball bearing against the shoulder counterbore in the pulley hub. Then install the snap ring in the pulley hub.
(3) Install the rear roller bearing outer ring and roller assembly against the shoulder in the counterbore of the pulley hub.
(4) Install a new oil seal with rubber side flush with the outer edge of the hub.
(5) Place the shaft and bracket on wood blocks setting on the bed of an arbor press. Then press the rear bearing inner ring or race onto the fan shaft.
(6) Pack the cavity in the hub 75% (minimum) full with Texaco Premium RB grease.
(7) Install the partially assembled fan hub over the rear bearing inner ring on the shaft and against the shoulder on the pulley hub shaft.
(8) Secure the hub with the washer and 1/2"-20 lock bolt. Tighten the bolt to 83-93 ft-lbs (113-126 Nm) torque while rotating the pulley hub.
(9) Fill a new fan hub cap 75% (minimum) full of grease and install it in the end of the pulley hub.

57.7 Install Fan, Hub and Bracket

(1) Secure the fan and spacer to the pulley hub with the six bolts, nuts and lockwashers. Tighten the nuts to 15-19 ft-lbs (20-26 Nm) torque.
(2) Place the fan belts on the pulley.
(3) Position the fan, hub and adjusting bracket against the support bracket and install the bolts finger tight in the support.
(4) Adjust the bracket to provide the proper tension the fan belts (refer to Operator’s Manual). Tighten the bracket and bracket adjusting bolts.

Fan and radiator cooled engines are equipped with an air-cooled exhaust manifold.

The outlet flange is located at the end of the exhaust manifold. A flexible exhaust connection or a muffler may be attached to the outlet flange. The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

**Service Manual** SM1-63-59.0 Exhaust Manifold (Air Cooled)

The case air-cooled manifold (Fig. 1) has a uniform circular cross-section and tapers upward from each end toward the center where a flange is provided for the attachment of the exhaust piping or muffler.

59.1 Remove Exhaust Manifold

Usually, the exhaust manifold will be removed with the cylinder head. However, when the exhaust manifold gaskets only need to be replaced, the manifold may be removed in the following manner without removing the cylinder head:

(1) Loosen the flange seal connecting the exhaust manifold at the outlet tube.
(2) Disconnect the exhaust pipe or muffler from the exhaust manifold flange.
(3) Loosen and remove the nuts and bevel washers which secure the exhaust manifold to the cylinder head. It is suggested that, as a safeguard, one nut and washer be loosened and left on one of the center studs until all other nuts and washers have been removed.
(4) Support the manifold and remove the nut and washer from the center stud.
(5) Lift the manifold away from cylinder head.
(6) Remove the manifold gaskets.

59.2 Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. It is especially important to clean the manifold used on a turbocharged unit to eliminate the possibility of loose scale entering and damaging the turbocharger.

Examine the exhaust manifold studs for damage. If necessary, replace the studs. New studs are driven to 25-40 ft-lbs (34-54 Nm) torque.

59.3 Install Exhaust Manifold

With all traces of the old gaskets removed from the cylinder head and bolting flanges of the exhaust manifold, install it as follows:

(1) Make sure the internal walls of the manifold are clean to eliminate possible damage to the turbocharger, if used.
(2) Place a new gasket over the studs and up against the cylinder head.
(3) Position the exhaust manifold over the studs and up against the gasket.


*Fig. 1. Typical Cast Air-Cooled Exhaust Manifold Mounting*

Note: Be sure the locating pads on the exhaust manifold rests on the cylinder block locating pads.

(4) Install the bevel washers and nuts on the studs and draw the exhaust manifold up against the gasket. Tighten the nuts to 30-35 ft-lbs (41-47 Nm) torque. Note: Set the bevel washers in position so that outer diameter will rest on the manifold and the crown at the center is next to the nut.

Important: Lighten the exhaust manifold stud nuts from the center of the exhaust manifold outward, alternating toward either end.

(5) Connect the exhaust pipe or muffler to the exhaust manifold flange.
(6) Tighten the flange seal connecting the exhaust manifold to the outlet tube.

A typical engine electrical system generally consists of a starting motor, a battery-charging alternator, a storage battery and the necessary wiring.

Additional equipment such as an engine protective system may also be included.

Detailed information on maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco-Remy Division of General Motors corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from AC-Delco service outlets, or from the Technical Literature Section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Allison. For electrical equipment manufactured by Delco-Remy Division, re- pair service and parts are available through AC- Delco branches and repair stations.

The battery-charging alternator (Fig. 1) is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

61.1 Hinge-Mounted Alternator (Belt-Driven)

The hinge-mounted alternating current self- rectifying alternator (Fig. 1), mounted at the rear of the engine, is belt-driven. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.

An adequate alternator drive ratio is necessary for an engine equipped with extra electrical accessories and one that has to operate for ex- tended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase A.C. voltage to provide D.C. voltage at the battery terminal of the alternator, thereby eliminating the need for an external rectifier.

To adjust the voltage setting on the alternators, remove the rectifier end plate. The voltage regulator adjustment is located on the voltage regulator circuit board. Refer to the pertinent Delco Service Bulletin for complete adjustment procedure.

61.2 Alternator Maintenance

(1) Maintain proper drive belt tension as noted in Operator's Manual. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the alternator drive.

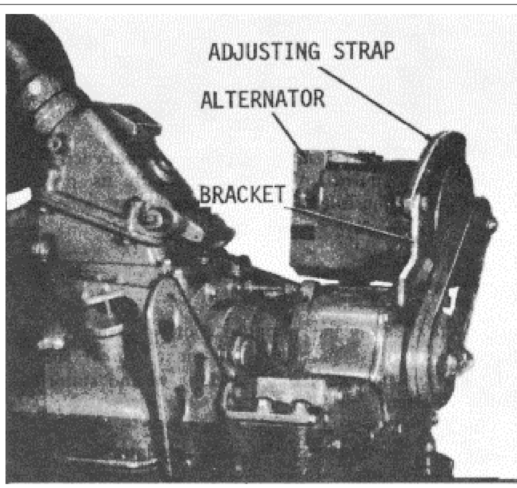



*Fig. 1. Typical Hinge-Mounted Alternator (Belt-Driven)*

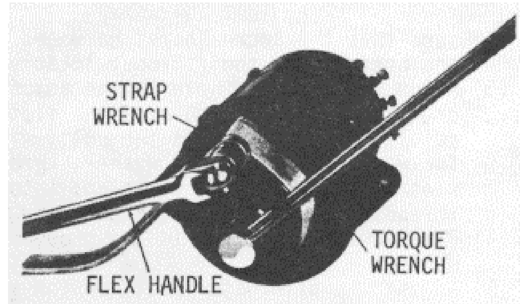



*Fig. 2. Tightening Alternator Pulley Retaining Nut*

Note: When installing or adjusting an alternator drive belt, be sure the bolt at the alternator pivot point is properly tightened, as well as the bolt in the adjusting slot.

(2) Alternator bearings are permanently lubricated. There are no external oiler fittings.

61.3 Remove Alternator

(1) Disconnect the cables at the battery supply. Disconnect all leads from the alternator and tag each one to ensure correct reinstallation.
(2) Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.
(3) While supporting the alternator, remove the adjusting strap bolt, hardened washer and lockwasher. Then remove the mounting bolts, hardened washer, lockwasher and nuts. Re-move the alternator carefully and protect it from costly physical damage.
(4) Remove the pulley assembly if the alternator is to be replaced.

61.4 Alternator Service

Repairs and overhaul work on alternators should be referred to an authorized repair station of the manufacturer of this equipment. Replacement parts for alternators should be ordered through the equipment manufacturer's outlets. For alternators manufactured by Delco-Remy Division, repair service and parts are available through AC Delco branches and repair stations.

61.5 Install Alternator

(1) Install the drive pulley, if it was removed. Tighten the pulley retaining nut to 50-60 ft-lbs (68-81 Nm) torque. Note: If the pulley was not removed, check the retaining nut for proper torque.
(2) Position the alternator on the mounting brackets and start the bolts, with lock- washers and hardened washers in place, through the bolt holes in the alternator end frames. If nuts are used, insert the bolts through the bolt holes in the mounting bracket and alternator end frame and make

sure that the lockwashers, hardened washers and nuts are in their proper locations.

(3) Align the threaded hole in the adjusting lug of the drive end frame with the slot in the adjusting strap. Start the bolt, with the lockwasher and hardened washer, through the slot of the adjusting strap and into the threaded hole in the alternator end frame.

(4) Place the drive belts in the grooves of the pulleys.

(5) Adjust the alternator belt tension as outlined in Operator's Manual. Tighten all of the bolts after belt tightening is completed.

(6) Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

61.6 Alternator Precautions

Precautions must be taken when working on or around alternators. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator.- Never run an alternator on an open circuit.

Grounding an alternator's output wire or terminals, which are always "hot" regardless of whether or not the engine is running, or accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme caution be used.

Accidentally reversing the battery connections must be avoided.

Never disconnect the battery while an alternator is in operation. Disconnecting the battery may result in damage to the diodes due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

In marine applications which have two sets of batteries, switching from one set of batteries to the other while the engine is running will momentarily disconnect the batteries and result in damage to the alternator diodes.

If a booster battery is to be used, the batteries must be connected correctly (negative to negative and positive to positive).

Never use a fast charger with the battery connected or as a booster for battery output.

Never attempt to polarize the alternator.

The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc. If faulty operation of an alternator occurs on an engine equipped with an insulated starting motor, check to be sure that a ground strap is present and is correctly installed

.

The starting motor is mounted on the flywheel housing as illustrated in Fig. 1. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine fly-wheel ring gear to crank the engine. When the engine starts, the drive pinion must be quickly disengaged to prevent the armature from overspeeding and damaging the starting motor. To accomplish this, the starting motor is equipped with a heavy-duty over- running clutch drive.

A solenoid switch, mounted on the starting motor housing, operates the overrunning clutch drive by linkage and a shift lever (Fig. 1). When the starting switch is engaged, the solenoid is energized and shifts the starting motor pinion into mesh with the flywheel ring gear and closes the main contacts with-in the solenoid. Once engaged, the clutch will not disengage during intermittent engine firing. To protect the armature from excessive speed when the engine, starts, the clutch "overruns"; or turns faster than the armature, which permits the pinion to disengage itself from the flywheel ring gear.

The solenoid plunger and shift lever is totally en-closed to protect them from dirt, water and other foreign material.

An oil seal, between the shaft and the lever housing, and a linkage seal (Fig. 2) prevents the entry of transmission oil into the main frame of the starting motor and solenoid case, allowing the motor to be used on wet clutch applications.

The nose housing can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. The nose housing, on starters equipped with the heavy-duty clutch, is attached to the lever housing by six bolts located around the outside of the housing (Fig. 2).

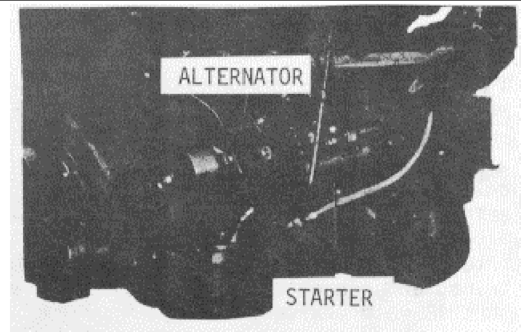



*Fig. 1. Typical Starting Motor Mounting*

When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

(1) Remove the six socket head screws (1 short and 5 long) and six neoprene plugs, if a twelve hole starter mounting flange is used.

(2) Turn the nose housing to the required position. Note: The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and interfere with solenoid and shift lever operation, which may result in failure to engage and crank.

(3) Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs, if a twelve hole starter mounting flange is used.

(4) Tighten the screws to 13-17 ft-lbs (18-23 Nm) torque.

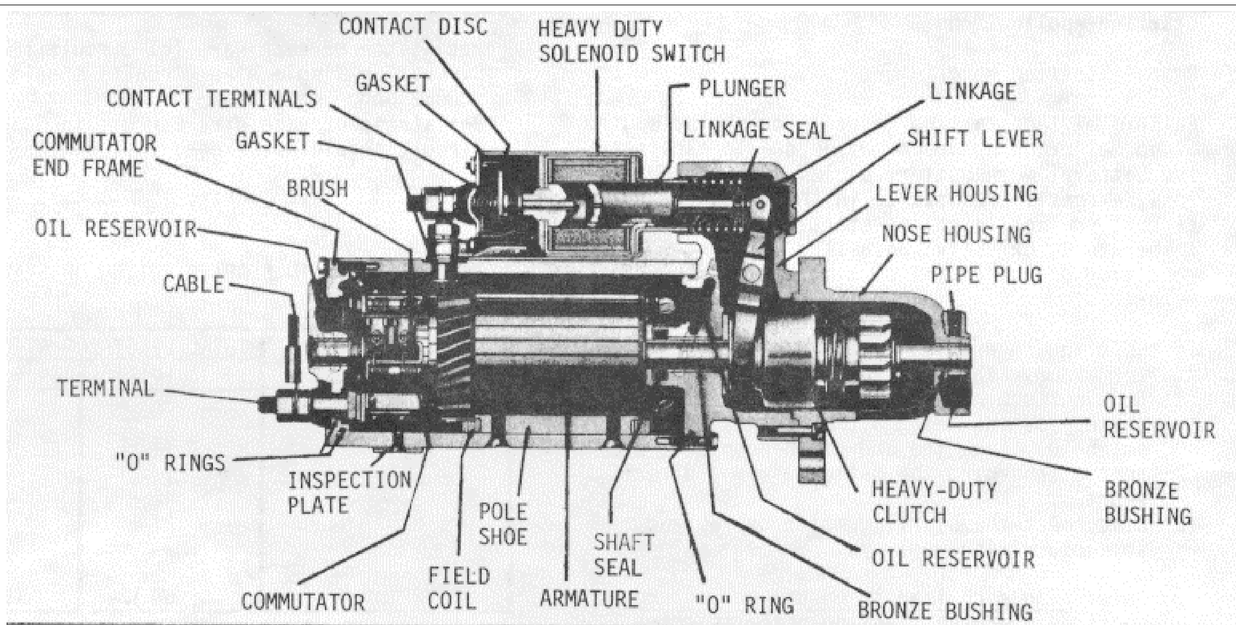



*Fig. 2. Cross-Section of Starting Motor with Heavy-Duty Clutch Drive*

62.1 High-Output Starting Motor

A high-output 12 volt starting motor, with an overrunning clutch type drive, is provided for some engine applications which require the equivalent of 24 volts for cranking the engine and 12 volts for lighting and operation of electrical accessories. The same total battery capacity recommended for use with a 24 volt starter (two 205 ampere-hour batteries) must be retained and connected in parallel for the high-output 12 volt starter.

Battery cable sizes and lengths required for proper cranking circuit resistance for 12 volt high-output starter are shown in Starting Motor to Battery Cable Size Chart 1. To assure starter engagement, starter switch leads should be of proper resistance and are shown in Starting Motor to Starter Switch or Relay Circuit Chart 2. A 12 volt high-output starter model is not avail- able for all engine sizes that require 24 volt cranking.

62.2 Lubrication

Starting motors which are provided with lubrication fittings (hinge cap oilers, oil tubes sealed with pipe plugs, or grease cups) should be lubricated periodically (refer to Operator's Manual).

62.3 Flywheel Ring Gears

The starting motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth. Properly chamfered ring gear teeth are recommended to minimize butt engagements. Chamfered ring gears must be used on automatic starting applications.

62.4 Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections, excessive resistance in the cranking circuit, defective engine starting switch, low temperature, excessive parasitic cranking load, condition of the engine or a defective starting motor.

If the cranking problem is isolated to the starter, remove the starting motor as follows:

(1) Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to pre- vent discharging the battery from a direct short.

(2) Disconnect the starting motor cables and solenoid wiring.

Note: Tag each lead to ensure correct connections when the starting motor is rein- stalled.

(3) Support the motor and remove the three bolts and lockwashers which secure it to the fly-wheel housing. Then pull the motor forward to remove it from the flywheel housing. Check the starting motor in accordance with the Delco-Remy "Cranking Circuit" maintenance handbook.

62.5 Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the 5/8"-11 starter attaching bolts to 137-147 ft-lbs (186-200 Nm) torque or to 85-95 ft-lbs (115-129 Nm) torque when an aluminum flywheel housing is used. Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connections to 16-30 in.-lbs (1.8-3.4 Nm) torque and the 1/2"-13 connections to 20-25 ft-lbs (27-34 Nm) torque.

12 VOLT HIGH-OUTPUT STARTING MOTOR TO BATTERY CABLE SIZE CHART

| Cable Size B & S Gage | TOTAL LENGTH - FEET Dual Wire Circuit* | Single Wire Circuit* |
|---|---|---|
| 00 | 12 | 5.75 |
| 000 | 15 | 7.50 |
| 0000 | 19 | 9.60 |
| 300,000 C.M. | 27 | 13.50 |
| 350,000 C.M. | 32 | 16.00 |
| 500,000 C.M. | 45 | 22.50 |
| 750,000 C.M. | 68 | 34.00 |
| 1,000,000 C.M. | 90 | 45.00 |

*Resistance of each Parallel Circuit (Dual Wire Circuit or Single Wire Circuit) should not exceed .00052 ohm.
+Resistance of each Wire Circuit in Dual Wire Circuit should not exceed .001 ohm.

Chart 1

STARTING MOTOR TO STARTER SWITCH OR STARTER RELAY CIRCUIT CHART

| Wire Size | TOTAL LENGTH OF A + B - FEET* 12 Volt | 24 & 32 Volt |
|---|---|---|
| 12 | 8 | 16 |
| 10 | 11 | 22 |
| 8 | 17 | 34 |
| 6 | 27 | 54 |
| 4 | 42 | 84 |
| 2 | 64 | 132 |

*Resistance of Starter Switch Circuit should not exceed .0114 ohm total.

Chart 2

**Service Manual** SM1-63-63.0 Tachometer Drive

A tachometer drive shaft may be installed at any one of several locations on the engine.

At the rear of the engine, the tachometer drive shaft is installed in the end of the blower drive shaft, (Fig. 1). A tachometer drive shaft adapter is attached to the blower rear end plate cover.

When required, a tachometer drive cable adapter is used to change speed or to change direction of rotation, depending upon the location of the tachometer drive. A special key is used to connect the drive shaft to the tachometer drive cable adapter.

The cable connection at the tachometer head is a 5/8" threaded connection. To eliminate possible misalignment, the tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output shaft key size is SAE 3/16".

63.1 Remove Tachometer Drive (Driven by Blower Rotor Shaft)

If replacement is necessary, remove the tachometer drive shaft as follows:

(1) Disconnect the tachometer drive cable from the tachometer drive cable adapter.
(2) Remove the tachometer drive cable adapter and key.
(3) Remove the blower from the engine as outlined in SM1-63-42.0.
(4) Remove the blower rear end plate cover.
(5) Remove the tachometer drive shaft, which also functions as the L.H. blower rotor gear retaining bolt, with a 3/4" wrench.

63.2 Install Tachometer Drive (Driven by Blower Rotor Shaft)

(1) Lubricate the threads with engine oil and install the combination blower rotor retaining bolt and tachometer drive shaft. Tighten it to 55-65 ft-lbs (75-88 Nm) torque.
(2) Install the blower rear end plate cover.

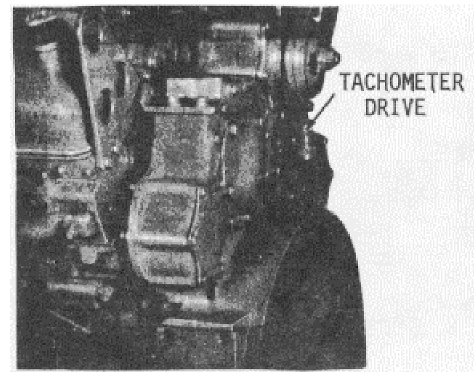



*Fig. 1. Rear Mounted Tachometer Drive*

(3) Align the blower rear end plate cover with the tachometer drive shaft. Check the alignment of the drive shaft as outlined in SM1- 63-64.0.
(4) Install the blower on the engine as outlined in SM1-63-42.0.
(5) Install the tachometer drive cable adapter and key.
(6) Attach the tachometer drive cable.

64.1 Alignment Tools for Tachometer Drive Covers and Adapters

Whenever a tachometer drive cover assembly or a tachometer drive adapter is installed on a engine, it is important that the cover assembly or adapter be aligned properly with the tachometer drive shaft.

Misalignment of a tachometer drive shaft can impose a side load on a tachometer drive cable adapter resulting in possible seizure and damage to other related components.

Use one of three tools in set J 23068 to establish the proper alignment. Fig. 1 illustrates the use of the tools.

Because of the many different combinations of tachometer drive shafts, covers and adapters, it is not practical to itemize specific usages for each tool. When confronted with an alignment job, test fit each tool to determine which provides the best fit and proceed to make the alignment with that tool.

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand rotation of the engine is made.

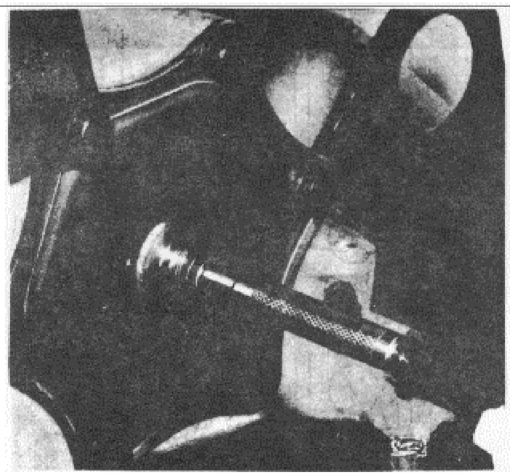


*Fig. 1. Checking Tachometer Drive Shaft Alignment*

**Service Manual** SM1-63-65.0 Air Compressor

The air compressor (Fig. 1) is flanged-mounted to the flywheel housing and gear driven by means of an accessory drive attached to a camshaft gear.

The air compressor runs continuously while the engine is running. While the compressor is running, actual compression of air is controlled by the compressor governor which acts in conjunction with the unloading mechanism in the compressor cylinder block. The governor starts and stops the compression of air by loading or unloading the compressor when the air pressure in the system reaches the desired minimum or maximum pressure.

During the down stroke of each piston, a partial vacuum is created above the piston which unseats the inlet valve and then allows air drawn from the air box in the engine cylinder block or through an intake strainer to enter the cylinder above the piston. As the piston starts the upward stroke, the air pressure on top of the inlet valves, plus the inlet valve return spring force, closes the inlet valve. The air above the piston is further compressed until the pressure lifts the discharge valve and the compressed air is discharged through the discharge line into the reservoir.

As each piston starts its downstroke, the discharge valve above it returns to its seat, preventing the compressed air from returning to the cylinder and the same cycle is repeated.

When the air pressure in the reservoir reaches the maximum setting of the governor, compressed air from the reservoir passes through the governor into the cavity below the unloading pistons in the compressor cylinder block. The air pressure lifts the unloading pistons which in turn lifts the inlet valves off their seats.

With the inlet valves held off their seats, the air during each upstroke of the piston is merely passed back through the air inlet cavity and to the other cylinder where the piston is on the downstroke. When the air pressure in the reservoir drops to the minimum setting of the governor, the governor releases the air pressure beneath the unloading pistons. The unloading piston return spring then forces the piston down and the inlet valve springs return the inlet valves to their seats and compression is resumed.

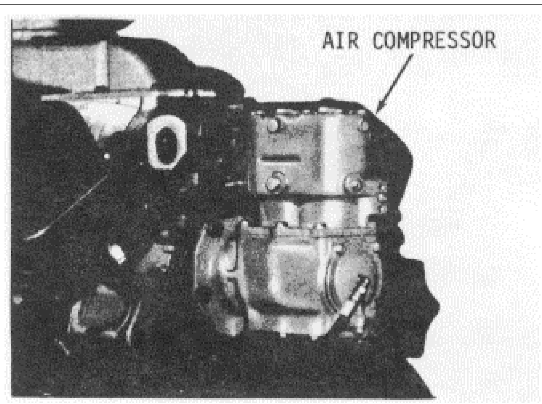



*Fig. 1. Air Compressor Mounting*

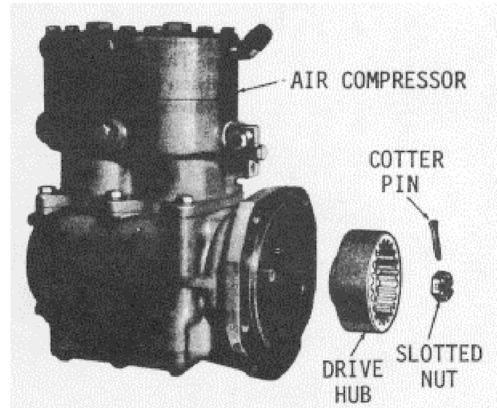



*Fig. 2. Typical Air Compressor with Drive Hub*

65.1 Service Notes

When installing a pulley or a drive hub on a flange mounted air compressor (Fig. 2), it is important the 3/4"-10 drive shaft slotted nut be tightened to 100 ft-lbs (136 Nm) torque minimum before installing the 3/32" x 1-1/4" cotter pin.

The air compressor drive shaft will turn during the torquing operation unless some provision is made to hold it. One way this can be done is to weld a modified drive coupling to a support or base which in turn can be anchored to the mounting flange of the compressor. An old flywheel housing cover that matches the flange of the compressor makes an ideal base for the modified coupling. With the exterior splines of the coupling in mesh with the internal splines of the drive hub and the entire assembly secured to the compressor housing, the hub and shaft are kept from rotating when the torque is applied. Thatpart of the base within the inner diameter of the coupling must be removed to permit placement of the wrench socket on the nut. Two bolts will secure the base to the compressor during the torquing operation

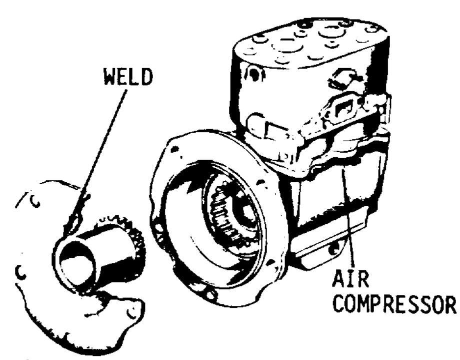



*Fig. 3. Fixture for Holding Drive While Installing or Removing Slotted Nut*

This chart is included as an aid for engine operation and trouble shooting. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Make sure that the readings represent true values before attempting to make corrections to the engine.

Note: <u>The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery it will be 10°lower than the oil pan temperature.</u>

6V-92T ENGINE WITH TURBOCHARGER (T18A40 1.14 A/R HOUSING)*

| | 1800 rpm | 2000 rpm | 2100 rpm |
|---|---|---|---|
| Lubrication System | | | |
| Lubricating oil pressure (psi): | | | |
| Normal | 50-70 | 50-70 | 50-70 |
| Lubricating oil temperature (degr. F.) - max.: | | | |
| Minimum for safe operation | 30 | 30 | 30 |
| Normal | 200-250 | 200-250 | 200-250 |
| Air System | | | |
| Air box pressure (inches mercury) - min. at full load: | | | |
| At zero exhaust back pressure | | | |
| 80 injectors | 21.0 | 25.5 | 28.0 |
| 85 injector | 22.5 | 27.0 | 29.5 |
| 90 injector | 24.0 | 29.031.5 | |
| 95 injector | 25.5 | -- | -- |
| At max, full load exh. back press. (clean ports) | | | |
| 80 injectors | 19.5 | 23.726.0 | |
| 85 injector | 20.9 | 25.127.4 | |
| 90 injector | 22.3 | 27.029.3 | |
| 95 injector | 23.4 | -- | -- |
| Air inlet restriction (inches water) - full load max: | | | |
| Dirty air cleaner - dry type | 14.5 | 18.020.0 | |
| Clean air cleaner: | | | |
| dry type with precleaner | 8.7 | 10.812.0 | |
| dry type less precleaner | 5.8 | 7.2 | 8.0 |
| Crankcase pressure (inches water) - max | 2.2 | 2.7 | 3.0 |
| Exhaust back pressure (inches mercury) - max.: | | | |
| Full load | 1.8 | 2.2 2.5 | |
| No load | 1.3 | 1.6 | 1.8 |
| Fuel System | | | |
| Fuel pressure at inlet manifold (psi): | | | |
| Normal with .080" restriction fitting | 50-70 | 50-70 | 50-70 |
| Minimum | 30 | 30 | 30 |
| Fuel spill (gpm) - minimum at no-load: | | | |
| .080" restriction fitting | 0.9 | 0.9 | 0.9 |
| Fuel pump suction at pump inlet (inches mercury) - max.: | | | |
| Clean system | 6 | 6 | 6 |
| Dirty system | 12 | 12 | 12 |
| Cooling System | | | |
| Coolant temperature (degr. F.) - normal | 160-185 | 160-185 | 160-185 |
| Compression | | | |
| Compression pressure (psi at sea level): | | | |
| Average - new engine - at 600 rpm ... 430 | | | |
| Minimum - at 600 rpm ... 380 | | | |

* Indicates Area and Radius

Following a complete overhaul or any major repair Job involving the installation of piston rings, pistons, cylinder liners or bearings, the engine should be "Run-in" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the serviceman to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (160-185°F or 71-85°C) should be maintained throughout the Run-in.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 100 higher than the water inlet temperature. Though a 100 rise across an engine is recommended, it has been found that a 15° temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow. Therefore, be sure they are in place and fully operative or the engine will overheat during the Run-in. However, if the dynamometer has a water standpipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without thermostats.

The Run-In Schedules are shown in Tables 1 and 2. The horsepower shown is at SAE conditions: dry air density .0705 lb/cu. ft. (1.129 Kg/m3), air temperature of 850F (29.40C), and 500 ft. (152 m) elevation.

67.1 Dynamometer Test and Run-In Procedures

67.2 The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes .

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the Basic Engine Run-In Schedule. The following items are included on the basic engine: blower, fuel pump, water pump and governor. The fan and battery-charging alternator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the Engine Test Report. The effects of this additional equipment on engine performance should then be considered when evaluating test results.

67.3 Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (ft-lb) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

BHP = (T x RPM)/5250

Where:

BHP = brake horsepower
T = torque in ft-lb
RPM = revolutions per minute

Some dynamometers indicate direct brake horse-power readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an Engine Test Report (see sample on page 3),

67.4 Instrumentation

Certain instrumentation is necessary so that data required to complete the Engine Test Report may be obtained. The following list contains both the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

(a) Oil pressure gauge installed in one of the engine main oil galleries.
(b) Oil temperature gauge installed in the oil pan, or thermometer installed in the dip- stick hole in the oil pan
(c) Adapter for connecting a pressure gauge or mercury manometer to the engine air box.
(d) Water temperature gauge installed in the thermostat housing or water outlet manifold.
(e) Adapter for connecting a pressure gauge or water manometer to the crankcase.
(f) Adapter for connecting a pressure gauge or mercury manometer to the exhaust manifold at the flange.
(g) Adapter for connecting a vacuum gauge or water manometer to the blower inlet.

BASIC ENGINE RUN-IN SCHEDULE

| TIME MINUTES | SPEED RPM | INJECTORS | ENGINE BRAKE HORSEPOWER | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 6V | 6VT | 8V | 8VT | 16V | 16VT |
| 10 | 1200 | ALL | 54 | 54 | 72 | 72 | 144 | 144 |
| 30 | 1800 | ALL | 195 | 225 | 260 | 300 | 520 | 600 |
| 30* | 2100 | 70 | 216 | --- | 288 | --- | 576 | --- |
| 30* | 2100 | 75 | 230 | --- | 306 | --- | 612 | --- |
| 30* | 2100 | 80 | 243 | --- | 324 | --- | 648 | --- |
| 30* | 2100 | 85 | 257 | --- | 342 | --- | 684 | --- |
| 30* | 2100 | 80 | --- | 252 | --- | 338 | --- | 675 |
| 30* | 2100 | 85 | --- | 270 | --- | 360 | --- | 720 |
| 30* | 2100 | 90 | --- | 290 | --- | 387 | --- | 774 |

*Use speed-injector combination applicable to engine on test.

Table 1

FINAL ENGINE RUN-IN SCHEDULE

FINAL ENGINE RUN-IN SCHEDULE

| TIME MINUTES | SPEED RPM | INJECTORS | +ENGINE BRAKE HORSEPOWER | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 6V | 6VT | 8V | 8VT | 16V | 16VT |
| 30* | 2100 | 70 | 240 | --- | 320 | --- | 640 | --- |
| 30* | 2100 | 75 | 255 | --- | 340 | --- | 680 | --- |
| 30* | 2100 | 80 | 270 | 280 | 360 | 375 | 720 | 750 |
| 30* | 2100 | 85 | 285 | 300 | 380 | 400 | 760 | 800 |
| 30* | 2100 | 90 | --- | 322 | --- | 430 | --- | 860 |

*Use speed-injector combination applicable to engine on test.
+Within 5% of brake horsepower rating shown above at governor speed..
Table 2

(h) Adapter for connecting a fuel pressure gauge to the fuel manifold inlet passage.

(i) Adapter for connecting a pressure gauge or mercury manometer to the turbocharger.

In some cases, gauges reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gauge be of low range and finely divided if accuracy is desired. This is especially true of a gauge reading in psi, the reading of which is to be converted to inches of water. The following con- version factors may be helpful.

Inches of water = psi x 27.7"
Inches of mercury = psi x 2.04"

Note: Before starting the Run-In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on Preparation for Starting Engine First Time in SM1-63-67.0.

67.5 Run-In Procedure

The procedure outlined below will follow the order of the sample Engine Test Report.

A. PRE-STARTING
(1) Fill the lubrication system as outlined under Lubrication System-Preparation for Starting Engine First Time in Operator’s Manual.
(2) Prime the fuel system as outlined under Fuel System--Preparation for Starting Engine First Time in Operator’s Manual.

# ENGINE TEST REPORT

Date ______________________ Unit Number ______________________

Repair Order Number ______________________ Model Number ______________________

## A PRE-STARTING

| 1. PRIME LUBE OIL SYSTEM | 2. PRIME FUEL SYSTEM | 3. ADJUST VALVES | 4. TIME INJ. | 5. ADJ. GOV. | 6. ADJUST INJ. RACKS |
|---|---|---|---|---|---|
| | | | | | |

## B BASIC ENGINE RUN-IN

| TIME AT SPEED | TIME START | TIME STOP | RPM | BHP | WATER TEMP. | LUBE OIL PRESS. |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

## C BASIC RUN-IN INSPECTION

| | |
|---|---|
| 1. Check oil at rocker arm mechanism | |
| 2. Inspect for lube oil leaks | |
| 3. Inspect for fuel oil leaks | |
| 4. Inspect for water leaks | |
| 5. Check and tighten all external bolts | |
| 6. | |

## D INSPECTION AFTER BASIC RUN-IN

| | | | |
|---|---|---|---|
| 1. Tighten Cylinder Head & Rocker Shaft Bolts | | 4. Adjust Governor Gap | |
| 2. Adjust Valves (Hot) | | 5. Adjust Injector Racks | |
| 3. Time Injectors | | 6. | |

## E FINAL RUN-IN

| TIME START | TIME STOP | TOP RPM NO LOAD | TOP RPM FULL LOAD | BHP | AIR BOX PRESSURE FULL LOAD | EXHAUST BACK PRESSURE F/L | CRANKCASE PRESSURE F/L |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

| BLOWER INTAKE RES. - F/L | FUEL OIL PRESSURE RET. MAN. F/L | WATER TEMP. FULL LOAD | LUBE OIL TEMP. F/L | LUBE OIL PRESSURE FULL LOAD | LUBE OIL PRESSURE IDLE | IDLE SPEED |
|---|---|---|---|---|---|---|
| | | | | | | |

## F INSPECTION AFTER FINAL RUN

| | |
|---|---|
| 1. Inspect Air Box, Pistons, Liners, Rings | 6. Tighten Oil Pump Bolts |
| 2. Inspect Blower | 7. Inspect Oil Pump Drive |
| 3. Check Generator Charging Plate | 8. Replace Lube Filter Elements |
| 4. Wash Oil Pan, Check Gasket | 9. Tighten Flywheel Bolts |
| 5. Clean Oil Pump Screen | 10. Rust Proof Cooling System |

REMARKS:

Final Run OK'd ______________ Dynamometer Operator ______________ Date ______________

NOTE: Operator must initial each check and sign this report.

NOTE: Operator must initial each check and sign this report.

(3) A preliminary valve clearance adjustment must be made before the engine is started. See Valve Clearance Adjustment in SM1-63-68.0.

(4) A preliminary injector timing check must be made before starting the engine. See Fuel Injector Timing in SM1-63-68.0.

(5) Preliminary governor adjustments must be made as outlined in SM1-63-68.0.

(6) Preliminary injector rack adjustment must be made (SM1-63-68.0).

Note: Prior to starting a turbocharged engine, remove the oil supply line at each turbocharger and add clean engine oil to the oil inlet to ensure pre-lubrication of the turbochargers. Reconnect the oil lines and idle the engine for at least one minute after starting and before increasing the speed.

B. BASIC ENGINE RUN-IN

The operator should be observant at all times, so that any malfunction which may develop will be detected. Since the engine has just been reconditioned, this Run-in will be a test of the workmanship of the serviceman who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also inspect the exhaust system, being sure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 ft-lbs on the torque gauge (or 10-15 HP on a horsepower gauge). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the Engine Test Report sample which establishes the sequence of events for the test and run-in, and to the Basic Engine Run-In Schedule which indicates the speed (rpm), length of time and the brake horsepower required for each phase of the test. Also refer to the Operating Conditions in SM1-63-66.0 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full-load speed designated for the Run-in. If a governor is encountered which can, not be adjusted to this speed, a stock governor should be installed for the Run-in,

After checking the engine performance at idle speed and being certain the engine and dynamo-meter are operating properly, increase the engine speed to half speed and apply the load indicated on the Basic Engine Run-In Schedule.

The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature and lubricating oil pressure on the Engine Test Report.

Run the engine at each speed and rating for the length of time indicated in the Basic Engine Run-In Schedule. This is the Basic Run, In. During this time, engine performance will improve as new parts begin to "seat in", Record all of the required data.

C. BASIC RUN-IN INSPECTION

While the engine is undergoing the Basic Run-In, check each item indicated in Section "C" of the Engine Test Report. Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Basic Run-in, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Basic Run-In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN-IN

The primary purpose of this inspection is to provide a fine engine tune-up. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next complete the applicable tune-up procedure. Refer to SM1-63-68.0.

E. FINAL RUN-IN

After all of the tests have been made and the Engine Test Report is completed through Section "D", the engine is ready for final test. This portion of the test and Run-in procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm-up period of 10 minutes at the same speed and load used for warm-up in the Basic Run-In. If piston rings, cylinder liners or bearings have been re- placed as a result of findings in the Basic Run- In, the entire Basic Run-In must be repeated as though the Run-in and test procedure were started anew.

All readings observed during the Final Run-In should fall within the range specified in the Operating Conditions in SM1-63-66.0 and should be taken at full load unless otherwise specified.

Following is a brief discussion of each condition to be observed.

The engine water temperature should be taken during the last portion of the Basic Run-In at full load. It should be recorded and should be within the specified range.

The lubricating oil temperature reading must be taken while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range.

The lubricating oil pressure should be recorded in psi after being taken at engine speeds indicated in the Operating Conditions, SM1-63-66.0. The fuel oil pressure at the fuel manifold inlet passage should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine speed during the Final Run-In.

Check the air box pressure while the engine is operating at maximum speed and load. This check *may* be made by attaching a suitable gauge (0-15 psi) or manometer (15-0-15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the crankcase pressure while the engine is operating at maximum Run-in speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the Run-in indicating that new rings are beginning to "seat-in".

Check the air inlet restriction with a water manometer connected to a fitting in the air in- let ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4" pipe tapped hole in the engine air inlet housing. If a hole is not provided, a stock housing should be drilled tapped and kept on hand for future use.

The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the in- let side of one of the turbochargers. The difference between the two readings, with and with- out the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air intake vacuum at various speeds (at no-load) and compare the results with the Engine Operating Conditions in SM1-63-66.0. Record these readings on the Engine Test Report, Check the exhaust back pressure (except turbo- charged engines) at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adapter installed at the tapped hole, If the exhaust manifold does not provide a 1/8" pipe tapped hole such a hole can be incorporated by reworking the exhaust manifold. Install a fitting for a pressure gauge or - manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet. The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is be- low the Maximum Exhaust Back Pressure for the engine (refer to SM1-68-66.0).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full-load and no-load speeds.

Refer to the Final Engine Run-In Schedule and determine the maximum rated brake horsepower and the full-load speed to be used during the Final Run-In. Apply the load thus determined to the dynamometer. If a hydraulic governor is used, the droop may be adjusted at this time *by* fol- lowing the prescribed procedure, The engine should be run at this speed and load for 1/2 hour. While making the Final Run-In the engine should develop, within 5% the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed *may* be either higher or lower than the maximum speed used during the Basic Run-In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run-In, of the Engine Test Report should be determined and filled in. After the prescribed time for the Final Run-In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run-In is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the Final Run-In and before the Engine Test Report is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur, This is accomplished by rustproofing the fuel system and adding a rust inhibitor into the cooling system (refer to the Operators Manual). The lubricating oil filters should also be changed.

**CAUTION**

A Rust Inhibitor In The Coolant System Of The V-92 Engine Is Particularly Important Because Of The Wet Cylinder Liners. Omission Of A Rust Inhibitor Will Cause Rusting Of The Outside Diameter Of The Cylinder Liners And Interference With Liner Heat Transfer.

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc, should only be required periodically to compensate for normal wear on parts.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if the cylinder head, governor or injectors have been replaced or overhauled, then certain preliminary adjustments are required before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

Note: If a supplementary governing device, such as the throttle delay mechanism, is used, it must be disconnected prior to the tune-up. After the governor and injector rack adjustments are completed, the supplementary governing device must be reconnected and adjusted.

To tune-up an engine completely, perform all of the adjustments in the applicable tune-up sequence given below after the engine has reached normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Use new valve rocker cover gaskets after the tune-up is completed.

68.1 Tune-Up Sequence for Mechanical Governors

Note: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the serviceman must determine that the injector racks move to the no- fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

(1) Adjust the exhaust valve clearance.
(2) Time the fuel injectors.
(3) Adjust the governor gap.
(4) Position the injector rack control levers.
(5) Adjust the maximum no-load speed.
(6) Adjust the idle speed.
(7) Adjust the buffer screw.
(8) Adjust the throttle booster spring (variable speed governor only).
(9) Adjust the supplementary governing device (if used).

68.2 Exhaust Valve Clearance Adjustment

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

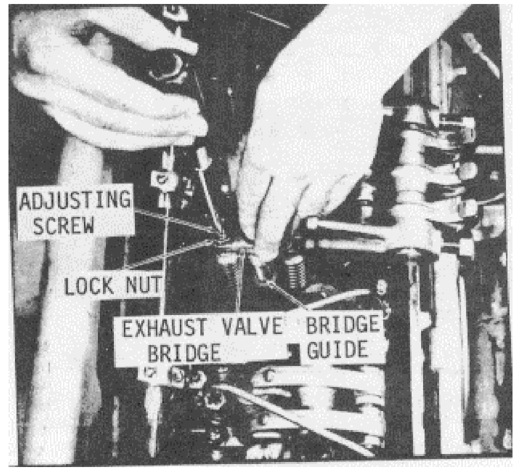



*Fig. 1. Bridge Balancing Adjustment*

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in nosily operation, increased valve face wear and valve lock damage.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

The exhaust valve bridges must be adjusted and the adjustment screws locked securely at the time the cylinder head is installed on the engine. Until wear occurs no further adjustment is required on the exhaust valve bridges. When wear is evident, make the necessary adjustments as outlined below.

68.3 Valve Bridge Adjustment

(1) Remove the loose dirt from the exterior of the engine and remove the valve rocker cover. Remove the injector fuel pipes and the rocker arm bracket bolts. Move the rocker arms away from the exhaust valve bridge.
(2) Remove the exhaust valve bridge (Fig. 1).
(3) Place the bridge in a vise or holding fixture J 21772 and loosen the locknut on the bridge adjusting screw.

Note: Loosening or tightening the locknut with the bridge in place may result in bending the bridge guide or the rear valve stem.

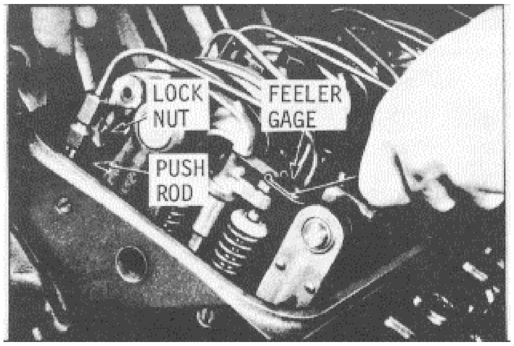



*Fig. 2. Adjusting Valve Clearances*

(4) Install the bridge on the bridge guide.
(5) While firmly pressing straight down on the pallet surface of the bridge, turn the adjusting screw clockwise until it just touches the valve stem. Then turn the screw an additional 1/8 to 1/4 turn clockwise and tighten the locknut finger tight.
(6) Remove the bridge and place it in a vise. Hold the screw from turning with a screw- driver and tighten the locknut on the adjustment screw. Complete the operation by tightening the locknut with a torque wrench to 25 ft-lbs (34 Nm), being sure that the screw does not turn.
(7) Lubricate the bridge guide and the bridge pilot with engine oil.
(8) Reinstall the bridge in its original position.
(9) Place a .0015" feeler gauge under each end of the bridge. When pressing down on the pallet surface of the bridge, both feeler gauges must be tight. If both feeler gauges are not tight, readjust the screw as out- lined in Steps 5 and 6.
(10) Adjust the remaining bridges as outlined above.
(11) Swing the rocker arm assembly into position being sure the bridges are properly positioned on the rear valve stems. This pre-caution is necessary to prevent valve damage due to mislocated bridges.
(12) Tighten the rocker arm bracket bolts to 90-100 ft-lbs (122-136 Nm) torque.
(13) Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932 to tighten the connectors to 12-15 ft-lbs (16-20 Nm) torque.

Note: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

68.4 Valve Clearance Adjustment (Cold Engine)

All of the exhaust valves may be adjusted, in firing order sequence, during one full revolution of the crankshaft. Refer to the General Specifications in the Operator's Manual for the engine firing order.

(1) Clean the loose dirt from the exterior of the engine and remove the valve rocker covers. Then cover any drain cavities in the cylinder head to prevent foreign material from entering.
(2) Place the stop lever in the no-fuel position.
(3) Rotate the crankshaft, with the starting motor or engine barring tool J 22582, until the injector follower is fully depressed on the cylinder to be adjusted.

Note: If a wrench is used on the crankshaft bolt or camshaft nut at the front of the engine, do not turn the engine in a left-hand direction of rotation as the bolt or nut will be loosened.

(4) Loosen the exhaust valve rocker arm push rod locknut.
(5) Place a .016" feeler gauge, J 9708-01, between the valve bridge and the valve rocker arm pallet (Fig. 2). Adjust the push rod to obtain a smooth "pull" on the feeler gauge.
(6) Remove the feeler gauge. Hold the push rod with a 5/16" wrench and tighten the locknut with a 1/2" wrench.
(7) Recheck the clearance and adjust the push rod if necessary.
(8) Check and adjust the remaining exhaust valves in the same manner above.

68.5 Valve Clearance Adjustment (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the final valve clearance adjustment. If the engine is allowed to cool off before setting any of the valves, the clearance when running at full load may become insufficient.

With the engine at normal operating temperature (160-185°F or 71-85°C), recheck the exhaust valve clearance with feeler gauge' J 9708.01. At this time, if the valve clearance is correct, the .014" feeler gauge will pass freely between the valve bridge and the rocker arm pallet.

68.6 Check Exhaust Valve Clearance Adjustments

(1) With the engine operating at 100°F (38°C) or less, check the valve clearance.
(2) If a .016" feeler gauge (J 9708-01) .004" will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary adjust the push rod.

68.7 Timing Fuel Injector

To time an injector properly, the injector fol- lower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed, in firing order sequence, during one full revolution of the crankshaft. Refer to the General Specifications in the Operator's Manual for the engine firing order.

| Injector | Timing Gage Dimension | Timing Gage Tool No. | Camshaft Timing |
|---|---|---|---|
| 9C90 | 1.484" | J1242 | Standard |

Injector Timing Gauge Chart
Use the proper timing gauge as indicated in the chart.

68.8 Time Fuel Injector

(1) Clean the loose dirt from the exterior of the engine and remove the valve rocker covers. Then cover any drain cavities in the cylinder head to prevent foreign material from entering.
(2) Place the stop lever in the no-fuel position.
(3) Rotate the crankshaft, by using the starting motor or engine barring tool J 22582, until the exhaust valves are fully depressed on the particular cylinder to be timed. Important: If a wrench is used on the crankshaft bolt or camshaft nut at the front of the engine, do not turn the engine in a left-hand direction or the bolt or nut will be loosened.
(4) Place the small end of the injector timing gauge in the hole provided in the top of the injector body, with the flat of the gauge toward the injector follower (Fig. 3).
(5) Loosen the push rod locknut.
(6) Turn the push rod and adjust the injector rocker arm until the extended part of the gauge will just pass over the top of the injector follower.
(7) Hold the push rod and tighten the locknut. Check the adjustment and, if necessary, readjust the push rod.
(8) Time the remaining injectors in the same manner as outlined above.
(9) If no further engine tune-up is required install the valve rocker covers, using a new gasket.

68.9 Limiting Speed Mechanical Governor and Injector Rack Control Adjustment

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers,

Note: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device.

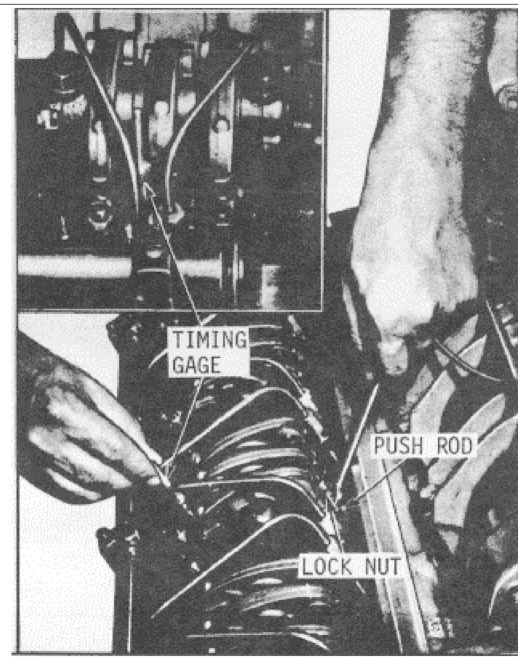



*Fig. 3. Timing Fuel Injector*

68.10 Adjust the Governor Gap
With the engine stopped and at normal operating temperature, adjust the governor gap as fol- lows:

(1) Remove the high speed spring retainer cover.
(2) Back out the buffer screw until it extends approximately 5/8U from the locknut (Fig. 11).
(3) Start the engine and loosen the idle speed adjusting screw locknut. Then adjust the idle screw (Fig.10) to obtain the desired idle speed. Hold the screw and tighten the locknut to hold the adjustment. Note: Limiting speed governors used in turbocharged engines include a starting aid screw threaded into the governor housing. Important: The recommended idle speed is 400-450 rpm, but may vary with special engine applications.
(4) Stop the engine. Clean and remove the governor cover and lever assembly and discard the gasket.
(5) Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever.

Note: Do not overspeed the engine.

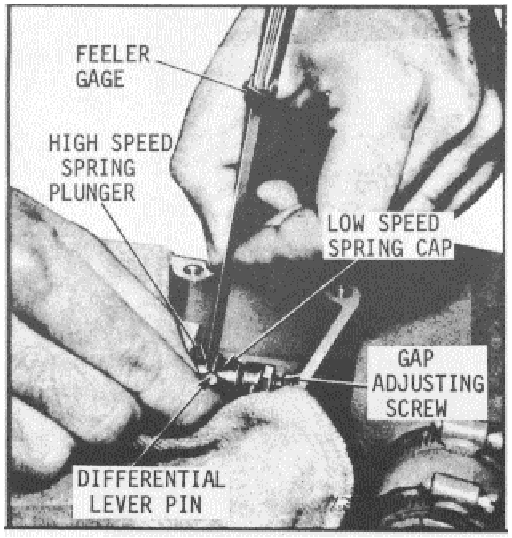



*Fig. 4. Adjusting Governor Gap*

(6) Check the gap between the low-speed spring cap and the high-speed spring plunger (Fig. 1) with a feeler gauge. The gap should be .001" - .004". If the gap setting is in- correct, reset the gap adjusting screw.
(7) Hold the gap adjusting screw and tighten the locknut.
(8) Recheck, the gap with the engine operating between 1100 and 1300 rpm and readjust if necessary.
(9) Stop the engine and, using a new gasket, install the governor cover and lever assembly. Tighten the screws.

68.11 Position Injector Rack Control Levers

The positions of the injector racks must be correctly set in relation to the governor. Their positions determine the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Note: <u>To ensure proper injector control rack adjustment, the injector racks must be adjusted with the yield link and governor cover that are to be used with the governor.</u>

Properly positioned injector rack control levers with the engine at full load will result in the following:
(1) Speed control lever at the maximum speed position.
(2) Governor low-speed gap closed.
(3) High-speed spring plunger on the seat in the governor control housing.
(4) Injector fuel control racks in the full-fuel position.

The letters R and L indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. The cylinders are

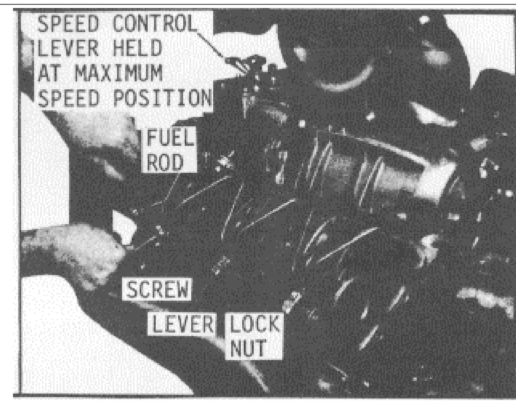



*Fig. 5. Position No. 1 Injector Rack Control Lever (One Screw and Locknut Assembly)*

numbered starting at the front of the engine on each cylinder bank, Adjust the No. 1L injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.
(1) Disconnect any linkage attached to the governor speed control lever.
(2) Turn the idle speed adjusting screw until one half of the threads (12,14 threads) project from the locknut when the nut is against the high speed plunger.

Note: <u>A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.</u>

This adjustment lowers the tension on the low-speed spring so it can be easily compressed. This permits closing the low-speed gap without bending the fuel rods or causing the yield mechanism springs to yield or stretch.

Injector racks must be adjusted so the effort to move the throttle from the idle speed position to the maximum speed position

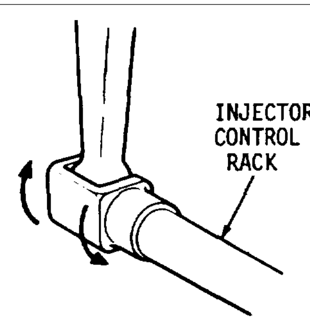



*Fig. 6. Checking Rotating Movement of Injector Control Rack*

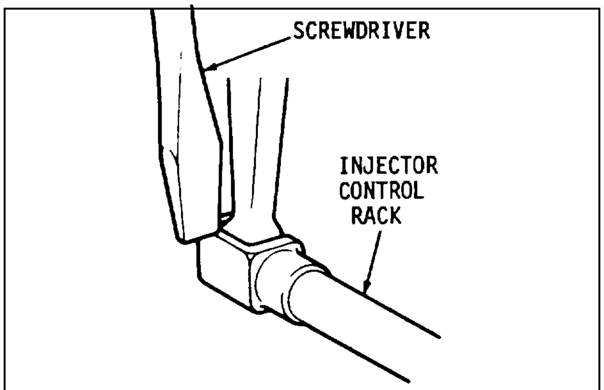



*Fig. 7*
*Checking Injector Control Rack "Spring"*

is uniform. A sudden increase in effort can result from:

(a) Injector rack adjusted to tight causing the yield link to separate.

(b) Binding of the fuel rods.

(c) Failure to back out idle screw.

(3) Back out the buffer screw approximately 5/8", if it has not already been done.

(4) Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

(5) Loosen all of the inner and outer injector rack control lever adjusting screw and locknut on both cylinder heads. Be sure all of the injector rack control levers are free on the injector control tubes.

(6) To be sure of the proper rack adjustment, hold the speed control lever in the maximum speed position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack (Fig. 5). Hold the speed control lever in the maximum speed position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 2) and when the pressure of the screwdriver is released, the control rack should "spring" back up-ward.

If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly.

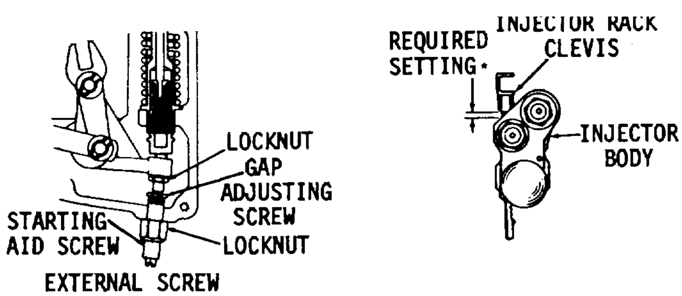
The setting is too tight if, when moving the T speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel. To correct this condition, back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly.

(7) Remove the clevis pin from the fuel rod at the left bank injector control tube lever.

(8) Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 1R injector rack control lever as previously outlined in Step 6 for the No. 1L injector rack control lever.

(9) Insert the clevis pin in the fuel rod at the left bank injector control tube lever. Verify the adjustments for the No. 1L and 1R injector racks are equal. To do this, move the speed control lever to the maximum speed position. Rotate the clevis pins at the injector control tube levers and note the drag or resistance to rotate the pins. This resistance or drag should be equal for both pins. If the drag is not equal, turn the No. 1R injector rack adjusting screw clockwise to increase drag on the right bank clevis pin or counterclockwise to decrease the pin drag. Adjust No. IR adjusting screw and lock securely to ensure equal drag for both clevis pins.

(10) When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the full-fuel position, check each control rack as in Step 6. All of the control racks must have the same "spring" condition with the control tube lever in the full-fuel position.




| INJECTOR | GAGE SETTING | TOOL NUMBER |
|---|---|---|
| 9C90 | .454" | J23190 |

*Figure. 8*
*Starting Aid Screw Adjusting*

(11)Insert the clevis pin in the fuel rod and the injector control tube levers.

(12)Turn the idle speed adjusting screw in until it projects 3/16" from the locknut, to permit starting the engine.

(13)Use new gaskets and replace the valve rocker covers.

68. 12 Adjust Starting Aid Screw - Turbocharged Engines

The starting aid screw (Fig. 8) is threaded into the governor housing. This screw is adjusted to position the injector racks at less than full fuel when the governor speed control lever is in the idle position. The reduced fuel makes starting easier and reduces the amount of smoke on start-up.

Important: The effectiveness of the starting aid screw will be eliminated if the speed control lever is advanced to wide open throttle during starting.

After the normal governor running gap of .002"-.004" has been set and the injector racks positioned, adjust the starting aid screw. (1) On turbocharged engines, adjust the external starting aid screw as follows:

(a) With the engine stopped, place the governor stop lever in the run position and the speed control lever in the idle speed position.

(b) Adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body (Fig. 8). Select the proper gauge and measure the setting at any convenient cylinder. When the starting aid screw is properly adjusted, the gauge should have a small clearance of 1/64" (.397mm) in the space along the injector rack shaft between the rack clevis and the injector body.

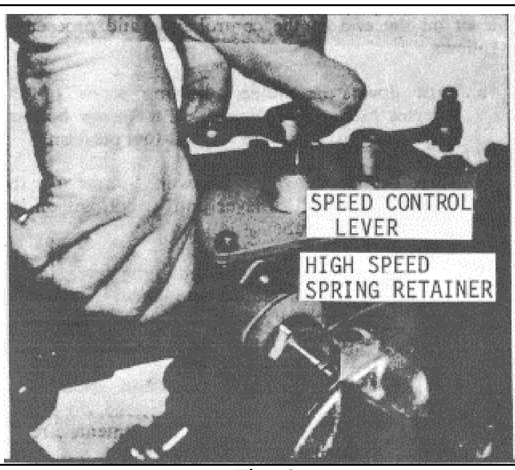



*Fig. 9*
*Adjusting Maximum No-Load Speed*

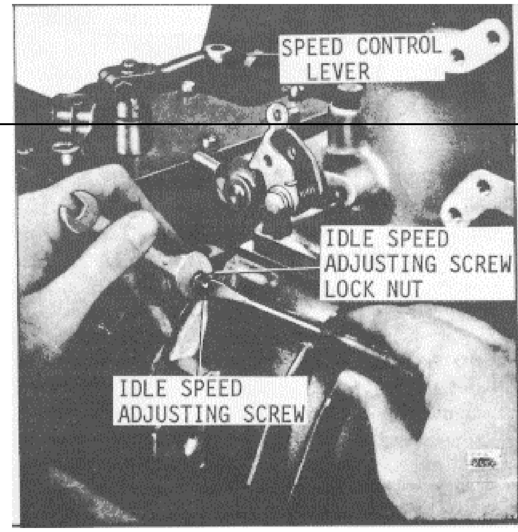



*Fig. 10*
*Adjusting Engine Idle Speed*

(c) After completing the adjustment, hold the starting aid screw and tighten the locknut.

(d) Check the injector rack clevis-to-body clearance after performing the following:

(1) Position the stop lever in the run position.
(2) Move the speed control lever from the idle speed position to the maximum speed position.
(3) Return the speed control lever to the idle speed position.

Note: Movement of the speed control lever is to take-up the clearance in the governor linkage. The injector rack clevis-to-body clearance can be increased by turning the starting aid screw farther in against the gap adjusting screw, or reduced by backing it out,

Important: The starting aid screw will be ineffective if the speed control lever is advanced toward wide open throttle during start, up.

(2) Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes in the cover. Tighten the screws.

Note: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the serviceman must determine that the injector racks return to the no fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever,

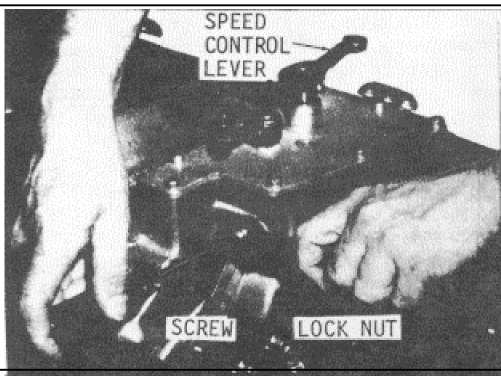



*Fig. 11*
*Adjusting Buffer Screw*

**WARNING**

An Overspeeding Engine Can Result In Engine Damage Which Could Cause Personal Injury.

(3) Use new gaskets and replace the valve rocker covers.

68.13 Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, set the maximum no-load speed as follows:

After positioning the injector rack control levers, set the maximum no-load engine speed as follows:

Note: Be sure the buffer screw projects 5/8" from the locknut to prevent interference while adjusting the maximum no-load speed,

(1) Loosen the spring retainer locknut (Fig. 9) and back off the high-speed spring retainer approximately five turns.
(2) With the engine running at operating temperature and no-load, place the speed control lever in the maximum speed position. Turn the high-speed spring retainer until the engine is operating at the recommended no-load speed,
(3) Hold the high-speed spring retainer and tighten the locknut, using spanner wrench J 5345-5.

68.14 Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

(1) With the engine running, at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever. turn the idle speed adjusting screw (Fig. 10) until the engine operates at approximately 15 rpm below the recommended idle speed,

Important: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established', to the previous setting (5/8").

Note! The recommended idle speed for non EPA certified engines is 400-450 rpm, but may vary with special engine applications.

(2) Hold the idle screw and tighten the lock- nut.
(3) Install the high-speed spring retainer cover and tighten the two bolts.

68.15 Adjust Buffer Screw

With the idle speed set, adjust the buffer screw as follows:

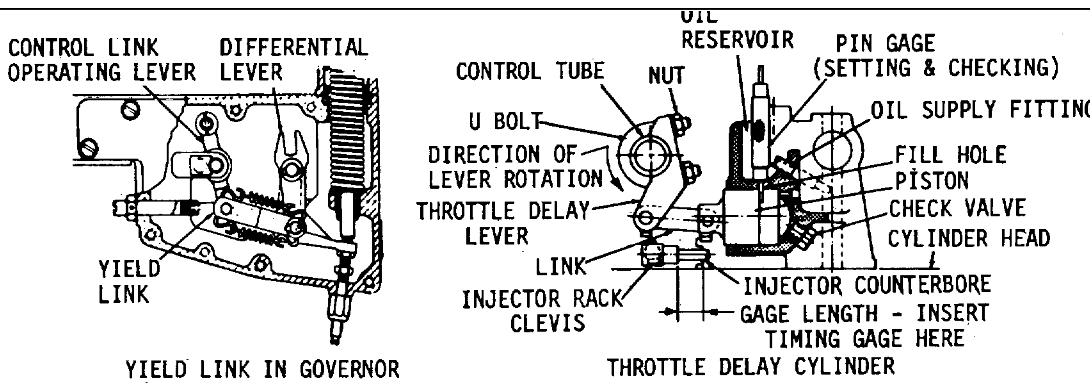



*Fig. 12*
*Throttle Delay Cylinder and Yield Link*

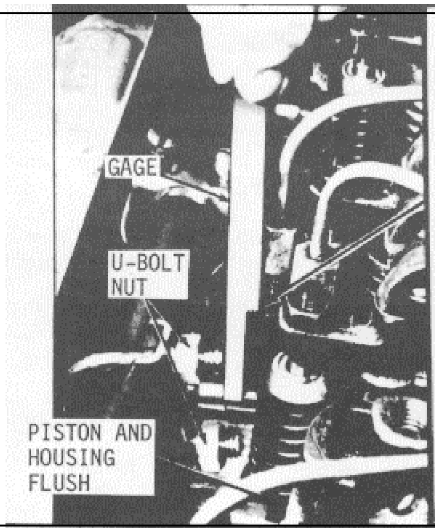



*Fig. 13*
*Adjusting Throttle Delay Cylinder*

(1) With the engine running at normal operating temperature, turn the buffer screw (Fig.11) in so it contacts the differential lever as lightly as possible and still eliminates the engine roll.

Note: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

(2) Recheck the maximum no-load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.
(3) Hold the buffer screw and tighten the lock- nut.

8.16 Throttle Delay Mechanism

The throttle delay mechanism is used to retard full-fuel injection when the engine is accelerated. This reduces exhaust smoke and also helps to improve fuel economy.

The throttle delay mechanism (Fig. 12) is in- stalled between the No. 1 and No. 2 cylinders on the right-bank cylinder head. It consists of a special rocker arm shaft bracket (which incorporates the throttle delay cylinder), a piston, throttle delay lever, connecting link. orifice plug, ball check valve and U-bolt.

A yield link replaces the standard operating lever connecting link in the governor.

68.17 Operation

Oil is supplied to a reservoir above the throttle delay cylinder through an orifice plug in the drilled oil passage in the rocker arm shaft bracket (Fig. 12). As the injector racks are moved toward the no-fuel position, free movement of the throttle delay piston is assured by air drawn into the cylinder through the ball check valve. Further movement of the piston uncovers an opening which permits oil from the reservoir to enter the cylinder and displace the air. When the engine is accelerated, movement of the injector racks toward the full-fuel position is momentarily-retarded while the piston expels the oil from the cylinder through an orifice. To permit full accelerator travel, regardless of the retarded injector rack position, a spring loaded yield link replaces the standard operating lever connecting link in the governor.

68.18 Inspection

The throttle delay bracket has a closer tolerance on the piston and cylinder bore. The piston link pin hole is offset below the piston centerline and has a larger pin boss diameter. The piston link has two tabs to ensure that the piston is installed with the piston pin hole offset down. The piston and link must be used together to ensure correct positioning of the piston. The check valve has a nylon check ball in place of the former brass ball. When inspecting the throttle delay hydraulic cylinder, it is important that the check valve be inspected for wear.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

To inspect the check valve, fill the throttle delay cylinder with diesel fuel oil and watch for check valve leakage while moving the engine throttle from the idle position to the full-fuel position. If more than a drop of leakage occurs. replace the check valve.

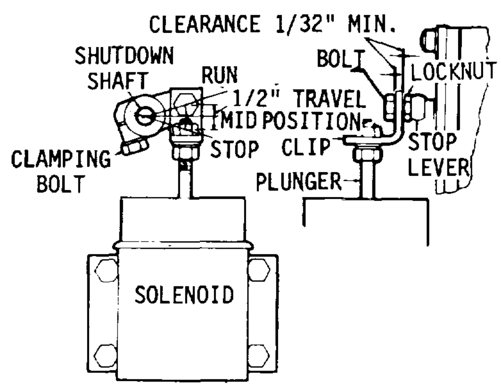



*Fig. 14*
*Typical Limiting Speed Governor Lever Position*

68.19 Adjustment

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the U-bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be readjusted. With the engine stopped, proceed as follows:

(1) Refer to Fig. 12 and insert gauge J 25559 (.570" setting) when 9285 mm injectors or lower output are used, or J 25560 (.636" setting) when 9290 mm injectors or higher output are used, between the injector body and the shoulder on the injector rack clevis of the injector nearest the throttle delay cylinder.

(2) Hold the governor throttle in the maximum speed position. This should cause the injector rack to move toward the full-fuel position and against the gauge.

(3) Insert the pin gauge J 25558 (.072" diameter setting end) in the cylinder fill hole.

(4) Rotate the throttle delay lever in the direction shown in Fig. 12, until further movement is limited by the piston contacting the pin gauge.

(5) Tighten the U-bolt nuts while exerting a slight amount of torque on the lever, in the direction of rotation. Be careful not to bend the gauge or damage the piston by using excessive force.

(6) Check the setting as follows:
   (a) Remove the pin gauge.
   (b) Attempt to reinstall the pin gauge (.072" diameter). It should not be possible to reinsert the gauge without moving the injector racks towards the no-fuel position.
   (c) Reverse the pin gauge to the .069" diameter end and insert it in the cylinder fill hole. It should enter the cylinder without resistance.

   Note: <u>If the .072" diameter end of the gauge enters the fill hole (Step 6b), increase the torque on the upper U-bolt nut. If the .069" diameter will not enter the fill hole (Step 6c) without resistance, increase the torque on the lower U-bolt nut</u>.

(7) Release the governor throttle and remove the timing gauge and pin gauge.

(8) Move the injector control tube assembly from the no-fuel to the full-fuel position to make sure there is no bind.

(9) Refer to Engine Tune-Up in Operator's Manual for maintenance.

68.19 Adjustment of Mechanical Governor Shutdown Solenoid

When a governor shutdown solenoid is used on an engine equipped with a mechanical governor, the governor stop lever must be properly adjusted to match the shutdown solenoid plunger travel.

The solenoid plunger can be properly aligned to the governor stop lever as follows:

(1) Remove the bolt connecting the right angle clip to the stop lever (Fig. 14). Align and clamp the lever-to the shutdown shaft in such a way that, at its mid-travel position, it is perpendicular to the solenoid plunger. This assures that the linkage will travel as straight as possible. The solenoid plunger has available 1/2" travel which is more than adequate to move the injector control racks from the full-fuel to the complete no-fuel position and shut down will occur prior to attaining complete travel,.

(2) With the stop lever in the run position, adjust the rod end eye or right angle clip for minimum engagement on the solenoid plunger when the connecting bolt is installed. The oversize hole in the eye or clip will there- by permit the solenoid to start closing the air gap, with a resultant build-up of pull-in force prior to initiating stop lever movement.

(3) The bolt through the rod end eye or the right angle clip should be locked to the stop lever and adjusted to a height that will permit the eye or clip to float vertically. The clearance above and below the eye or clip and the bolt head should be approximately 1/32" minimum.

   Note: <u>The locknut can be either on top of or below the stop lever</u>.

(4) Move the lever to the stop position and observe the plunger for any possible bind. If necessary, loosen the mounting bolts and realign the solenoid to provide free plunger motion.

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

(1) An adequate supply of air compressed to a sufficiently high compression pressure.

(2) The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air. Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

69.1 Locating a Misfiring Cylinder

(1) Start the engine and run it at part load until it reaches normal operating temperature.

(2) Stop the engine and remove the valve rocker

(3) Check the valve clearance (SM1-63-68.0).

| Minimum Compression Pressure at 600 rpm | | | | Altitude Above | | + Air |
|---|---|---|---|---|---|---|
| Turbocharged Engines | | Non-Turbocharged Engines | | Sea Level | | Density |
| psi | kPa | psi | kPa | feet | meters | |
| 450 | 3101 | 500 | 3445 | 500 | 152 | .0715 |
| 415 | 2859 | 465 | 3204 | 2,500 | 762 | .0663 |
| 385 | 2653 | 430 | 2963 | 5,000 | 1,524 | .0613 |
| 355 | 2446 | 395 | 2722 | 7,500 | 2,286 | .0567 |
| 330 | 2275 | 365 | 2515 | 10,000 | 3,048 | .0525 |

+ Air density at 500 feet altitude based on 850F (29.4"C) and 29.38 in. hg (99.49 kPa) wet barometer.

*Table 1*

(4) Start the engine. Then hold an injector follower down with a screwdriver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.

(5) If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

| | Gage Reading | |
|---|---|---|
| Cylinder | PSI | kPa |
| 1L | 470 | 3239 |
| 1R | 465 | 3204 |
| 2L | 430 | 2963 |
| 2R | 460 | 3170 |
| 3L | 465 | 3204 |
| 3R | 460 | 3170 |

*Table 2*

(6) If the cylinder is misfiring, check the following:

(a) Check the injector timing (refer to SM1-63-68.0).

(b) Check the compression pressure.

(c) Install a new injector.

(d) If the cylinder still misfires, remove the cam follower (refer to SM1-63-6.0) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

69.2 Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:

(1) Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.

(2) Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.

(3) Remove the injector and install an adaptor and pressure gauge (Fig. 1) from Diagnosis Kit J 9531-01.

(4) Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.

(5) Start the engine and run it at a 600 rpm. Observe and record the compression pressure indicated on the gauge. Do not crank the engine with the starting motor to obtain the compression pressure.

(6) Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In addition. the variation in compression pressures between cylinders must not exceed 25 psi (172 kPa) at 600 rpm.

Example: If the compression pressure read ings were as shown in Table 2, it would be evident that No. 2L cylinder should be examined and the cause of the low compression pressure be determined and corrected.

The pressures in Table 2 are for a turbocharged engine operating at an altitude near sea level.

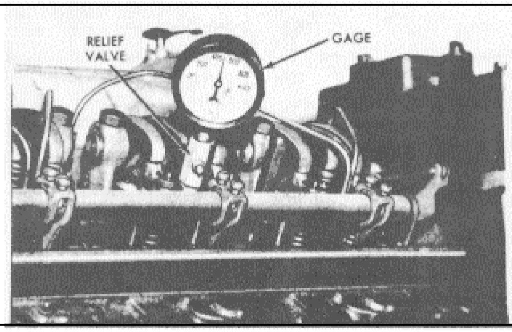



*Fig. 1*
*Checking Compression Pressure*

Note that all of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the No. 2L cylinder compression pressure indicates that something unusual has occurred and that a localized pressure leak has developed.

Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool (Fig. 2). A broken or stuck ring will not have a "spring-like" action.
B. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

69.3 Engine Out of Fuel

The problem in restarting the engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors. When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

(1) Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons (thirty-eight litres) of fuel.
(2) Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.
(3) Remove and fill the fuel filter shell and element with fuel oil as in Step 2.
(4) Start the engine. Check the filter and strainer for leaks.

Note: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

69.4 Fuel Flow Test

The proper flow of fuel is required or satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter, as outlined in SM1-63-69.0.

69.5 Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings. a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder gaskets, or excessive exhaust back pressure, Also, the breather tube or crankcase ventilator should be checked for obstructions.

The crankcase pressure may be checked with a manometer. The manometer should be connected to the oil level dipstick opening in the cylinder block.

Check the readings obtained at various engine speeds with the Engine Operating Conditions in SM1-63-66.0.

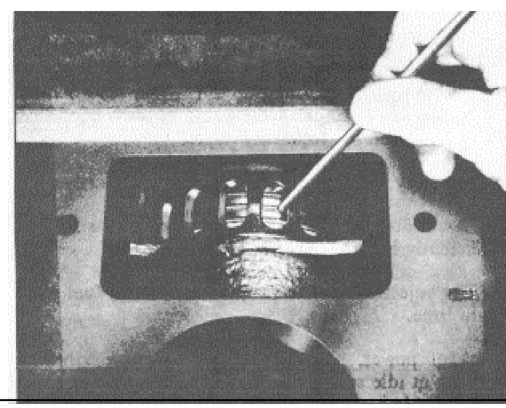


*Fig. 2*
*Inspecting Piston Rings*

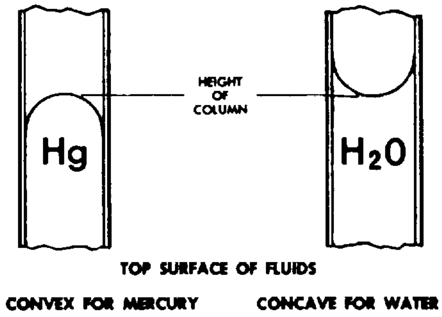



*Fig. 3*
*Comparison of Column Height for Mercury and Water Manometers*

Note: The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.

69.6 Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

The exhaust back pressure, measured in inches of mercury, may be checked with a manometer in the engine diagnosis test kit J 9531-01. Connect the manometer to an exhaust manifold (except on turbocharged engines) by removing the 1/8" pipe plug which is provided for that purpose. If there is no opening provided, drill an 11/32" hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8" pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the rear face of the turbine. The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds (at no-load) with the specifications in SM1-68-66.0.

69.7 Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen. Lack of power or black or grey exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

To check the air box pressure, connect a manometer to an air box drain tube.

Check the readings obtained at various speeds, with the Engine Operating Conditions in SM1-63-66.0.

69.8 Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction. Check the air inlet restriction with a water manometer connected to a fitting in the air intake ducting located 2" above the air inlet housing (non-turbocharged engines) or compressor inlet (turbocharged engines). When practicability prevents the insertion of a fitting at this point (non-turbocharged engines), the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the Engine Operating Conditions in SM163-66.0.

69.9 Proper Use of Manometer

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

| PRESSURE CONVERSION CHART | | |
|---|---|---|
| 1" Water | = | .0735" Mercury |
| 1" Water | = | .0361 Psi |
| 1" Mercury | = | 13.6000" Water |
| 1" Mercury | = | .4910 Psi |
| 1psi | = | 27.7000" Water |
| 1psi | = | 2.0360" Mercury |
| 1psi | = | 6.895 kPa |
| 1kPa | = | .145 psi |

*Table 3*

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 3) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired. Refer to Table 3 to convert the manometer reading into other units of measurement.

69.10 Trouble Shooting

The fuel pump is so constructed as to be inherently trouble free. By using clean water free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

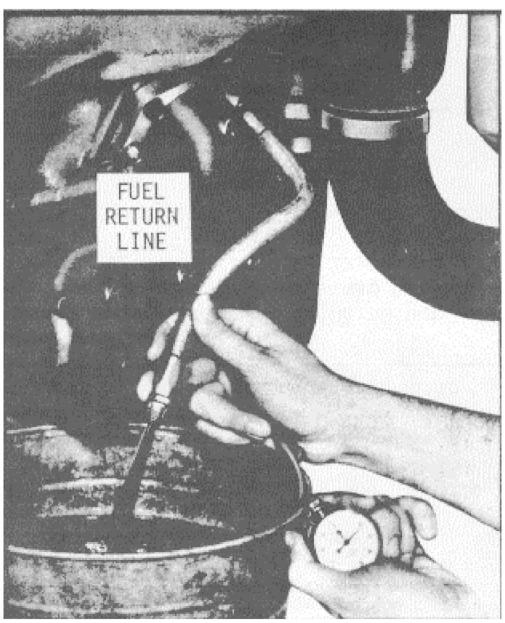



*Fig. 4*
*Measuring Fuel Flow from Fuel Return Manifold*

However, if the fuel pump fails to function satisfactorily, first check the level in the fuel tank, then make sure the fuel supply valve is open. Also check for external fuel leaks at the fuel line connections and filter gaskets. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through one of the pump flange drain holes, then crank the engine momentarily and note if the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds, or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may stick in a fully open or partially open position due to a small amount of grit or foreign material lodged between the relief valve and its bore or seat. This permits the fuel oil to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the fuel pump from the engine. Then remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. Reassemble the valve in the pump.

After the relief valve has been checked and the fuel pump reinstalled on the engine, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

69.11 Checking Fuel Flow

(1) Disconnect the fuel return line from the fitting at the fuel tank and hold the open end in a convenient receptacle (Fig. 4),

(2) For non-turbocharged engines, start and run the engine at 1200 rpm and measure the fuel flow for a period of one minute. A flow of approximately 0.8 gallon of fuel per minute is specified for 6V engines (with a fuel line restriction fitting having an .080" spill orifice).

For turbocharged engines (with a restriction fitting having a .070" spill orifice), start and run the engine at 1800 rpm and measure the fuel flow for a period of one minute. A flow of 1.4 gallons per minute is specified.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

(3) Immerse the end of the fuel line in the fuel in the container. Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.

(4) If the fuel flow is insufficient for satisfactory engine performance, then:

(a) Replace the element in the fuel strain er. Then start the engine and run it at 1200 rpm to check the fuel flow. If the flow is still unsatisfactory, perform step "b" below.

(b) Replace the element in the fuel filter. If the flow is still unsatisfactory, do as instructed in step "c".

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(c) Substitute another fuel pump that is know to be in good condition and again check the fuel flow. When changing a fuel pump, clean all of the fuel liners with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault and may be checked as follows:

(1) Run the engine at idle speed and cut out each injector, in turn, by holding the injector follower down with a screwdriver. If a cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out.

(2) Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.

(3) Hold a finger over the injector fuel outlet and crank the engine with the starter. A gush of fuel while turning the engine indicates an ample fuel supply; otherwise, the injector filters are clogged and the injector must be removed for service.

69.12 Trouble Shooting Charts

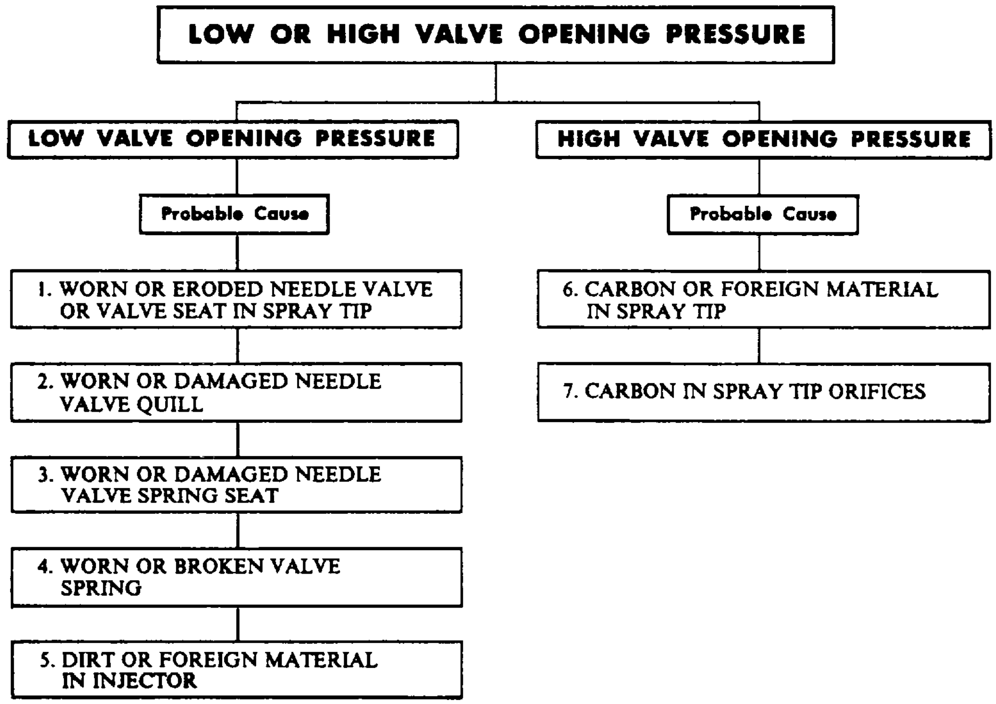



*Chart 1*

**Suggested Remedy**

(1) Replace the needle valve and tip assembly.
(2) Replace the needle valve and tip assembly.
(3) Replace the spring seat.
(4) Replace the valve spring.
(5) Disassemble the injector and clean the parts.
(6) Remove the carbon in the spray tip with tip reamer J 9464-01 which is especially designed and ground For this purpose.
(7) Check the size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

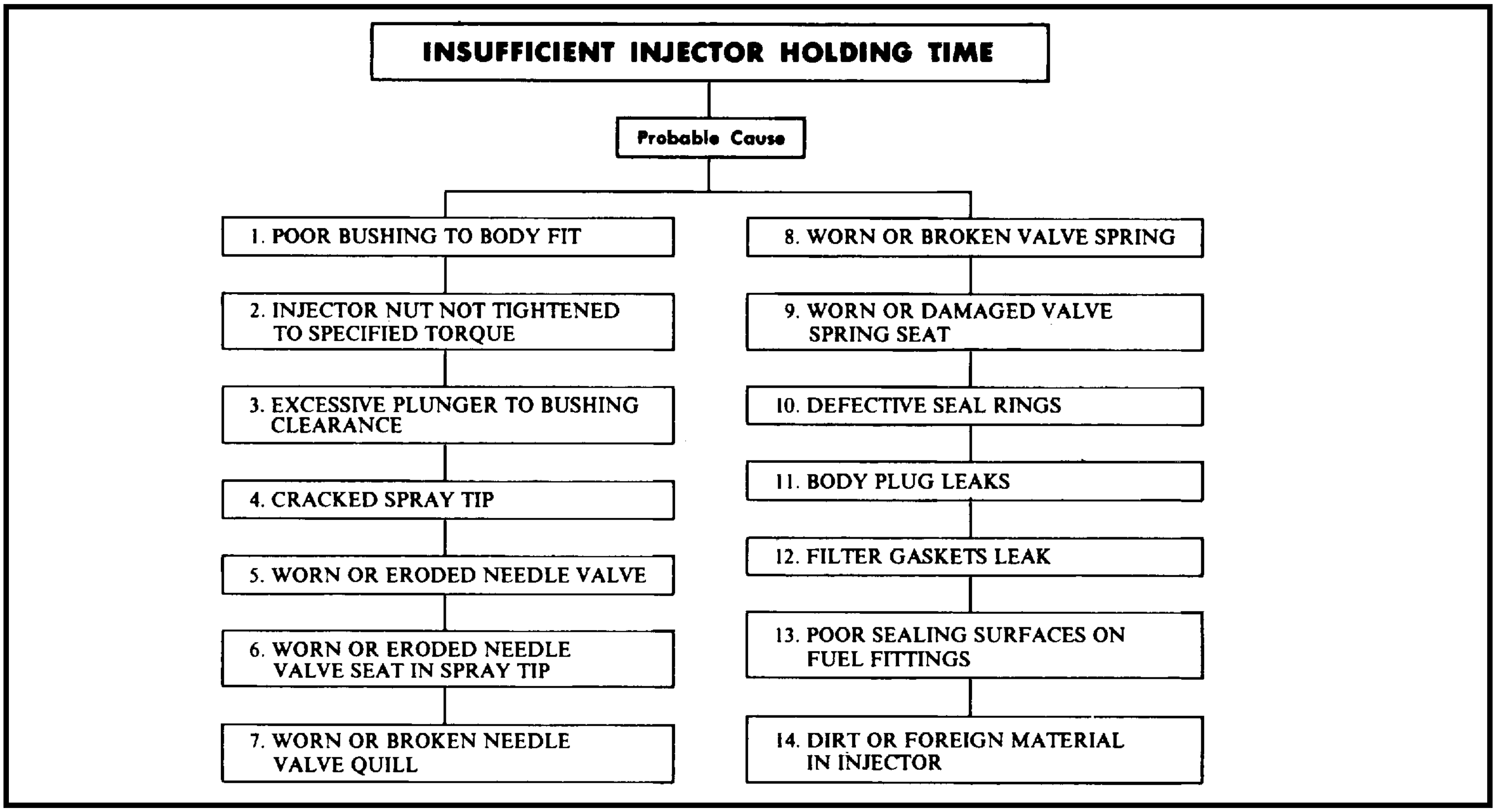



*Chart 2*

**SUGGESTED REMEDY**

(1) Lap the injector body.
(2) Tighten the nut to 75-85 ft-lbs (102-115 Nm) torque. Do not exceed the specified torque.
(3) Replace the plunger and bushing.
(4,5,6 & 7) Replace the needle valve and spray tip assembly.
(8) Replace the valve spring.
(9) Replace the valve spring seat.
(10) Replace the seal rings.
(11) Install new body plugs.
(12) Replace the filter cap gaskets and tighten the Filter caps to 65-75 ft-lbs (88-102 Nm) torque.
(13) Clean up the sealing surfaces or replace the filter caps, if necessary. Replace the filter if a cap is replaced.
(14) Disassemble the injector and clean all of the parts.

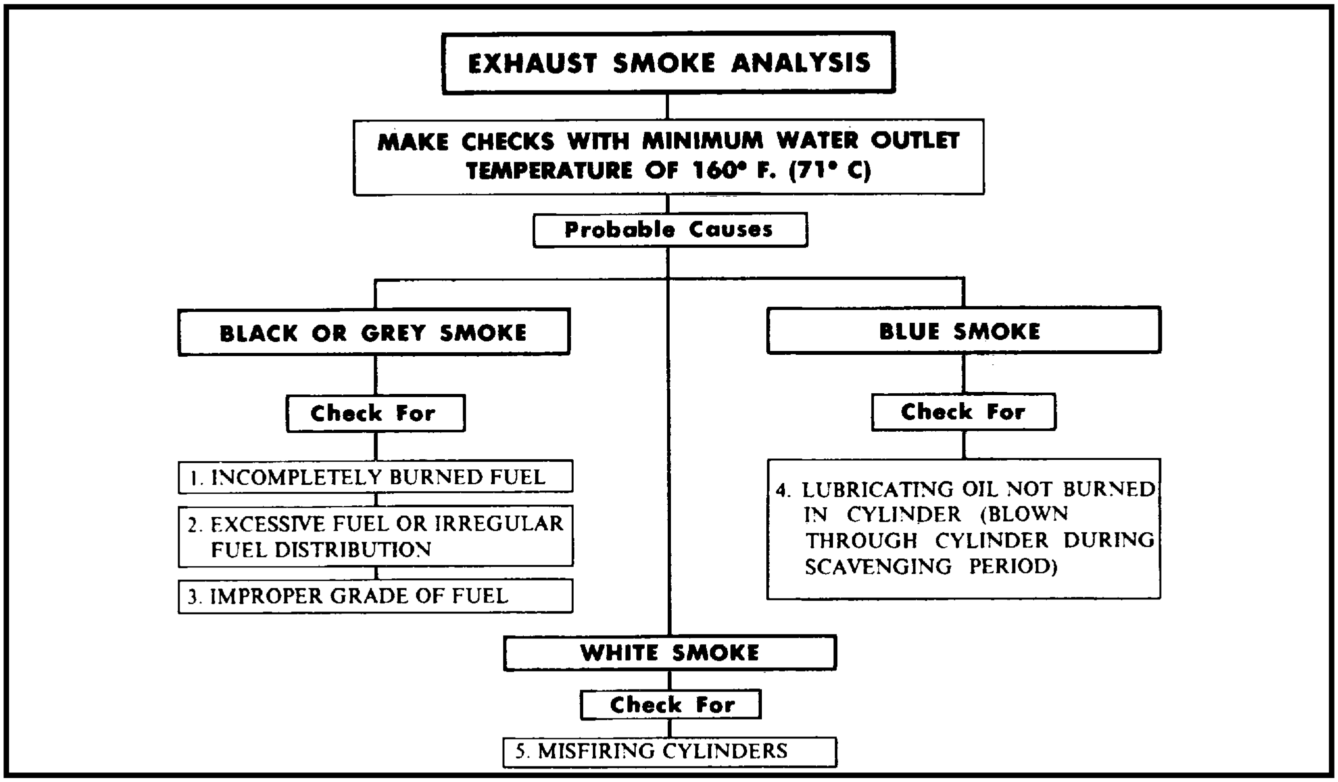



*Chart 3*

**SUGGESTED REMEDY**

(1) High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinder is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

(2) If the engine is equipped with a throttle delay, check for the proper setting, leaky check valve and restricted filling of the piston cavity with oil from the reservoir.

If the engine is equipped with a fuel modulator, check the cam to determine if it is stuck in the full fuel position. Verify tightness of the roller lever clamp on the control tube. Determine correctness (refer to SM1-63-34.0) of the installed fuel modulator piston spring and check if the spring has taken a permanent "set" or if the spring rate is too low.

The above affects only excessive acceleration smoke, but does not affect smoke at constant speed.

Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune-up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up. Avoid lugging the engine as this will cause incomplete combustion.

(3) Check for use of an improper grade of fuel. Refer to Fuel Oil Specifications in Operator's Manual.

(4) Check for internal lubricating oil leaks and refer to the High Lubricating Oil Consumption chart.

(5) Check for faulty injectors and replace as neces- sary,

Check for low compression and consult the Hard Starting chart.

The use of low octane fuel will cause this condition. Refer to Fuel Oil Specifications in Operator's Manual.

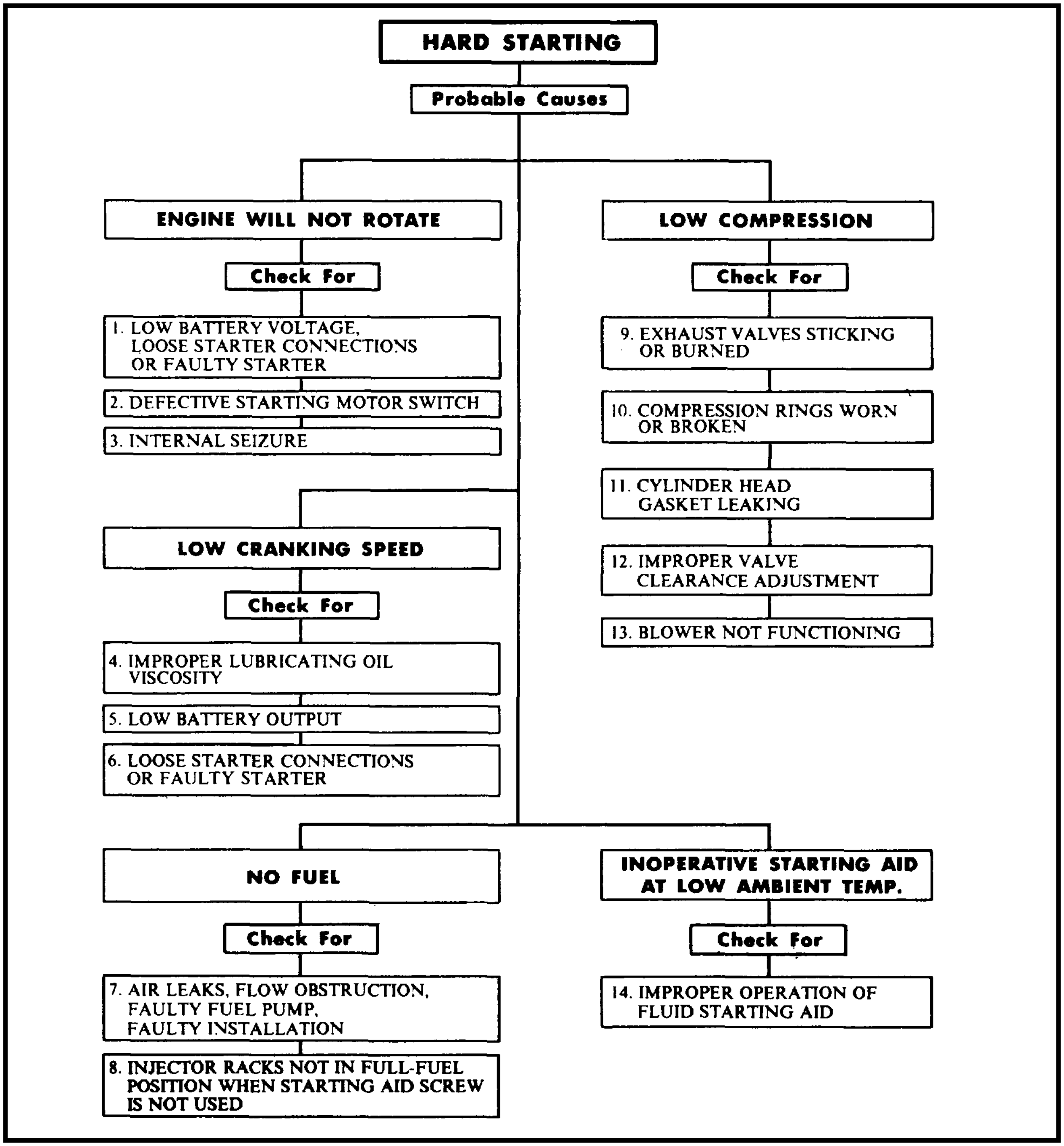

HARD STARTING
Probable Causes
ENGINE WILL NOT ROTATE
Check For
1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE
LOW CRANKING SPEED
Check For
4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER
NO FUEL
Check For
7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION WHEN STARTING AID SCREW IS NOT USED
LOW COMPRESSION
Check For
9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.
Check For
14. IMPROPER OPERATION OF FLUID STARTING AID

*Chart 4*

**Service Manual.**

SM1-63-69.0 Trouble Shooting

**HARD STARTING**
**SUGGESTED REMEDY**

(1) Refer to Items 2, 3 and 5 and perform the opera tion listed.
(2) Replace the starting motor switch.
(3) and crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.
(4) Refer to Lubricating Oil Specifications in Operator's Manual for the recommended grade of oil.
(5) Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.
Replace terminals that are damaged or corroded.

At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.
(6) Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.
(7) To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the No Fuel or Insufficient Fuel chart.
(8) Check for bind in the governor-to-injector link- age. Readjust the governor and injector controls if necessary.
(9) Remove the cylinder head and recondition the exhaust valves.
(10) Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.
(11) To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.
(12) Adjust the exhaust valve clearance.
(13) Remove the flywheel housing cover at the blower drive support. Then remove the snap ring and withdraw the blower drive shaft from the blower. Inspect the blower drive shaft and drive coupling. Replace the damaged parts. Bar the engine over. If the blower does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If visual distress is noted, remove the blower (see SM1-63-27.0).
(14) Operate the starting aid according to the instructions under Cold Weather Starting Aids.

SM1-63-69.0 Trouble Shooting

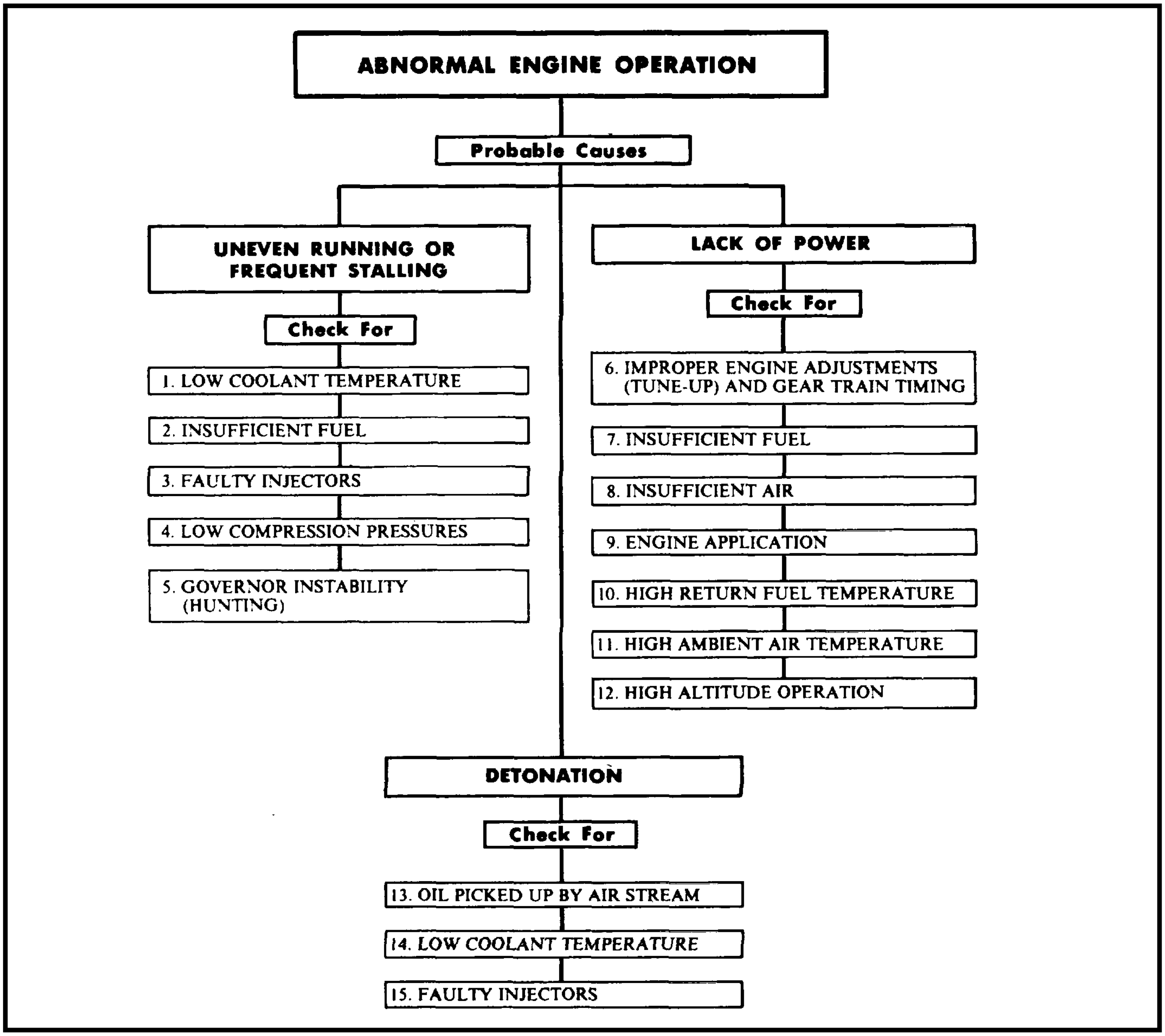



*Chart 5*

**Service Manual**

SM1-63-69.0 Trouble Shooting

## ABNORMAL ENGINE OPERATION

## SUGGESTED REMEDY

(1) Check the engine coolant temperature gauge and if the temperature does not reach 160-185°F (71-850C) while the engine is operating, consult the Abnormal Engine Coolant Temperature chart.

(2) Check engine fuel spill back and if the return is less than specified, consult the No Fuel or In- sufficient Fuel chart.

(3) Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

(4) Check the compression pressures within the cylinders and consult the Hard Starting chart if compression pressures are low.

(5) Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

(6) If the engine is equipped with a throttle delay, check for the proper setting, binding or burrs on the piston or bracket, and a plugged discharge orifice.

If equipped with a fuel modulator, determine if there is any interference with the roller assembly or roller contact with the cam at wide open throttle (WOT) position. Check for burrs and binding on the piston and bracket bore. Determine correctness (refer to SM1-63-68.0) of the installed fuel modulator spring and check if the spring has taken a permanent "set", or if the spring rate is too high.

Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

(7) Perform a Fuel Flow Test and, if less than the specified fuel is returning to the fuel tank, consult the No Fuel or Insufficient Fuel chart.

(8) Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair and replace faulty parts.

Check the compression pressures (consult the Hard Starting chart).

(9) Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

(10) Refer to Item 13 on Chart 4.

(11) Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size, for each 10°F (6 C) temperature rise above 90"F (32°C) will occur. Relocate the engine air intake to provide a cooler source of air.

(12) Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

(13) Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine. Check for a defective blower-to-block gasket. Replace the gasket, if necessary.

(14) Refer to Item 1 of this chart.

(15) Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

Clean the air box drain tubes and check valve (if used) to prevent accumulation that may be picked up by the air stream and enter the engine cylinders.
Inspect the check valve as follows:

(1) Disconnect the drain tube between the check valve and the air box drain tube nut at the air box cover.

(2) Run the engine and note the air flow through the valve at idle engine speed.

('3) If the check valve is operating properly, there will be no air flow at engine speeds above idle.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

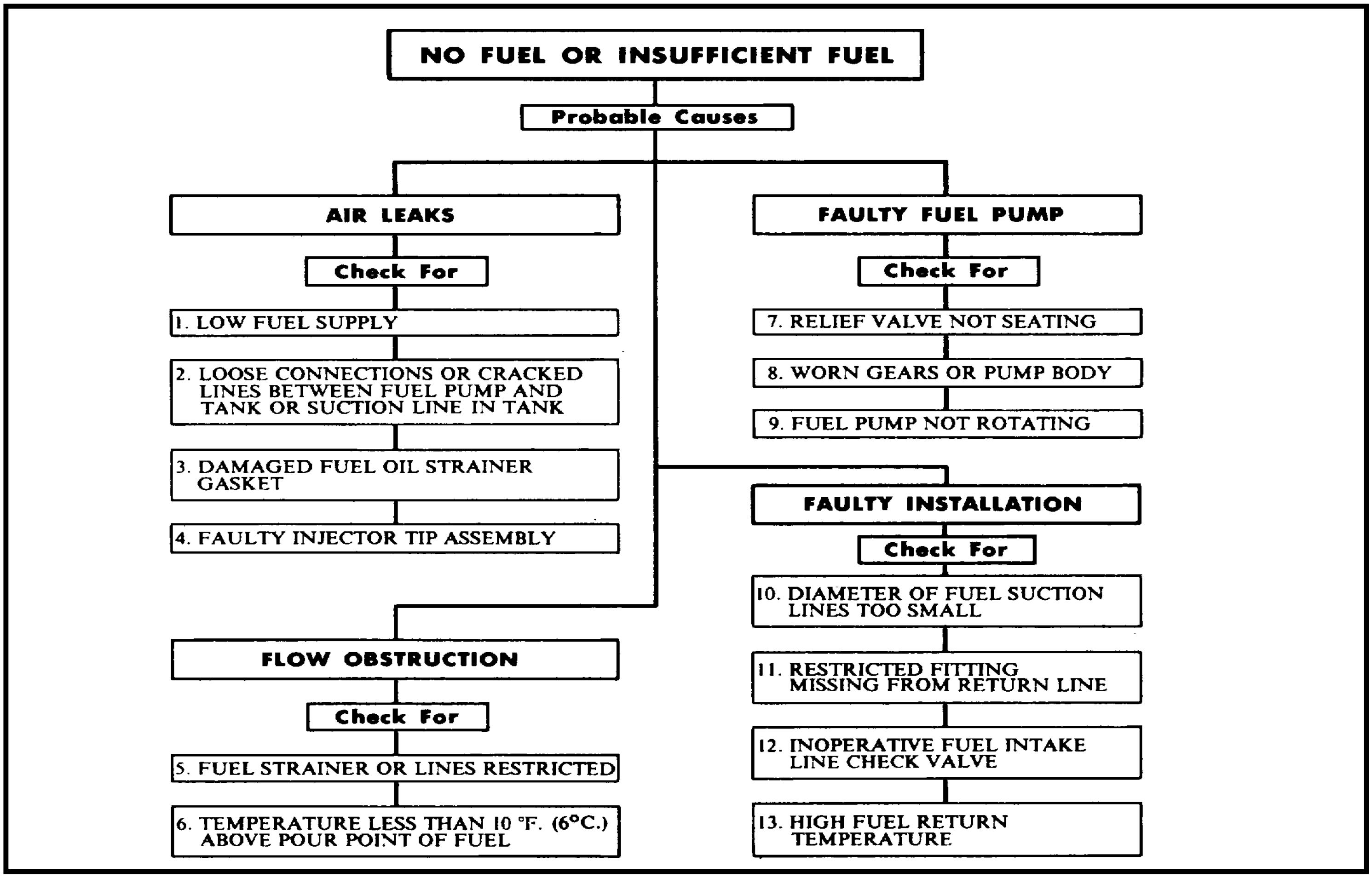



*Chart 7*

**SUGGESTED REMEDY**

(1) The fuel tank should be filled above the level of the fuel suction tube.
(2) Perform a Fuel Flow Test and, if air is present, tighten loose connections and replace cracked
(3) Perform a Fuel Flow Test and, if air is present, replace the fuel strainer gasket when changing the strainer element.
(4) Perform a Fuel Flow Test and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.
(5) Perform a Fuel Flow Test and replace the fuel strainer and filter elements and the fuel lines, if necessary.
(6) Consult the Fuel Oil Specifications for the recommended grade of fuel.
(7) Perform a Fuel Flow Test and if adequate, clean and inspect the valve seat assembly.
(8) Replace the gear and shaft assembly or the pump body.
(9) Check the condition of the fuel pump drive and blower drive and replace defective parts.
(10) Replace with larger tank-to-engine fuel lines.
(11) Install a restricted fitting in the return line.
(12) Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.
(13) Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150 F (66 C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

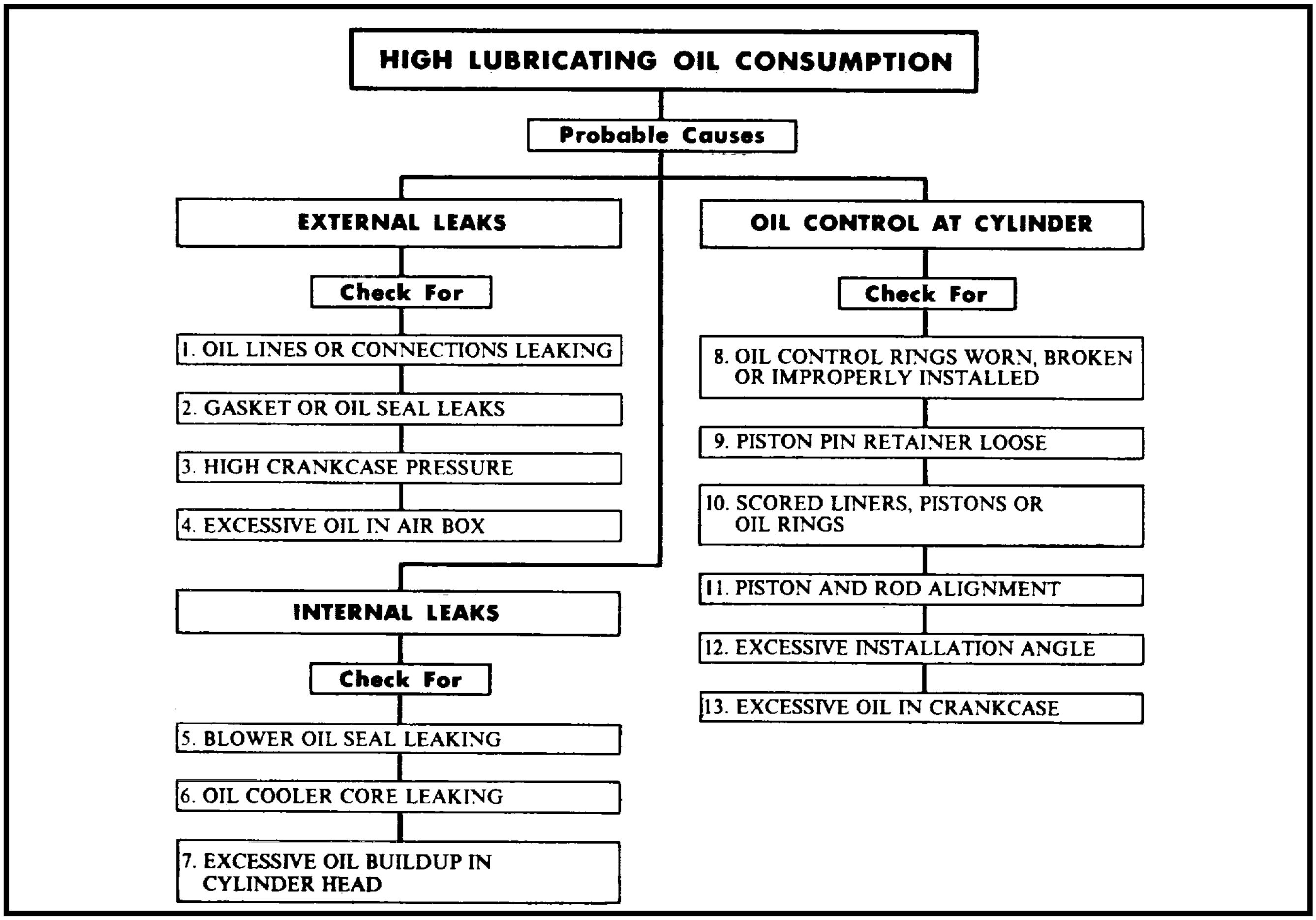



*Chart 8*

**SUGGESTED REMEDY**

(1) Tighten or replace the defective parts.
(2) Replace defective gaskets or oil seals.
(3) Refer to the Excessive Crankcase Pressure chart.
(4) Refer to the Abnormal Engine Operation chart.
(5) Remove the air inlet housing and inspect the blower end plates while the engine is operating. If oil is seen on the end plate radiating away from the oil seal, overhaul the blower.
(6) Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.
(7) Check for plugged or improper breather.
(8) Replace the oil control rings on the piston.
(9) Replace the piston pin retainer and defective parts.
(10) Remove and replace the defective parts.
(11) Check the crankshaft thrust washers for wear. Replace all worn and defective parts.
(12) Decrease the installation angle.
(13) Fill the crankcase to the proper level only.

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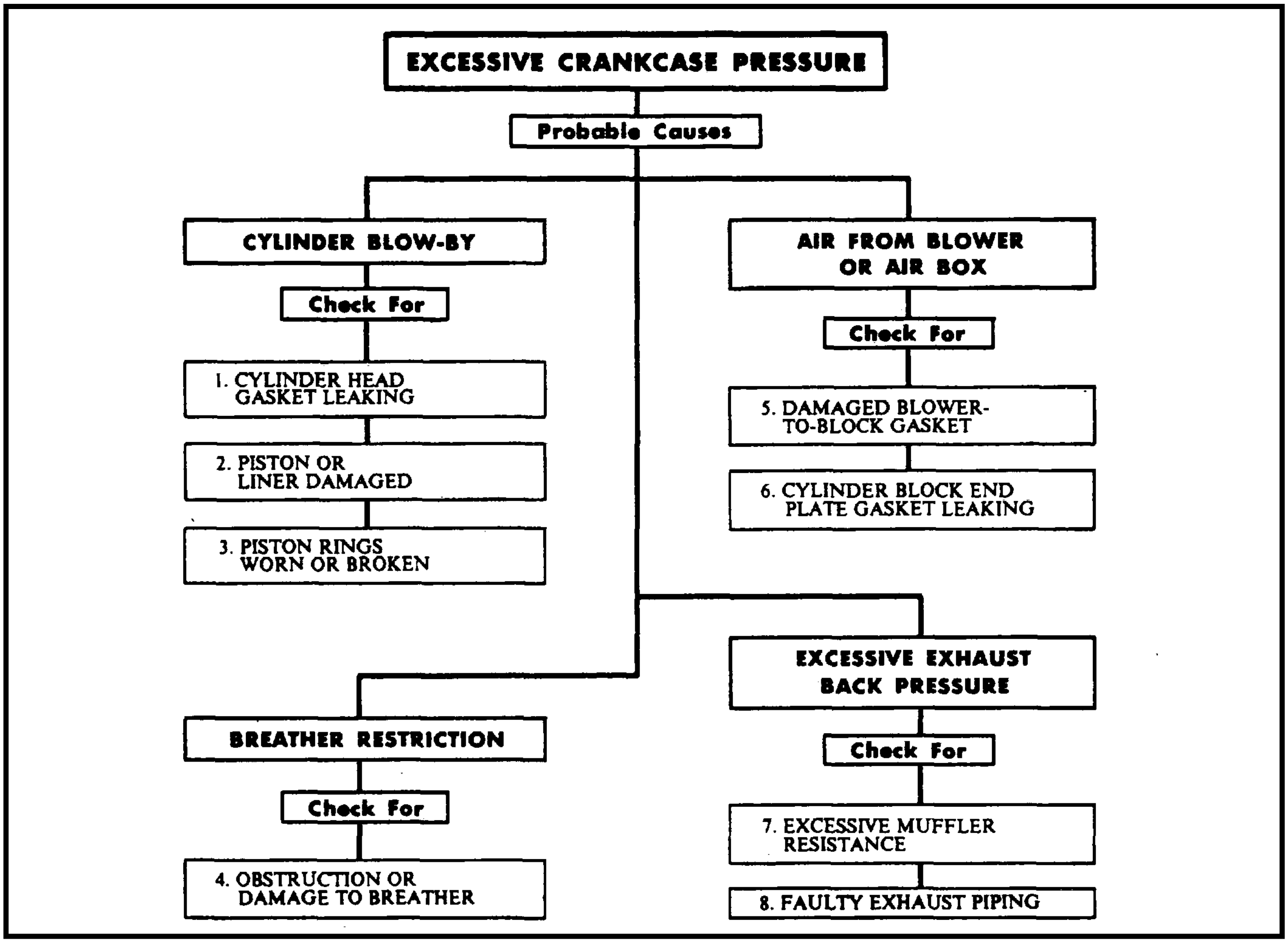


*Chart 9*

**SUGGESTED REMEDY**

(1) Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.
(2) Inspect the piston and liner and replace damaged parts.
(3) Install new piston rings.
(4) Clean and repair or replace the breather assembly.
too small, too long or has too many bends.

(5) Replace the blower-to-block gasket.
(6) Replace the end plate gasket.
(7) Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.
(8) Check the exhaust back pressure and install lar ger piping if it is determined that the piping is

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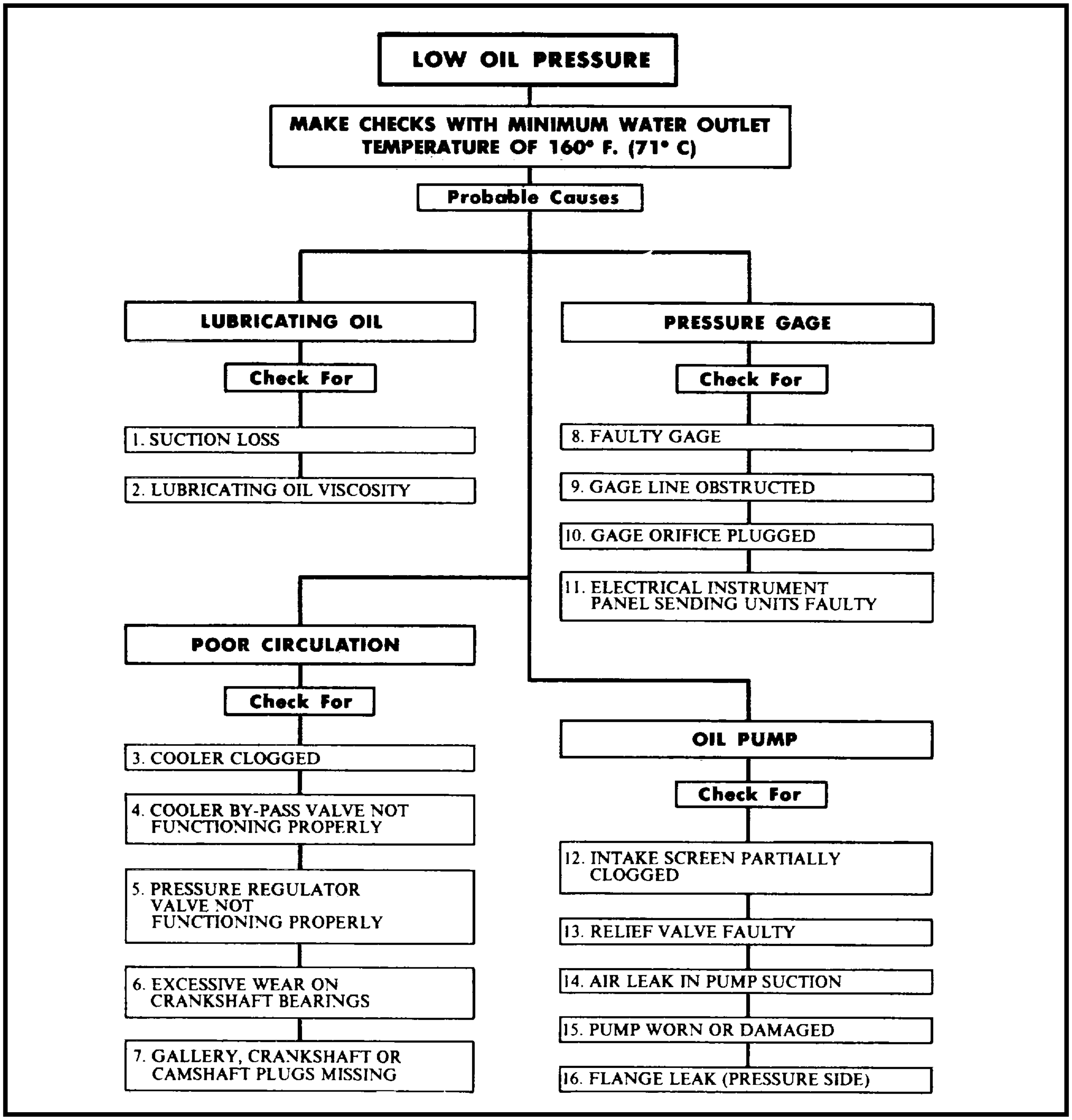


*Chart 10*

### LOW OIL PRESSURE

**SUGGESTED REMEDY**

(1) Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

(2) Consult the Lubricating Oil Specifications in Operator's Manual for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution. Refer to SM1-63-69.O.

(3) A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and lean the oil cooler core.

(4) Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

(5) Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

(6) Change the bearings. Consult the Lubricating Oil Specifications in Operator's Manual for the proper grade and viscosity of oil. Change the oil filters.

(7) Replace missing plugs.

(8) Check the oil pressure with a reliable gauge and replace the gauge if found faulty.

(9) Remove and clean the gauge line; replace it, if necessary.

(10) Remove and clean the gauge orifice.

(11) Repair or replace defective electrical equipment.

(12) Remove and clean the oil pan and oil intake screen. Consult the Lubricating Oil Specifications in Operator's Manual for proper grade and viscosity of oil. Change the oil filters.

(13) Remove and inspect the valve, valve bore and spring. Replace faulty parts.

(14) Disassemble the piping and install new gaskets.

(15) Remove the pump. Clean and replace defective parts.

(16) Remove the flange and replace the gasket.

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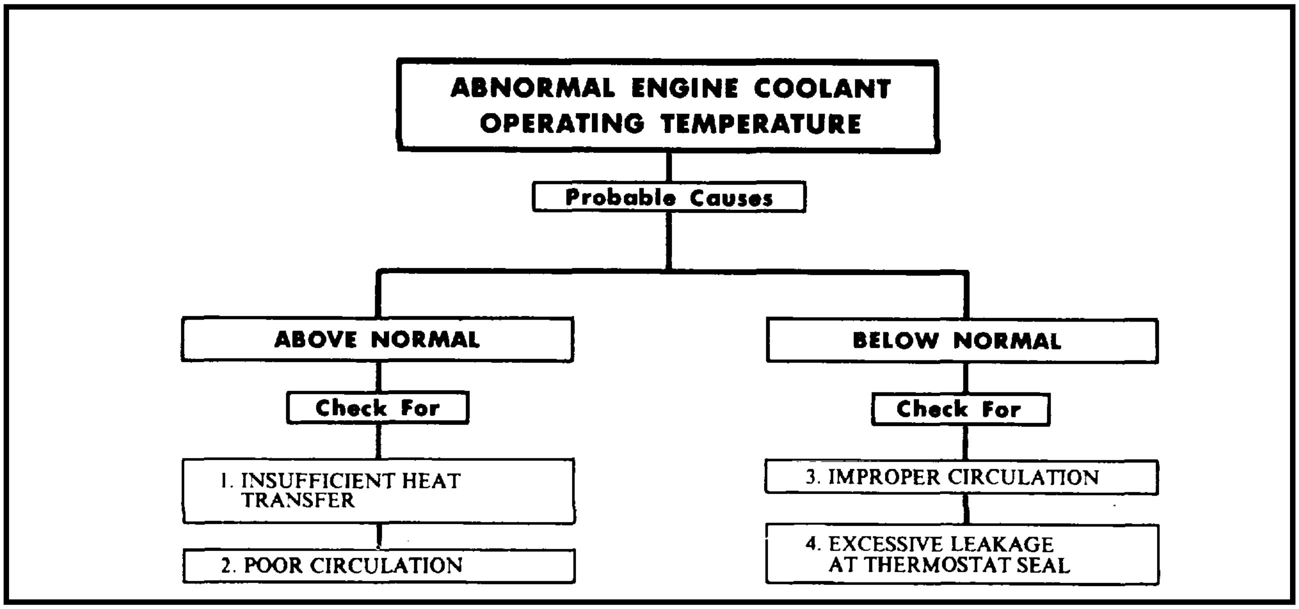


*Chart 11*

**SUGGESTED REMEDY**

(1) Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature-controlled fan or inoperative shutters.

(2) Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

(3) The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

(4) Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

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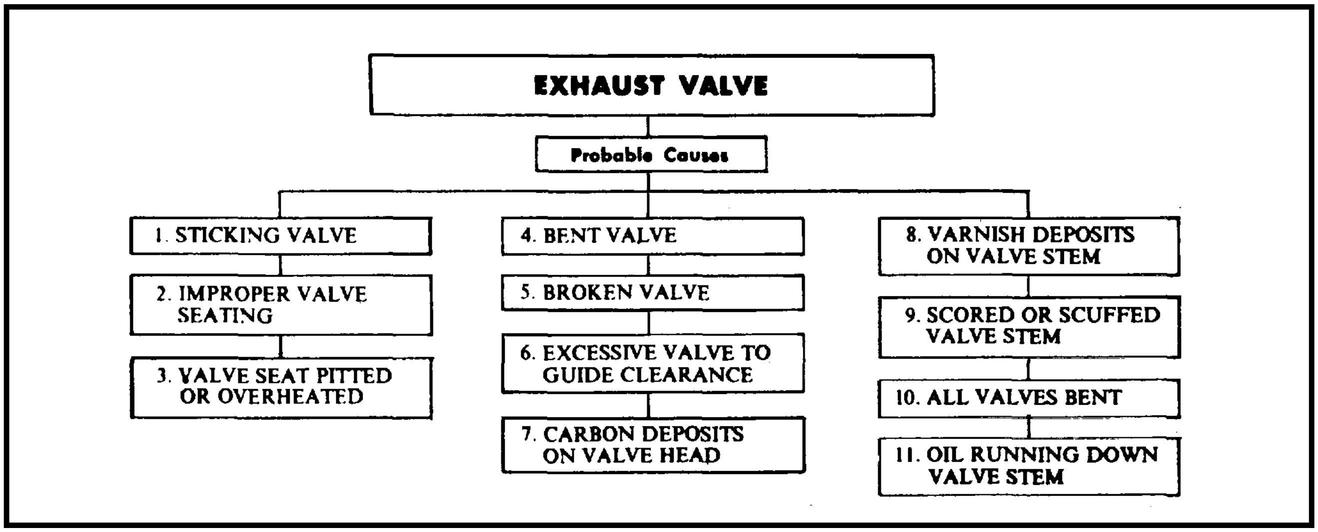


*Chart 12*

**SUGGESTED REMEDY**

(1) Check for carbon deposits, a bent valve guide, defective spring or antifreeze (glycol) in the lubricating oil. Replace a bent guide. Clean-up and reface the valve. Replace the valve if necessary.

(2) Check for excessive valve-to-guide clearance, bent valve guide or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary

(3) Check the operating conditions of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder-face valve if the operating conditions warrant.

(4) Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge (four valve head) or a defective spring. Check the valve guide, insert, cylinder head and piston for damage. Replace damaged parts.

(5) Check for excessive valve-to-buide clearance, a defective valve spring or etching of the valve stem at the weld. Improper valve clearance is also a cause of this type of failure. Check the guide, insert, cylinder head and piston for damage. Replace damaged parts.

(6) Replace a worn valve guide. Check and replace the valve, if necessary.

(7) Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.

(8) Check for a worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace.

(9) Check for a bent valve stem or guide, metal chips or dirt, or for lack of lubrication. lean up the valve stem with crocus cloth wet with fuel oil or replace the valve. Replace the guide. When installing a valve, use care in depressing the spring so that the spring cap DOES NOT scrape the valve stem.

(10) Check for a gear train failure or for improper gear train timing.

(11) Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

SM1-63-69.0 Trouble Shooting

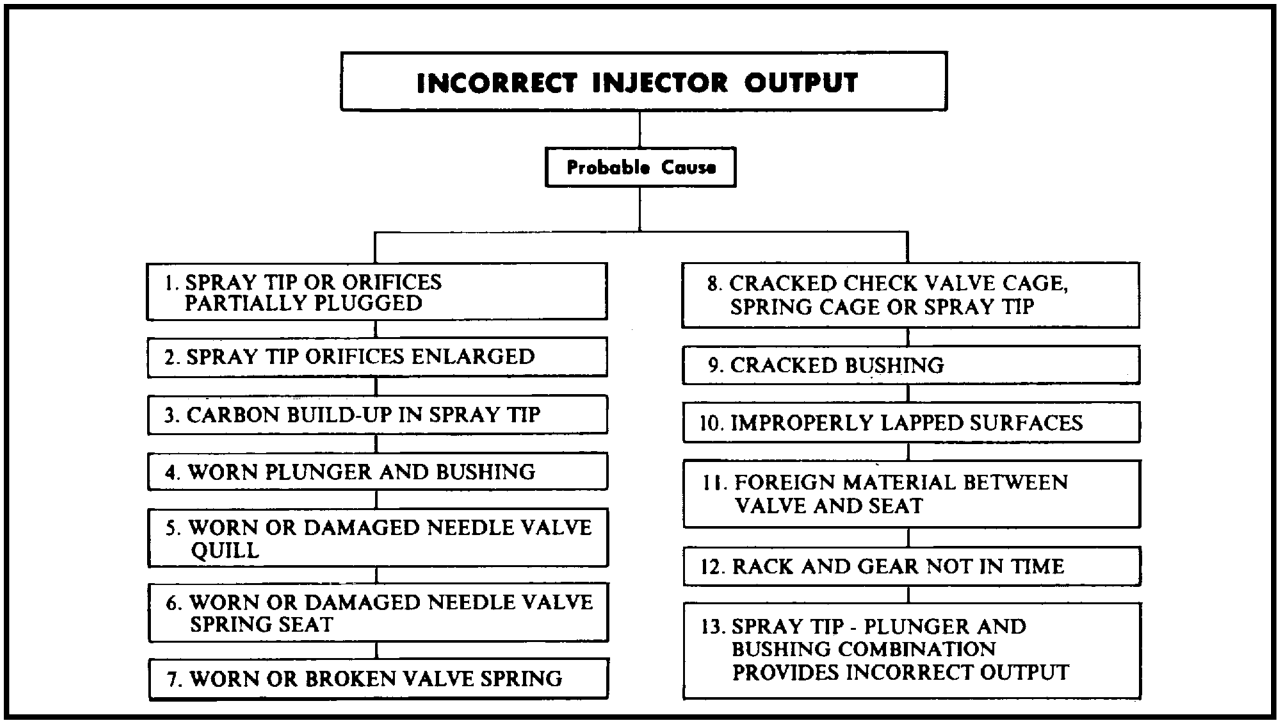


*Chart 13*

**SUGGESTED REMEDY**

(1) Clean the spray tip as outlined under Clean Injector Parts.
(2) Replace the needle valve and spray tip assembly.
(3) Clean the spray tip with tool J 1243.
(4) After the possibility of an incorrect or faulty spray tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

Note: The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the Fuel Output Check Chart, try changing the spray tip. However, use only a tip specified for the injector being tested.

(5) Replace the needle valve and spray tip assembly.
(6) Replace the spring seat.
(7) Replace the valve spring.
(8) Replace the cracked parts.
(9) Replace the plunger and bushing assembly.
(10) Lap the sealing surfaces.
(11) Disassemble the injector and clean the parts.
(12) Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth of the rack.
(13) Replace the spray tip and the plunger and bushing assembly to provide the correct output

SM1-63-69.0 Trouble Shooting

TURBOCHARGER

| CONDITION | PROBABLE CAUSE | SUGGESTED REMEDY |
|---|---|---|
| Noisy Operation Or Vibration | Wheel shaft bearings are not being lubricated. | Locate cause of loss of oil pressure and repair. Remove, disassemble and inspect turbo-charger for bearing damage. |
| | Improper clearance between turbine wheel and housing. | Remove, disassemble and inspect turbocharger. |
| | Leak in engine air intake or exhaust manifold. | Tighten all loose connections or replace exhaust manifold gaskets as necessary. |
| Engine Will Not Deliver Rated Power | Clogged air intake system | Check air cleaner and clean air intake ducts. |
| | Foreign material lodged in compressor or turbine wheels. | Remove, disassemble and clean turbocharger. |
| | Excessive dirt build-up in compressor. | Thoroughly clean compressor assembly. Clean air cleaner and check for leaks. |
| | Leak in engine air intake or exhaust manifold. | Tighten all loose connections or replace exhaust manifold gaskets as necessary. |
| | Rotating assembly bearing seizure. | Remove and overhaul turbocharger. |

SM1-63-70.0 Specifications

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently -replaced in engine overhaul work. For additional information, refer to the text.

70.1 Table of specifications, New Clearances and Wear Limits These limits also apply to oversize and undersize parts.

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Cylinder Block | | | |
| Block bore: | | | |
| Diameter upper pilot (A) | 5.3595" | 5.3620" | 5.3635" |
| Diameter (lower two seal ring lands (B) | 5.3365" | 5.3385" | 5.3395" |
| Diameter (water jacket (C) | .5.2160" | 5.2175" | 5.2135" |
| Diameter (water jacket (D) | .5.2160" | 5.2180" | 5.2185" |
| Out-of-round | | .0010" | |
| Taper (lower bore) 0010" | | | |
| Cylinder liner counterbore: | | | |
| Diameter | 5.5550" | 5.5600" | |
| Depth (standard) | .4755" | .4770" | |
| Depth (.015" deeper) | .4905" | .4920" | |
| Main bearing bore: | | | |
| Inside diameter (vertical axis) | 4.8120" | 4.8130" | |
| Top surface of block: | | | |
| Centerline of main bearing bore to top of block | 16.1840" | 16.1890" | |
| Flatness--transverse (all) | | | 0030" |
| Flatness--longitudinal | | | 0060" |
| Depth of counterbores (top surface): | | | |
| Cylinder head seal strip groove | .970" | .1070" | |
| Combination water and oil holes | .0840" | .0890" | |
| Cylinder Liner | | | |
| Outside diameter (upper surface) | 5.3577" | 5.3595" | |
| Outside diameter (seal ring surface) | 5.3347" | 5.3365" | |
| Outside diameter (lower surface) | 5.2142" | 5.2160" | |
| Inside diameter | 4.8390" | 4.8415" | |
| Out-of-round--inside diameter | | .0020" | .0025" |
| Taper--inside diameter | | .0015" | .0025" |
| Depth of flange BELOW block | .0418" | .0482" | |
| Variation in depth between adjacent liners | | .0015" | |
| Cross-Head Pistons and Rings V-92T Engines | | | |
| Piston crown: | | | |
| Saddle-to-crown distance: | | | |
| T piston (17:1 compr. ratio) | 2.7025" | 2.7095" | |
| Diameter: | | | |
| At top | 4.8104” | 4.8134” | |
| Below both compression rings | 4.8273" | 4.8303" | |
| Above and below seal ring groove | 4.4650" | 4.4750" | |
| Above and below bearing saddle | 3.2360" | 3.2370" | |
| Compression rings: | | | |
| Gap (top-fire ring) | .0250" | .0450" | .0600" |
| Gap (No. 2 and 3) | .0250" | .0450" | .0600" |
| *Top (Keystone fire ring) | .0010" | .0050" | .0070" |
| Clearance--ring- to-groove: | | | |
| No. 2 (rectangular section) | .0100" | .0130" | .0220" |
| No. 3 (rectangular section) | .0040" | .0070" | .0130" |

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| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Seal Ring: | | | |
| Gap (in skirt counterbore) | .0020" | .0170" | |
| Clearance | .0005" | .0030" | .0040" |
| Piston skirt: | | | |
| +Diameter (includes tin) | 4.8318" | 4.8340" | |
| C1 Clearance--skirt-to-l i ner | .0051" | .0097" | .0120" |
| Seal ring bore | 4.5000" | 4.5030" | |
| Piston pin bore | 1.5025" | 1.5035" | 1.5040" |
| Oil Control rings: | | | |
| Gap (two rings in lower groove-turbo) | .0100" | .0250" | .0430" |
| Gap (two rings in upper groove--turbo) | .0070" | .0170" | .0350" |
| Clearance | .0015" | .0055" | .0080" |
| Piston Pins (Cross-Head Piston) | | | |
| Diameter | 1.4996" | 1.5000" | 1.4980" |
| Slipper Bearing (bushing) | | | |
| Thickness at center | .0870" | .0880" | .0860" |
| in piston | .0005" | .0105" | .0120" |
| Clearance (edge of bushing to groove | | | |

* Measured with Keystone fire ring flush with outside diameter of piston crown.
\+ Diameter above and below the piston pin may be 4.8280".

| Crankshaft | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Journal diameter--main bearing | 4.4985" | 4.5002" | |
| Journal diameter--conn. rod bearing | 2.9985" | 3.0002" | |
| Journal out-of-round | | .0005" | .0005" |
| Journal taper | | .0004" | .0004" |
| @Runout on journals--total indicator reading: | | | |
| 6V-92 crankshaft (mounted on No. 1 and No. 4 journals): | | | |
| At No. 2 and No. 3 journals | | .0020" | |
| Thrust washer thickness | .1190" | .1220" | |
| End play (end thrust clearance) | .0040" | .0110" | .0180" |
| Connecting Rod Bearing: | | | |
| Inside diameter (vertical axis) | 3.0010" | 3.0030 | |
| Bearing-to-journal clearance | .0008" | .0045" | .0045" |
| Bearing thickness 90° from parting line | .1240" | .1245" | |
| Main Bearings | | | |
| Inside diameter (vertical axis) | 4.5016" | 4.5040" | |
| Bearing-to-journal clearance | .0014" | .0055" | .0055" |
| Bearing thickness 90° from parting line | .1545" | .1552" | |
| Camshaft | | | |
| Diameter (at bearing journals): | | | |
| Front and rear | 1.4970" | 1.4975" | |
| Center and intermediate | 1.4980" | 1.4985" | |
| Runout at center bearing (when mounted on end bearings) | | .0020" | |
| End thrust | .0040" | .0120" | .0180" |
| Thrust washer thickness | .1190" | .1-20" | |

@ Runout tolerance given for guidance when regrinding crankshaft. When the runout on adjacent journals is in the opposite direction, the sum must not exceed .003" total indicator reading. When the runout on adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. When high spots of the runout on adjacent journals are at right angles to each other, the sum must not exceed .004" total indicator reading or .002" on each journal.

**Service Manual**

SM1-63-70.0 Specifications

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| **Camshaft Bearings** | | | |
| Inside diameter: | | | |
| Front and rear | 1.5000" | 1.5010" | |
| Center and intermediate 1.5010" | 1.5030" | 1 | |
| Clearance—bearing-to-shaft: | | | |
| Front and rear | .0015" | .0040" | .0060" |
| Center and intermediate | .0025" | .0050" | .0090" |
| Outside diameter | | | |
| Front and rear | 2.1880" | 2.1885" | |
| Center and intermediate | 2.1840" | 2.1860" | |
| Diameter of cylinder block bore | 2.1875" | 2.1885" | |
| Clearance—bearing-to-block: | | | |
| Front and rear | .0010" press. | .0005" loose | |
| Intermediate | .0015" | .0045" | |
| **Camshaft Gears** | | | |
| Inside diameter | 1.1865" | 1.1875" | |
| Clearance--gear-to-shaft | .0015" press. | .0000" | |
| Backlash | .0020" | .0080" | .0100" |
| **Idler Gear** | | | |
| Backlash | .0020" | .0080" | .0100" |
| Pre-load--Variation on pull 2 lbs. 11 oz. | 1/2 lb. | | |
| **Crankshaft Timing Gear** | | | |
| Inside diameter | 5.2490" | 5.2510" | |
| Clearance--gear-to-shaft | .001" press. | .001" loose | |
| Backlash | .0020" | .0080" | .0100" |
| **Blower Drive Gear (Turbo-engine) -2.1:1 ratio** | | | |
| Backlash | 0020" | .0080" | .0100" |
| Inside diameter (support bushing) | 1.6260" | 1.6265" | |
| Hub diameter (at bearing) | 1.6240" | 1.6250" | |
| Hub-to-support bushing clearance | .0010" | .0025" | .0050" |
| Thrust washer thickness | .2350" | .2450" | |
| Thrust bearing thickness | .0590" | .0610" | |
| End thrust | .0050" | .0100" | .0120" |
| **Blower Drive Step-up Gear** | | | |
| Backlash | .0020" | .0080" | .0100" |
| Left Bank Accessory Drive Gear - 2.1:1 ratio | | | |
| Backlash | .0020" | .0080" | .0100" |
| Inside diameter (support bushing) | 1.6260" | 1.6265" | |
| Hub diameter (at bearing) | 1.6240" | 1.6250" | |
| Hub-to-support bushing clearance | .0010" | .0025" | .0050" |
| Thrust washer thickness | .2350" | .2450" | |
| Thrust bearing thickness | .0590" | .0610" | |
| End thrust | .0050" | .0100" | .0120" |
| **Cylinder Head** | | | |
| Flatness—transverse | | | .0040 " |
| Flatness--longitudinal | | | .0055" |
| Distance between top deck and fire deck | 3.5560" | 3.5680" | 3.5360" |
| Water nozzles | .0040" recess | Flush | |
| Cam follower bores | 1.0620" | 1.0630" | 1.0650" |
| Exhaust Valve Insert Counterbore: | | | |
| Diameter | 1.4400" | 1.4410" | |
| Depth | .3395" | .3505" | |

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| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Exhaust Valve Seat Inserts | | | |
| Outside diameter ..... | 1.4415" | 1.4425" | |
| Seat width ..... | .0781" | .0781" | .0781" |
| Valve seat runout ..... | .0020" | .0020" | |
| Exhaust Valves | | | |
| Stem diameter ..... | 3100" | .3108" | .3090" |
| Valve head-to-cylinder head: | | | |
| 30° ..... | 012" recess | .006" protr. | |
| Valve Guides | | | |
| Height above cylinder head ..... | 6700" | .7100" | |
| Diameter--inside ..... | 3125" | .3135" | .3140" |
| Clearance--valve-to-guide ..... | 0017" | .0035" | .0050" |
| Valve Bridge Guides | | | |
| Height above cylinder head ..... | 2.0400" | 2.0400" | |
| Rocker Arms and shafts | | | |
| Diameter--rocker shaft ..... | 8735" | .8740" | |
| Diameter--inside (rocker arm bushing) ..... | 8750" | .8760" | |
| Clearance--shaft-to-bushing ..... | 0010" | .0025" | .0040" |
| Cam Followers | | | |
| Diameter ..... | 1.0600" | 1.0610" | |
| Clearance--fol lower-to-head ..... | .0010" | .0030" | .0060" |
| Rollers and Pins: | | | |
| Clearance--pin-to-bushing ..... | .0013" | .0021" | .010" Horiz. |
| Side clearance--roller to follower ..... | .0110" | .0230" | .0230" |
| Blower | | | |
| Backlash (timing gears) ..... | .0005" | .0025" | .0040" |
| Oil Seal (below end plate surface) ..... | .0020" | .0080" | |
| Oil Strainer (below end plate surface) ..... | .0000" | .0150" | |
| Dowel Pin (projection beyond inside face of front end plate) ..... | .3200" | | |
| Dowel Pin (projection beyond inside face of rear end plate) ..... | .3200" | | |
| Clearances: | | | |
| Rotor to end plate (gear end) ..... | .0070" | | |
| Rotor to end plate (front end 6V) ..... | .0120" | | |
| Rotor to housing (inlet side) ..... | .0150" | | |
| Rotor to housing (outlet side) ..... | .0040" | | |
| edge of L.H. helix rotor ..... | .0040" | .0080" | .0080" |
| Leading edge of R.H. helix rotor to trailing edge of L.H. helix rotor ..... | .0100" | | |
| TV81 Turbocharger (Airesearch) | | | |
| End play--rotating shaft ..... | .0030" | .0100" | |
| Radial movement--rotating shaft ..... | .0040" | .0050" | |
| Turbine wheel shaft journal bearing: | | | |
| Inside diameter ..... | 6268" | .6272" | |
| Outside diameter ..... | | 9782" | .9787" |
| Journal diameter--turbine wheel shaft ..... | 6250" | .6254" | |
| Bearing bore--center housing: | | | |
| Inside diameter ..... | 9827" | .9832" | .9842" |
| Black Plate Seal Bore: | | | |
| Inside diameter ..... | 6875" | .6885" | .6895" |
| Thrust Collar: | | | |
| Thickness ..... | 2990" | .3000" | .2970" |
| Bore--Inside diameter ..... | 3754" | .3758" | .3778" |
| Thrust Spacer: | | | |
| Outside diameter ..... | | 6715" | .6725" .6705" |
| Ring groove width ..... | 0685" | .0695" | .0715" |

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Thrust Washer, Inboard: | | | |
| Thickness | | 0900" | .0920" |
| Compressor Wheel Bore: | | | |
| Inside diameter | .3736" | .3739" | .3749" |

## 70.2 STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

| THREAD SIZE | 260M BOLTS TORQUE (ft-lb) | 260M BOLTS TORQUE (Nm) | THREAD SIZE | 260M BOLTS TORQUE (ft-lb) | 260M BOLTS TORQUE (Nm) |
|---|---|---|---|---|---|
| 1/4 -20 | 5-7 | 7-9 | 1/4 -20 | 7-9 | 10-12 |
| 1/4 -28 | 6-8 | 8-11 | 1/4 -28 | 8-10 | 11-14 |
| 5/16-18 | 10-13 | 14-18 | 5/16-18 | 13-17 | 18-23 |
| 5/16-24 | 11-14 | 15-19 | 5/16-24 | 15-19 | 20-26 |
| 3/8 -16 | 23-26 | 31-35 | 3/8 -16 | 30-35 | 41-47 |
| 3/8 -24 | 26-29 | 35-40 | 3/8 -24 | 35-39 | 47-53 |
| 7/16-14 | 35-38 | 47-51 | 7/16-14 | 46-50 | 62-68 |
| 7/16-20 | 43-46 | 58-62 | 7/16-20 | 57-61 | 77-83 |
| 1/2 -13 | 53-56 | 72-76 | 1/2 -13 | 71-75 | 96-102 |
| 1/2 -20 | 62-70 | 84-95 | 1/2 -20 | 83-93 | 113-126 |
| 9/16-12 | 68-75 | 92-102 | 9/16-12 | 90-100 | 122-136 |
| 9/16-18 | 80-88 | 109-119 | 9/16-18 | 107-117 | 146-159 |
| 5/8 -11 | 103-110 | 140-149 | 5/8 -11 | 137-147 | 186-200 |
| 5/8 -18 | 126-134 | 171-181 | 5/8 -18 | 168-178 | 228-242 |
| 3/4 -10 | 180-188 | 244-254 | 3/4 -10 | 240-250 | 325-339 |
| 3/4 -16 | 218-225 | 295-305 | 3/4 -16 | 290-300 | 393-407 |
| 7/8 - 9 | 308-315 | 417-427 | 7/8 - 9 | 410-420 | 556-569 |
| 7/8 -14 | 356-364 | 483-494 | 7/8 -14 | 475-485 | 644-657 |
| 1. -8 | 435-443 | 590-600 | 1 - 8 | 580-590 | 786-800 |
| 1 -14 | 514-521 | 697-705 | 1 -14 | 685-695 | 928-942 |

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

| Grade Identification Marking On Bolt Head | GM Number | SAE Grade Designation | Nominal Size Diameter (inch) | Tensile Strength Min. (psi) |
|---|---|---|---|---|
| None | GM 255-M | 1 | No. 6 thru 1 1/2 | 60,000 |
| None | GM 260-M | 2 | No. 6 thru 3/4<br>over 3/4 to 1 1/2 | 74,000<br>60,000 |
| Bolts and Screws | GM280-M | 5 | No. 6 thru 1<br>over 1 to 1 1/2 | 120,000<br>105,000 |
| Hex Head Sems Only | GM 275-M | 5.1 | No. 6 thru 3/8 | 120,000 |
| Bolts and Screws | GM 290-M | 7 | 1/4 thru 1 1/2 | 133,000 |
| Bolts and Screws | GM 300-M | 8 | 1/4 thru 1 1/2 | 150,000 |
| Bolts and Screws | GM 455-M | None | No. 6 thru 1 1/2 | 55,000 |

**BOLT IDENTIFICATION CHART**

## 70.3 EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

| APPLICATION | THREAD SIZE | TORQUE (ft-lb) | TORQUE (Nm) |
|---|---|---|---|
| Cam follower guide bolt | 1/4 -20 | 12-15 | 16-20 |
| Injector control shaft bracket bolt | 1/4 -20 | 10-12 | 14-16 |
| Air box cover bolt | 5/16-18 | 8-12 | 11-16 |
| Blower drive gear support to thrust collar bolt | 5/16-18 | 16-21 | 22-28 |
| Oil pan bolts (lower pan) | 5/16-18 | 10-12 | 14-16 |
| Exhaust valve bridge adjusting screw locknut | 5/16-24 | 20-25 | 27-34 |
| Idler gear bearing retainer bolts | 5/16-24 | 24-29 | 33-39 |
| Camshaft end bearing bolts | 3/8 -16 | 35-40 | 47-54 |
| Engine front cover bolts | 3/8 -16 | 25-30 | 34-41 |
| Flywheel housing bolts | 3/8 -16 | 25-30 | 34-41 |
| Front accessory drive pulley bolt | 3/8 -16 | 25 | 34 |
| jacket plug) | 3/8 -16 | 20-25 | 27-34 |
| Front end plate bolt (two bolts into water | | | |
| Idler gear hub and spacer bolts | 3/8 -16 | 40-45 | 54-61 |
| Injector clamp bolts | 3/8 -16 | 20-25 | 27-34 |
| Oil pan bolts (upper) | 3/8-16 | 15-20 | 20-27 |
| Water manifold cover bolt | 3/8 -16 | 20-25 | 27-34 |
| Accessory drive disc to camshaft gear bolt | 3/8 -24 | 45-50 | 61-68 |
| Accessory drive hub to camshaft gear bolt | 3/8 -24 | 45-50 | 61-68 |
| Balance weight-to-camshaft gear bolt | 3/8 -24 | 15-18 | 20-24 |
| Blower drive gear hub to'spring plate bolt | 3/8 -24 | 40-45 | 54-61 |
| Blower drive step-up gear bolt | 3/8 -24 | 50-60 | 68-81 |
| Blower drive support bolts and nuts (T engines) | 3/8 -24 | 25-30 | 34-41 |
| Camshaft intermediate bearing lock screw | 3/8 -24 | 15-20 | 20-27 |
| Exhaust manifold outlet flange nuts (brass) | 3/8 -24 | 20-25 | 27-34 |
| Flywheel housing bolts (threaded into plug nuts) | 3/8 -24 | 25-30 | 34-41 |
| Flywheel housing cover (small cover) stud nut | 3/8 -24 | 20-25 | 27-34 |
| Flywheel housing cover (small hole) bolt | 3/8 -24 | 30-35 | 41-47 |
| Fuel pipe nuts | 3/8 -24 | 12-15 | 16-20 |
| Left bank accessory drive support bolts and nuts | 3/8 -24 | 25-30 | 34-41 |
| Water manifold cover bolts | 3/8 -24 | 20-25 | 27-34 |
| Flywheel housing cover (large hole) bolt | 7/16-14 | 30-35 | 41-47 |
| Generator drive bearing retaining bolt | 7/16-14 | 30-35 | 41-47 |
| Generator drive oil seal retaining bolt | 7/16-14 | 30-35 | 41-47 |
| Rear accessory drive pulley bolt | 7/16-14 | 35 | 47 |
| Connecting rod nut | 7/16-20 | 60-70 | 81-95 |
| Cross-head piston pin to conn. rod bolt | 7/16-20 | 55-60 | 75-81 |
| Exhaust manifold nuts | 7/16-20 | 30-35 | 41-47 |
| Fuel manifold connector nuts | 7/16-20 | 30-35 | 41-47 |
| Fuel manifold connectors (steel washer) | 7/16-20 | 40-45 | 54-61 |
| Alternator drive bearing retaining bolt | 1/2 -13 | 30-35 | 41-47 |
| Alternator drive oil seal retaining bolt | 1/2 -13 | 30-35 | 41-47 |
| Crankshaft front cover bolts | 1/2 -13 | 80-90 | 108-122 |
| Flywheel housing bolts | 1/2 -13 | 90-100 | 122-136 |
| Flywheel housing cover (large hole) bolt | 1/2 -13 | 30-35 | 41-47 |
| Idler gear hub and dummy hub bolt | 1/2 -13 | 80-90 | 108-122 |
| @Rocker shaft bolts | 1/2 -13 | 90-100 | 122-136 |
| Engine drive shaft flexible coupling bolt | 1/2 -20 | 96-115 | 130-156 |
| **Camshaft gear bolt (right-bank - 300M) | 9/16-18 | 180-190 | 244-258 |
| **Flywheel bolts (See SM1-63-14.0) | 9/16-18 | | |
| **Flywheel bolts (Undercut-See SM1-63-14.0) | 9/16-18 | | |

EXCEPTIONS TQ STANDARD BOLT AND NUT TORQUE SPECIFICATIONS (CONT'D.)

| APPLICATION | THREAD SIZE | TORQUE (ft-lb) | TORQUE (Nm) |
|---|---|---|---|
| **Cylinder head bolts | 11/16-11 | 250-269 | 339-352 |
| ***in bearing bolts (**assembly**) | 116-11 | 259-260 | 339-352 |
| **Main bearing bolts (boring) | 11/16-11 | 230-240 | 312-325 |
| Accessory drive pulley nut | 3/4 -16 | 120-140 | 163-190 |
| Crankshaft end bolt | 1-14 | 290-310 | 393-421 |
| Camshaft nut | 1-1/8-18 | 300-325 | 407-441 |
| Blower drive gear hub nut (T engines) | 1-7/16 -16 | 50-60 | 68-81 |
| Left bank accessory drive gear nut | 1-7/16 -16 | 60-60 | 68-81 |

@ 75-85 ft-lb (102-115 Nm) torque on the two bolts attaching load limit or power control screw bracket (if used) to the rocker arm shaft bracket.
* Lubricate at assembly With International Compound No 2, or equivalent (refer to Parts Catalog or Microfiche, Section 12,8000A),

| APPLICATION | THREAD SIZE | TORQUE (ft-lb) | TORQUE (Nm) |
|---|---|---|---|
| Control tube bracket bolts | 1/4 -20 | 10-12 | 14-16 |
| Variable speed spring lever Set Screw | 5/l16-24 | 12-15 | 16-2 |
| Governor weight shaft bearing retaining bolt | 5/16-24 | 15-19 | 2-26 |
| Injector clamp bol t | 3/8 -16 | 20-25 | 27-34 |
| Ailr inlet housing adaptor-to-blower housing bolt | 3/8 -16 | 16-20 | 22-27 |
| Air inlet housing-to-adaptor bolts 3wtG-ttt | 8 -16 | 16-20 | 22-27 |
| Fuel pipe nut | 3/8-24 | 12-15 | 16-20 |
| Blower end plate-to-cylinder block bolts | 7/16-14 | 40-45 | 54-61 |
| *Rocker arm bracket bolts | 1/2 -13 | 90-100 | 122-136 |
| Injector filter caps | 5/8-24 | 65-75 | 88-102 |
| Injector Nut | 15/16-24 | 75-85 | 102-115 |

* 75-85 ft-lb (102-115 Nm) torque on the two bolts attaching a load limit or power control screw bracket (if used) to the rocker arm shaft brackets,

| APPLICATION | THREAD SIZE | TORQUE (ft-lb) | TORQUE (Nm) |
|---|---|---|---|
| Blower drive coupling-to-rotor ger bolt | 5/16-24 | 2-25 | 22-27 |
| Air inlet housing adaptor-to-blower housing bolt | 3/8 -16 | 16-20 | 54-61 |
| Air inlet housing-to-4daptor bolt | 3/8 -16 | 16-20 | 22-27 |
| .lower end plate-tg-cylinder block bolt | 7/16-14 | 40-45 | 54-51 |
| Fuel pump drive disc bolt | 1/2 -2 | 55-65 | 75-8 |
| Blower rotor gear retainer bolt (large bearing blower) | 1/2 -20 | 100Q-11 | 136-150 |

| APPLICATION | THREAD SIZE | TORQUE (ft-lb) | TORQUE (Nm) |
|---|---|---|---|
| Backpl4te to center housing bolts | 5/16-18 | 90-110 | 20-12 |
| Compressor wheel locknut | 3/8 -24 | +125-150 | 14-17 |
| Compressor wheel locknut | 7/16-20 | +125-150 | 14-17 |
| Turbine houlng to center houssing bolts | 5/16-18 | 100-110 | 11-13 |
| "V" band oupling locknut | 1/4 -28 | 40-60 | 5-7 |

+Refer to 5Mo-63-43Q0 for additional lnstructions,

| APPLICATION | THREAD SIZE | TORQUE (ft-lb) | TORQUE (Nm) |
|---|---|---|---|
| Oil pan bolts | 3/16-18 | 19-12 | 14-16 |
| Oil pan bolts | 318 -16 | 10-12 | 14-27 |
| Lubricsatng oil filter center stud | 5/8 -18 | 50-6Q | 58-81 |
| Oil pan drain plug (nylon washer) | 18mm | 25-35 | 34-47 |

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS (CONT'D)

| APPLICATION | THREAD SIZE | TORQUE (ft-lb) | TORQUE (Nm) |
|---|---|---|---|
| Flange mounted alternator adaptor nut | 3/8 -24 | 15-20 | 20-27 |
| Tachometer drive cover bolt | 7/16-14 | 30-35 | 41-47 |
| Tachometer drive cover bolt | 1/2 -13 | 30-35 | 41-47 |
| Tachometer drive shaft (blower) | 1/2 -20 | 55-65 | 75-88 |
| Starting motor switch mounting nut | 5/8 -32 | ++ | ++ |
| Starting motor attaching bolts (alumn. flywheel) housing) | 5/8 -11 | 85-95 | 115-129 |
| ++36-48 in-lb (4-5.5 Nm). | | | |
| Water manifold nut | 3/8 -24 | 20-25 | 27-34 |
| Water pump impeller retaining nut | 7/16-20 | 45-50 | 61-68 |

70.4 STANDARD PIPE PLUG TORQUE SPECIFICATIONS
Use sealing compound on plugs without gaskets or teflon.

| NPTF SIZE THREAD | TORQUE (ft-lb) | (Nm) | NPTF SIZE THREAD | TORQUE (ft-lb) | (Nm) |
|---|---|---|---|---|---|
| 1/8 | 10-12 | 14-16 | 3/4 | 33-37 | 45-50 |
| 1/4 | 14-16 | 19-22 | 1 | 75-85 | 102-115 |
| 3/8 | 18-22 | 24-30 | 1-1/4 | 95-105 | 129-143 |
| 1/2 | 23-27 | 31-37 | 1-1/2 | 110-130 | 150-177 |

70.5 SPECIAL PLUG TORQUE SPECIFICATIONS

| APPLICATION | *PLUG | ASSEMBLY |
|---|---|---|
| Oil gallery plug | 3/8" Dryseal PTF thread | +Assemble with max. 0.0625" protrusion from |
| Cylinder head (side) | 3/8-16" | Assemble flush to 0.0625" protrusion from |
| Cylinder head (end) | 3/4" Dryseal PTF-SAE short | Flush to 0.1250" recessed |
| Core hole plug (air box floor) | 2-1/2"-16 | 230-270 ft-lb (312-366 Nm) torque |
| Oil drain plug (nylon washer) | 18mm | 25-35 ft-lb (34-47 Nm) torque |

*Apply sealing compound to plugs used without gaskets or teflon.
+After installation, a 2187" rod inserted in oil line must pass inner face of plug.

70.6 STUD TORQUE SPECIFICATIONS

| APPLICATION | TORQUE (ft-lb) | TORQUE (Nm) |
|---|---|---|
| Exhaust manifold stud | 25-40 | 34-54 |
| Water manifold cover stud | 10-25 | 14-34 |

| TOOL NAME | TOOL NO. |
|---|---|
| Cylinder Block | |
| Adaptor (1-5/8" diameter plugs) | J 21850 |
| Aftercooler adaptor plug remover and installer | J 28711 |
| Alignment Tool | J 21799 |
| Alignment Tool | J 21799 |
| Cup Plug Installer (2-1/2" diameter) | J 24597 |
| Cylinder Block Head Bolt Depth Gauge | J 26244 |
| Cylinder Block Head Bolt Hole Plug Tool Kit | J 26620 |
| Cylinder Block Line Boring Tool | J 29005 |
| Cylinder Block Tap | J 25384 |
| Cylinder Diameter Checking Gauge | J 5347-01 |
| Cylinder Hone Set (2 1/2" to 5 3/4") | J 5902-01 |
| Dial Bore Gauge Master Setting Fixture | J 23059-01 |
| Dial Indicator Set | J 22273 |
| Diesel Engine Parts Dolly | J 6387 |
| Engine Overhaul Stand | J 6837-01 |
| Engine Overhaul Stand Adaptor | J 8601-01 |
| Handle | 7079-2 |
| Master Ring Gauge for Block Bore | J 24564 |
| Special Plug Remover (dry cylinder block) | J 21996-01 |
| Special Plug Remover | J 23019 |
| Cylinder Head | |
| Cam Follower Service Fixture | J 5840-01 |
| Cylinder Head Bolt Hole Cleanout Tap | J 25384 |
| Cylinder Head Guide Studs (Set of 2) | J 24748 |
| Cylinder Head Holding Plate Set | J 3087-01 |
| Cylinder Head Lifting Fixture | J 22062-01 |
| Engine Barring Tool | J 22582 |
| Feeler Gauge Set (.0015" to .015") | J 3172 |
| Feeler Stock (.0015") | J 23185 |
| Fuel Line Nut Wrench | J 8932-01 |
| Injector Fuel Hole Brush | J 8152 |
| Injector Tube Swaging Tool | J 28611 |
| Push Rod Remover (Set of 3) | J 3092-01 |
| Slide Hammer | J 2619-01 |
| Spring Tester | J 22738-02 |
| Valve Bridge Holding Fixture | J 21772 |
| Valve Bridge Guide Remover (Broken) | J 7453 |
| Valve Bridge Guide Remover Set | J 7091-01 |
| Valve Bridge Guide Installer | J 7482 |
| Valve Guide Cleaner | J 5437 |
| Valve Guide Installer (Machined) | J 21520 |
| Valve Guide Remover | J 6569 |
| Valve Seat Dial Gauge | J 8165-2 |
| Valve Seat Grinder | J 8165-1 |
| Valve Seat Grinder Adaptor Set | J 24566 |
| Valve Seat Insert Installer | J 24357 |
| Valve Seat Insert Remover | J 23479-15 |
| Valve Seat Insert Remover Collet | J 23479-13 |
| Valve Spring Checking Gauge | J 25076-01 |
| Valve Spring Compressor | J 7455 |
| Water Nozzle Installer (intermediate) | J 24857 |
| Crankshaft | |
| Crankshaft Front Oil Seal Installer | J 9783 |
| Crankshaft Rear Oil Seal Expander | J 4239 |
| Crankshaft Rear Oil Seal Expander Stud Set | J 25002 |
| Crankshaft Rear Oil Seal Installer | J 21112 |
| Crankshaft Oil Seal Expander | J 22425 |
| Crankshaft Oil Seal Expander (oversize seal) | J 8682 |
| Dial Indicator Set | J 5959-01 |
| Driver Handle | J 3154-1 |
| Driver Handle- | J 8092 |
| Engine Barring Tool | J-22582 |
| Flywheel Housing Alignment Studs | J 1927-01 |

| TOOL NAME | TOOL NO. |
|---|---|
| Micrometer Ball Attachment | J 4757 |
| Universal Bar Type Puller | J 24420 |
| Flywheel | |
| Flywheel Lifting Fixture | J 25026 |
| Flywheel Lifting Fixture | J 250263- |
| Flywheel Lifting Tool | J 6361-01 |
| Oil Seal Removing and Replacing Tool Set | J 3154-04 |
| Slide Hammer Set | J 5901-01 |
| Flywheel Housing | |
| Flywheel Housing Aligning Studs (Set of 4) | J 1927-01 |
| Flywheel Housing Concentricity Gauge Set | J 9737-01 |
| Piston, Connecting Rod and Cylinder Liner | |
| Connecting Rod Bolt Hole Reamer | J 28460 |
| Connecting Rod Holding Fixture | J 7632 |
| Cylinder Liner Master Ring Gauge | J 24564 |
| Cylinder Hone Set (2 1/2" to 5 3/4" range) | J 5902-01 |
| Cylinder Liner Hold-Down Tool | J 24565-02 |
| Cylinder Liner Remover Set | J 24563 |
| Dial Bore Gauge Setting Fixture | J 23059-01 |
| Dial Indicator Set | J 24898 |
| Feeler Gauge Set | J 3172 |
| Micrometer Ball Attachment | J 4757 |
| Piston Crown Identification Gauge | J 25397 |
| Piston Pin Alignment Tool | J 24285 |
| Piston Pin Retainer Installer | J 23762 |
| Piston Pin Retainer Leak Detector | J 23987-01 |
| Piston Ring Compressor | J 24227 |
| Piston Ring Remover and Installer | J 8128 |
| Piston to Liner Feeler Gauge Set | J 5438-01 |
| Seal Ring Compressor | J 24226 |
| Camshaft | |
| Accessory Drive Hub Oil Seal Aligning Tool | J 21166 |
| Balance Weight Cover Oil Seal Installer | J 9791 |
| Camshaft Gear Puller | J 1902-01 |
| Camshaft Gear Puller Adaptor Plate Set | J 6202-01 |
| Camshaft and Oil Pump Gear Replacer | J 1903 |
| Dial Indicator and Attachment Set | J 5959-01 |
| Puller Adaptor | J 7932 |
| Slide Hammer | J 6471-02 |
| Spring Scale | J 8129 |
| Universal Bar Type Puller | J 24420 |
| Injector Tools | |
| Buffing Wheel (brass wire) | J 7944 |
| Fuel Pipe Socket | J 8932-01 |
| Injector Auxiliary Tester | J 22640 |
| Injector Body Reamer | J 21089 |
| Injector Bushing Inspectalite | J 21471 |
| Injector Calibrator | J 22410 |
| Injector Carbon Remover Set | J 9418 |
| Injector Holding Fixture | J 22396 |
| Injector Service Tool Set | J 23435-02 |
| Body Brush | J 8152 |
| Nut Socket Wrench | J 4983-01 |
| Nut Tip Seat Reamer | J 4986-01 |
| Rack Hole Brush | J 8150 |
| Spray Hole Cleaner Vise | J 4298-1 |
| Spray Tip Driver and Bushing Cleaner | J 1291-02 |
| Tip Cleaner | J 24838 |
| Wire Sharpening Stone | J 8170 |
| Injector Tag Remover and Installer | J 24767 |
| +Injector Test Oil | J 26400 |
| Injector Tip Cleaner Set | J 9464-01 |

+ Available in 5, 15, 30 and 55 gallons.

**Service Manual** SM1-63-71.0 Service Tools

| TOOL NAME | TOOL NO. |
|---|---|
| Injector Tip Concentricity Gauge | J 5119 |
| Injector Tester | J 9787 |
| Lapping Block Set | J 22090 |
| Lapping Compound | J 230381 |
| Methyl Ethyl Ketone Solvent (one gallon) | J 8257-01 |
| Polishing Stick Set | J 22964 |
| Spray Tip Cleaning Wire (.007" dia. holes) | J 21462-01 |
| Spray Tip Flow Gauge | J 25600 |
| Spray Tip Gauge | J 9462-02 |
| Spring Tester | J 22738-02 |
| Injector Tube Tools | |
| Cylinder Head Holding Plate Set | J 3087-01 |
| Cylinder Liner Depth Gauge | J 22273 |
| Injector Protrusion Gauge | J 25521 |
| Injector Tube Service Tool Set | J 22525 |
| Fuel Pump Tools | |
| Fuel Pump Tool Set | J 1508-03 |
| Fuel Pump Wrench | J 4242 |
| Fuel System Primer | J 5956 |
| Mechanical Governor Tools | |
| Control Link Operating Lever Bearing Remover and Installer | J 8985 |
| Governor Cover Bearing Installer | J 21068 |
| Governor Cover Bearing Remover and Installer | J 21967-01 |
| High Speed Spring Retainer and Installer | J 5345-5 |
| Variable Speed Governor Spring Housing Bearing Installer Set | J 9196 |
| Blower | |
| Blower Alignment Tool | J 24619 |
| Blower Clearance Feeler Set | J 1698-02 |
| Blower Drive Cam Installer | J 1471 |
| Blower Drive Coupling Aligning Tool Set | J 21834-01 |
| Blower Service Tool Set | J 6270-05 |
| Turbocharger (Ai research) | |
| Dial Indicator Set (magnetic base) | J 7872 |
| Turbocharger Inlet Shield | J 26554 |
| Turbocharger Aftercooler | |
| Adaptor Plug Remover and Installer | J 25275 |
| Miscellaneous Tools | |
| Bar Type Gear Puller | J 24420 |
| Oil Pump Drive Shaft Gear Installer (6) | J 22397 |
| Oil Pump Driven Shaft Gear Installer (6) | J 22398 |
| Oil Pump Driving Gear Installer (6) | J 22285 |
| Spring Tester | J 22738-02 |
| Strap Wrench (spin-on filter) | J 24783 |
| Handle | J 7079-2 |
| Oil Seal Installer | J 8501 |
| Pliers | J 4646 |
| Puller | J 24420 |
| Thermostat Seal Installer | J 8550 |
| Water Pump Bearing and Gear Installer | J 25257 |
| Water Pump Seal Remover Set | J 22150-01 |
| Slide Hammer | J 5901-01 |
| Puller Set | J 5901 |
| Tachometer Drive Alignment Tool Set | J 23068 |

## 72.1 Adjustment of the Torque Limiting Device

(a) Apply air pressure to the torque limiter air cylinder.
(b) Insert adjusting tool 21-7-004 (.411" setting) between the injector body and the shoulder on the injector rack clevis (as shown in Fig. 2), of the injector nearest the torque limiting assembly.
(c) Hold the injector control tube in full throttle position. This should cause the injector rack to move toward the full-fuel position and against the adjusting tool.
(d) Check the adjustment of the injector control rack with the adjusting tool. Lengthen or shorten air cylinder link to obtain correct adjustment.
(e) Remove air pressure from the torque limiter cylinder and check the following:
(1) Injector racks go to full throttle position.
(2) All of the throttle control linkage is absolutely free so governor can properly control engine speed.

**CAUTION**

Damage To The Engine Could Result If Step (e) Is Not Complied With.

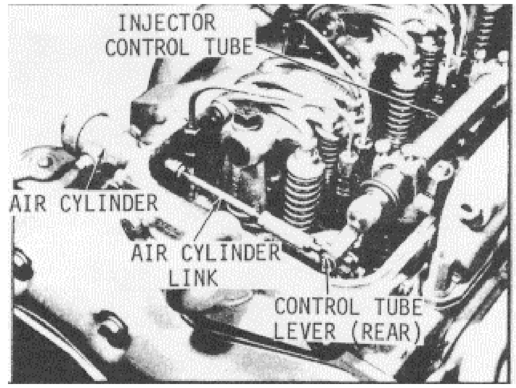



*Fig. 1 Torque Limiting Device*

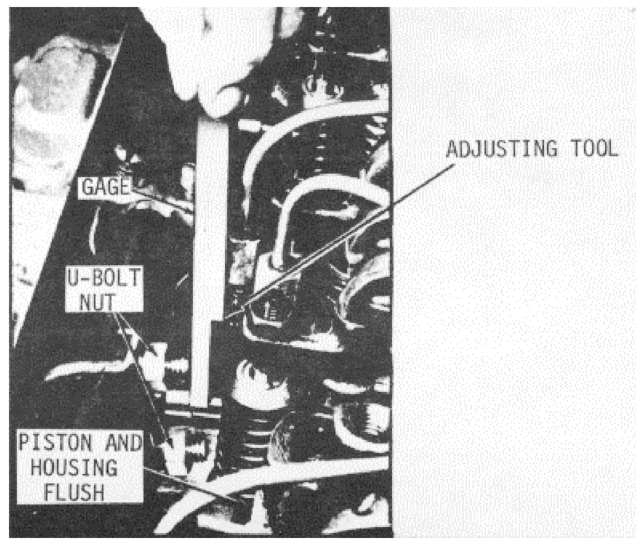
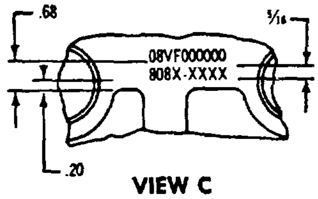
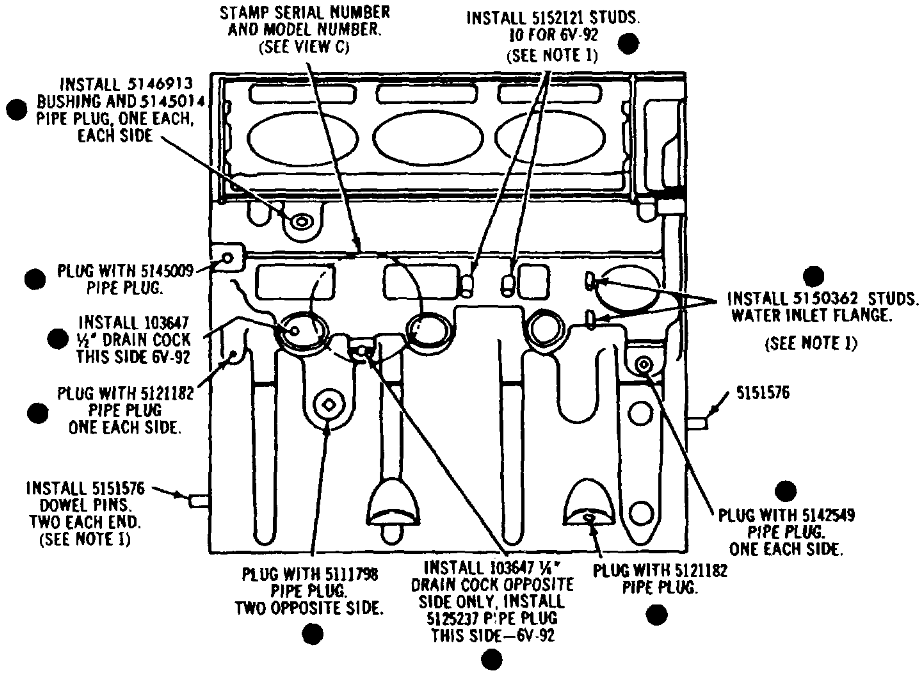


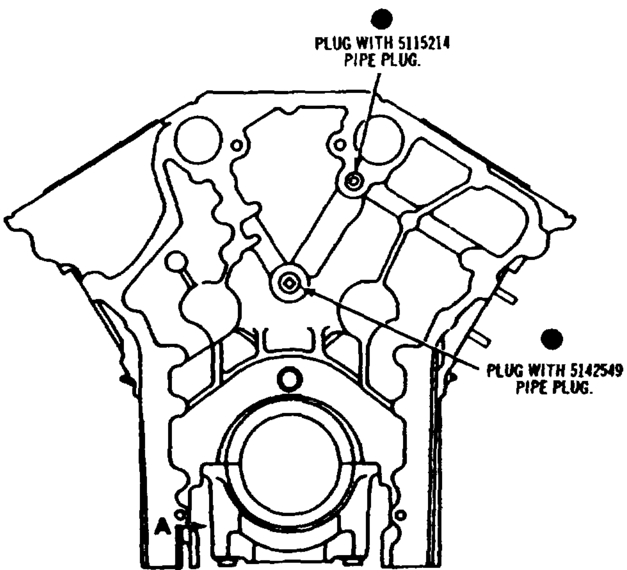

*Fig. 2 Check Injector Control Rack Adjustment*

HC238A

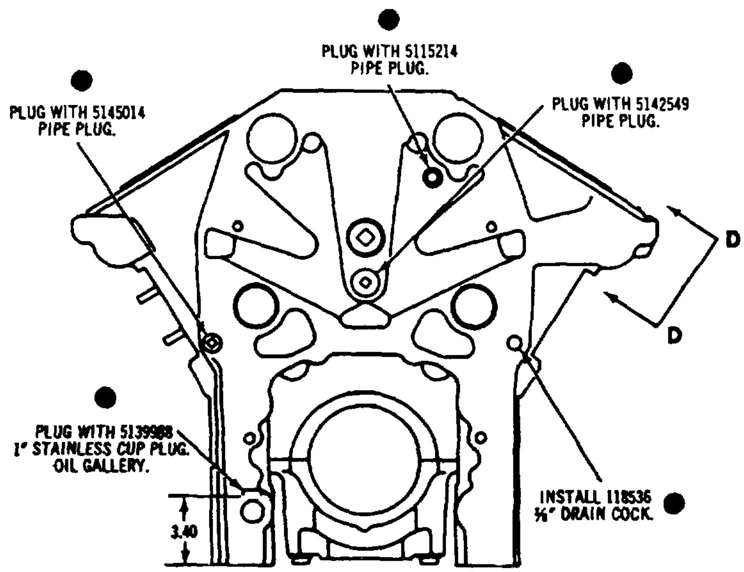



VIEW C

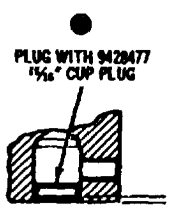


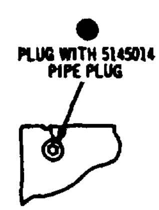

REAR



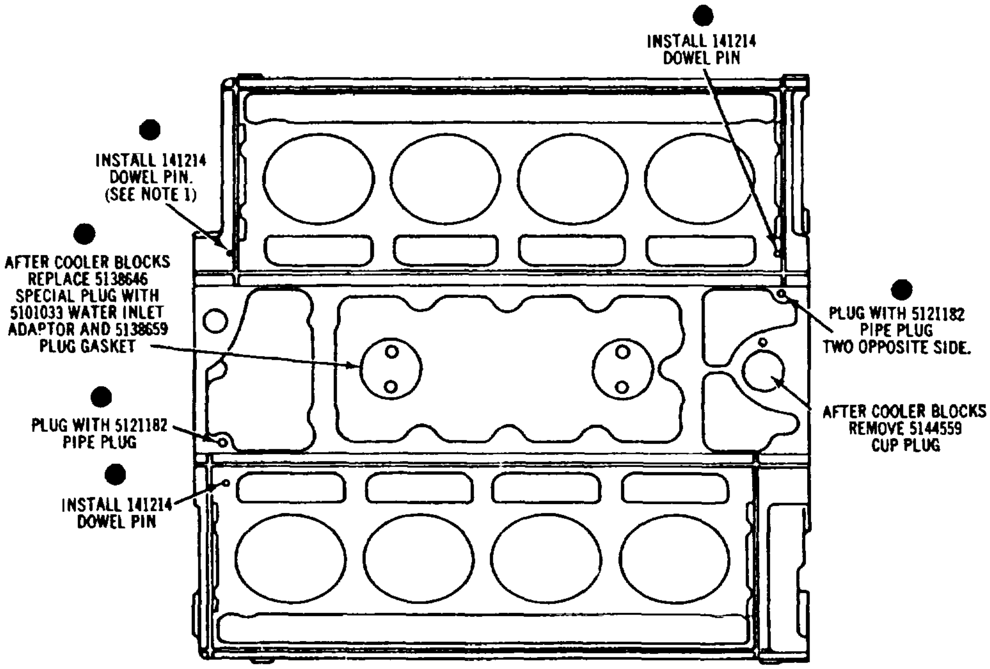

FRONT

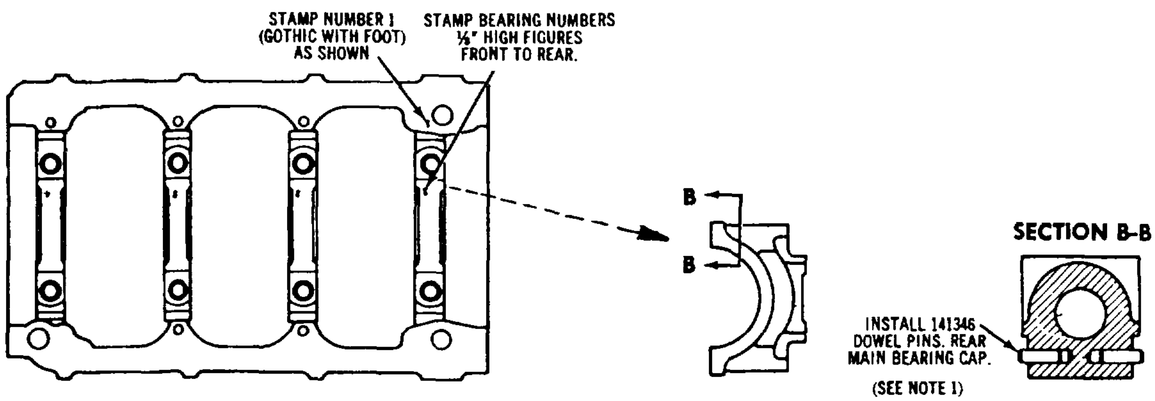



SECTION A-A




SECTION D-D




NOTES

(1) 103196 STUDS—INSTALL to 1.00 ± .030 PROJECTION.
141214 DOWEL PINS—INSTALL FLUSH WITH SURFACE.
141346 DOWEL PINS—DRIVE TO .115 ± .005 PROJECTION.
5151576 DOWEL PINS—DRIVE TO .880 ± .010 PROJECTION.
5152121 STUDS—INSTALL TO 1.00 ± .030 PROJECTION.
5142549 PIPE PLUG—INSTALL BELOW SURFACE.

(2) PLUGS INSTALL FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

● **APPLY LOCTITE J-26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.**

**STANDARD PIPE PLUG TORQUE**

| PIPE PLUG SIZE | TORQUE/FT. LBS. |
|---|---|
| 1/8 | 10-12 |
| 1/4 | 14-16 |
| 3/8 | 18-22 |
| 1/2 | 23-27 |
| 3/4 | 33-37 |
| 1 | 78-85 |

CAUTION—DO NOT OVER TORQUE TEFLON WRAPPED PIPE PLUGS.

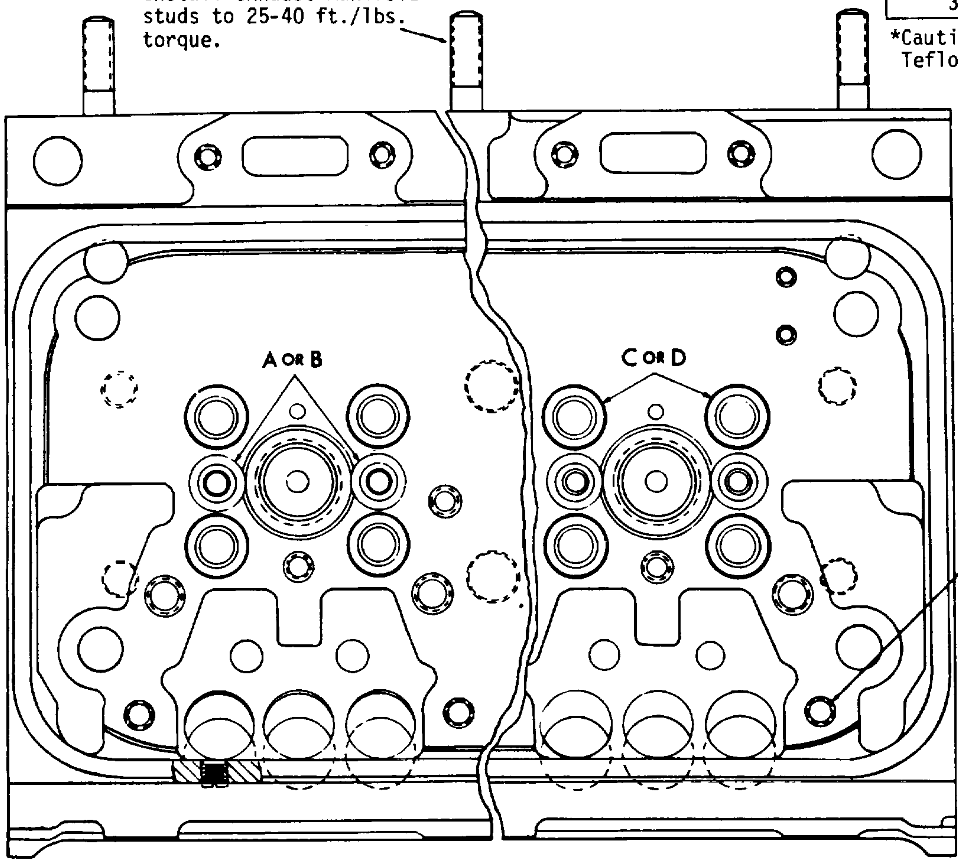
**CYLINDER HEAD PLUGGING CHART**

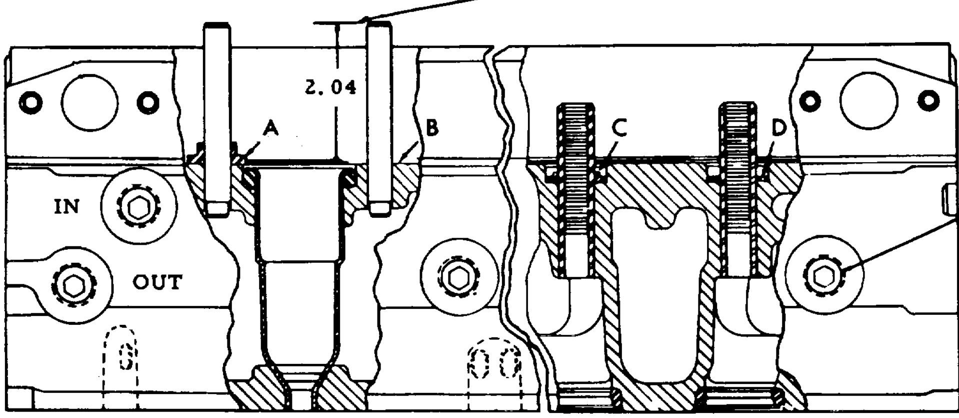
STANDARD PIPE PLUG TORQUE*

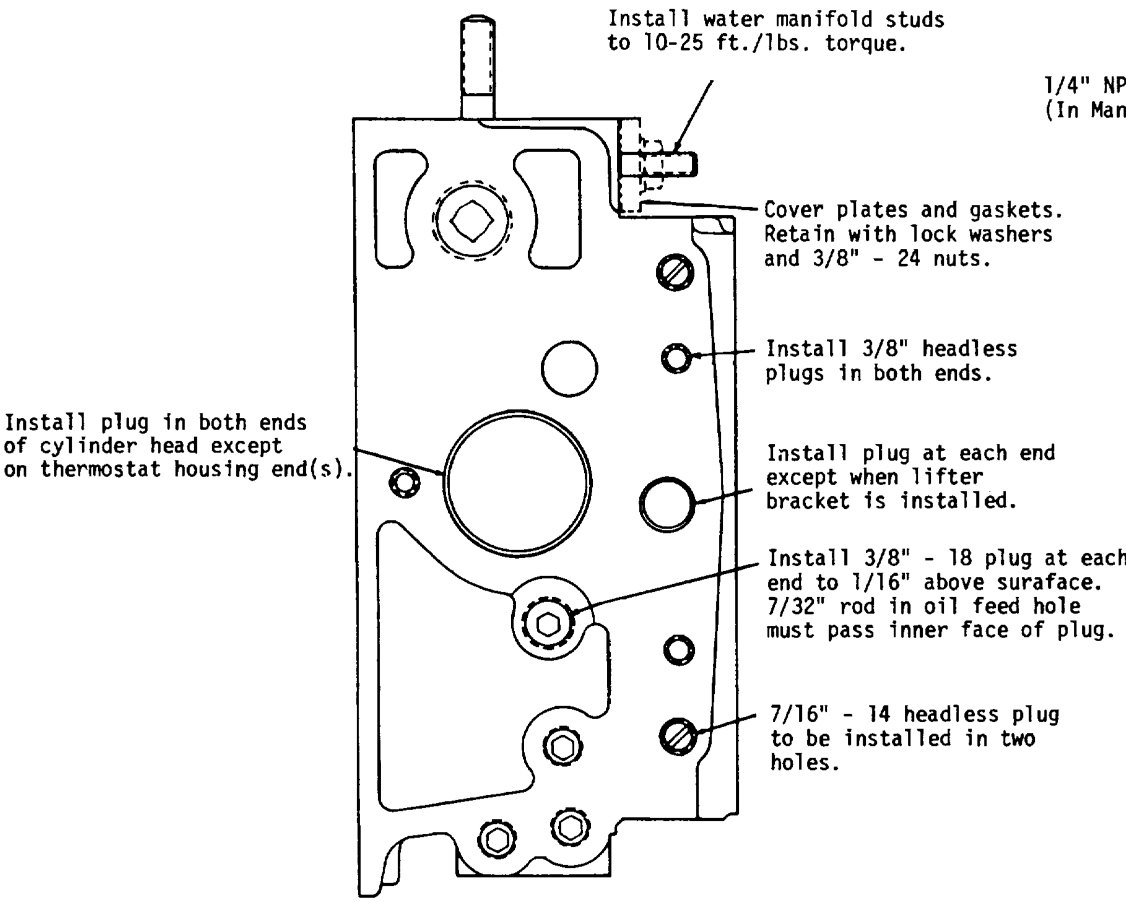
| PIPE PLUG SIZE | TORQUE (FT./LBS.) |
|---|---|
| 1/8 | 10-12 |
| 1/4 | 14-16 |
| 3/8 | 18-22 |
| 1/2 | 23-27 |
| 3/4 | 33-37 |

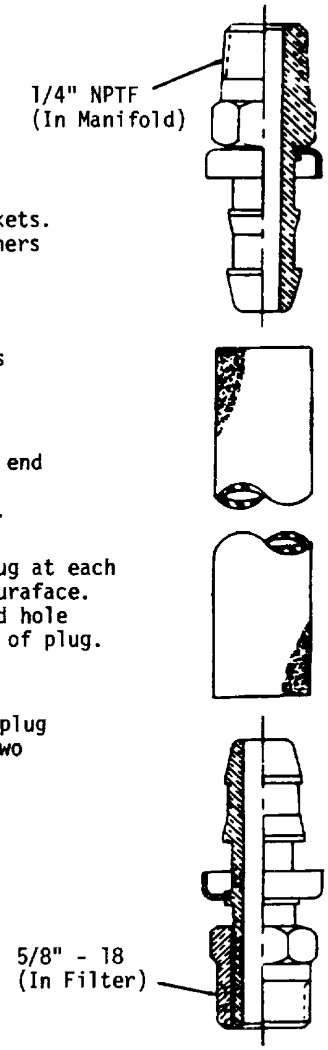
*Caution - Do Not Over Torque Teflon Wrapped Pipe Plugs.

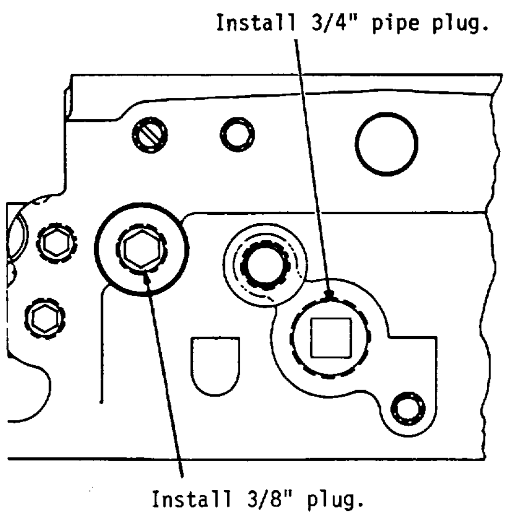
1






TO ASSEMBLE HOSE AND FITTING

(1) Cut hose to required length. Oil inside of hose and outside of nipple.
(2) Push hose on fitting underneath protective cap.

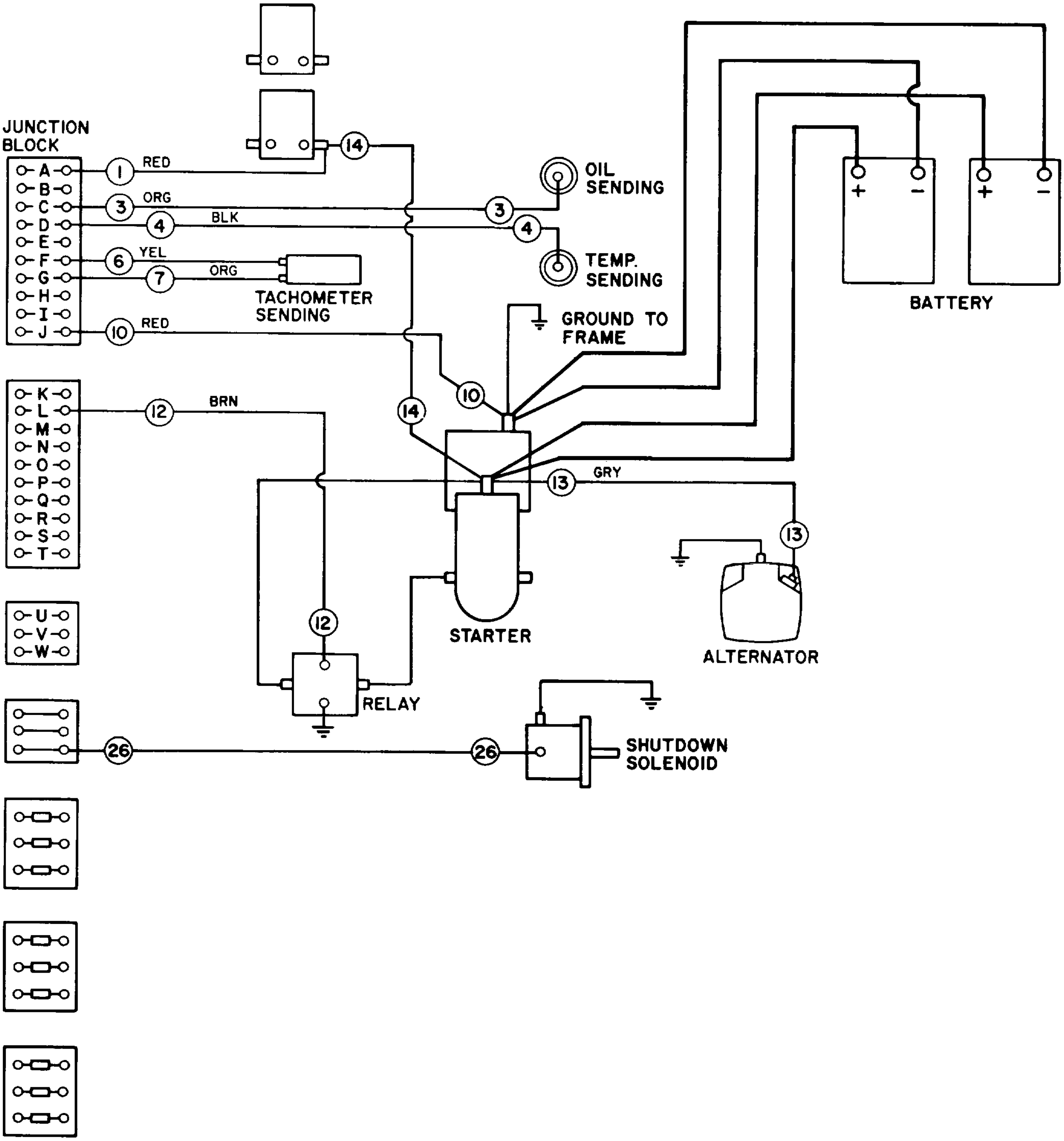



*Fig. 1 G. M. Engine Electrical Wiring*

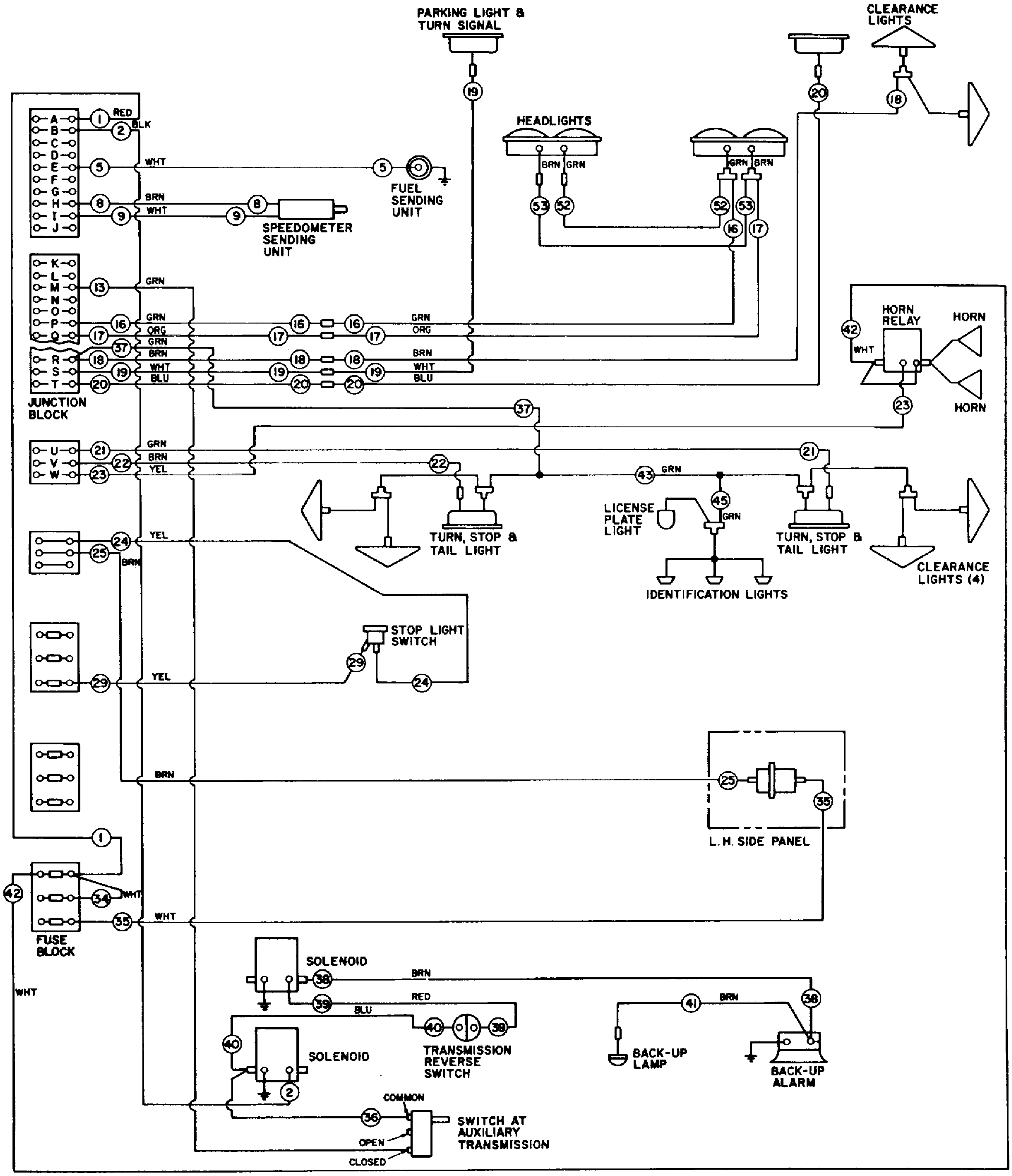



*Fig. 1. Carrier Electrical Wiring - Junction Block To Lights*

HC238A

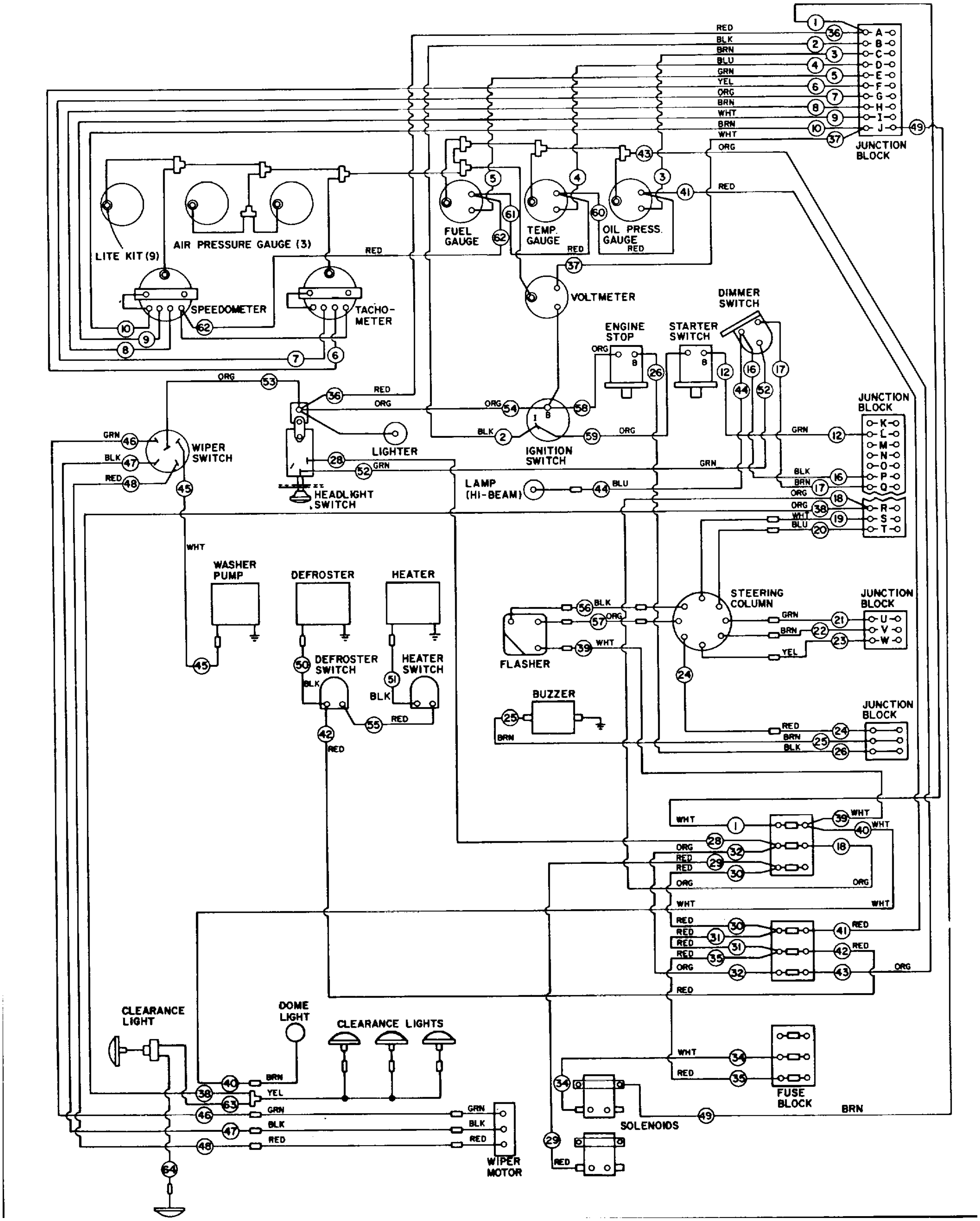



*Fig. 1. Cab Wiring*

HC238A

## 2.1 Safety Precautions for Mounting, Demounting, and Inflating Tires

**WARNING**

Many Accidents, Some Fatal, Have Resulted From Improper Handling Of Wheels And Tires. It Is Of The Utmost Importance That The Following Information Be Carefully Noted And Followed To Prevent Injury.

(1) Respect the potential power and explosive force of air under pressure. Serious accidents have resulted from lack of awareness of the explosive potential of compressed air. Respect it as you would dynamite (Fig. 1).

(2) Never work on tire and rim assemblies until you have reviewed safety practices and procedures.
(3) Make sure all tools are in good condition for use not damaged, dented, or deformed.
(4) Remove valve core and exhaust all air from the tire (or tires, in the case of a dual assembly) before demounting. Probe the valve stem with a wire as a final check to make sure valve is not plugged. Do not stand in front of valve opening, as dirt particles may be blown into eyes.
(5) Don't loosen lug nuts on duals until all air is exhausted from both tires. A broken or cracked rim part under pressure could blow apart and seriously injure or kill if lugs are removed before air is exhausted.
(6) Never apply heat or do repair work on an inflated tire, rim and wheel assembly. Heat can increase air pressure to a level sufficient to burst the tire or rim.
(7) Block vehicle in a positive manner so it cannot roll forward or backward after being jacked up.
(8) Place large hardwood blocks under the jack, regardless of how hard or firm the ground appears.
(9) Place safety jacks or crib up with blocks at a spot under the vehicle in case the jack slips.
(10) Dont't reinflate a tire that has been run flat or seriously underinflated without de- mounting that tire and checking the tire and tube for damage.
(11) Always check rim diameter to be sure it exactly matches rim diameter molded on tire.
(12) Clean and inspect used rim parts thoroughly. Don't mix rim parts of different manufacturers unless such use is approved by those manufacturers.
(13) Don't attempt, under any circumstances, to rework, weld, heat, or braze rim parts. Replace damaged parts with same size, type, and make.
(14) Always use new tubes and flaps in new tires.
(15) Never reuse tubes or flaps that have buckled or creased.
(16) Never use a tube in a tire larger or smaller than that for which the tube was designed.
(17) Inspect inside of tire for loose cords, cuts, penetrating objects, or other carcass damage. Scrap tires that are damaged beyond simple repair. Remove dirt, debris, and liquid from inside of tire before tube is installed.
(18) Lubricate with approved rubber lubricant such as thin vegetable oil soap solution, or "Ruglyde".
(19) Use a clip on check and extension hose with a remote control valve and pressure gauge, long enough to allow you to stand to one side.
(20) Center tire properly on rim before inflating.
(21) Securely lock wheel down, or place assembly in a safety cage or portable safety device before attempting to inflate tire to seat beads (Fig. 2).
(22) Never inflate beyond recommended bead seating pressure. Stand clear of tire when inflating.
(23) Check for proper flange & lock ring seating.

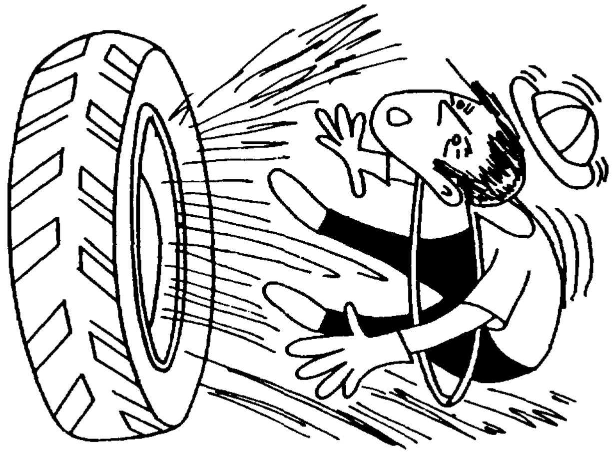


*Fig. 1. Don't Lose Your Head*

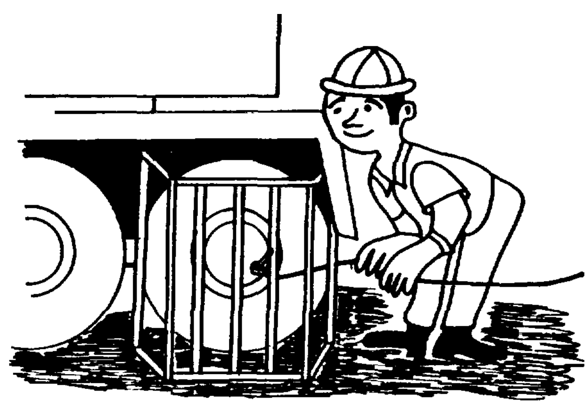


*Fig. 2. Use A Guard For Safety*

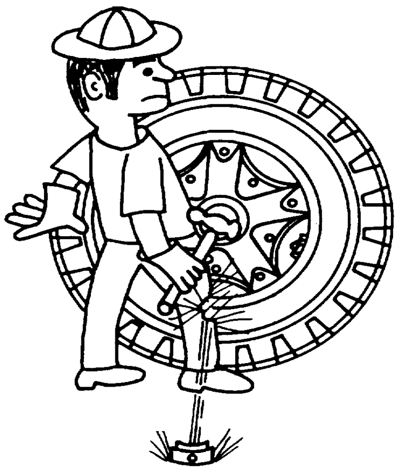


*Fig. 3. Rim Clamps Can "Snap Off"*

(24) After beads are seated, adjust air pressure to that shown on tire inflation chart.

(25) Inspect valve cores for proper air retention. Replace damaged or leaky cores.

(26) Don't transport fully inflated tires on multipiece rims. Inflate only enough (10 to 15 psi) to keep rim parts in place. Inflate tires to correct operating pressure only after tire and rim assembly has been fastened in place, all lug nuts properly tightened, and rim parts checked for proper fit. Fully inflated spare tires must be confined and locked in place.

## 2.2 Wheel Removal

(a) Jack up machine until wheel is clear of ground. Take all necessary precautions such as blocking machine so it cannot roll, applying park brake, blocking under jack, etc.

(b) Before removing tire and rim assembly from machine, the tire must be completely deflated. If dualed, both tires must be deflated before removal.

(c) Loosen all wheel nuts but allow full thread engagement of nuts.

(d) Unseat rim clamps with a sharp blow of a hammer or tire tool (Fig. 3).

**WARNING**

Extreme Care Must Be Taken In Removing Wheel Nuts. Rim Clamps Can Snap Off The Rim And Cause Serious Injury.

(e) Check each rim clamp to be certain it is unseated. Repeat step

(d) if necessary. Remove tire and rim assembly from machine. h To remove inner dual, remove spacer band, and then tire and rim assembly.

**WARNING**

Tire And Rim Assemblies Are Heavy. A Hoist Should Be Used To Lift Them On Or Off Machines. If A Hoist Is Not Available, Two Men Should Lift The Assembly From The Axle Hub With Pry Bars.

## 2.3 Tire and Rim Installation

Assemble inner dual rim, spacer band, and outer dual rim on hub. Rims should be assembled with valve protector lugs centered between spokes. Inner and outer valve stems should be 180° apart. Assemble rim clamps and nuts on wheel studs. Draw up, but do not tighten. Check clamp positioning, valve protector lug location, and dual rim alignment and seating on mounting bevel at back of wheel.

Assemble front single rim on wheel with valve protector lugs centered between adjacent wheel spokes. Assemble rim clamps and nuts on wheel studs. Draw up but do not tighten. Check clamp positioning, valve protector lug location, rim alignment, and seating on mounting bevel at front of wheel.

## 2.4 Wheel Tightening Procedure

One of the primary causes of misalignment of tire and rim assemblies mounted on spoke wheels is improper tightening of wheel studs. Incorrect torque on a dual spoke wheel can result in over 3/4 inch of wobble, causing accelerated torque loss and severe tire wear.

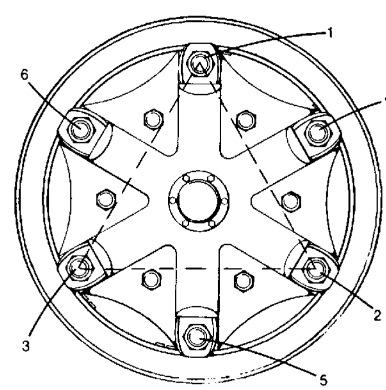
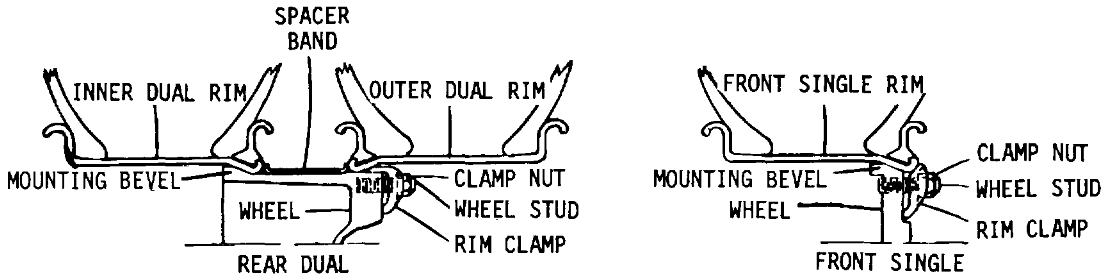



*Fig. 4. Wheel Tightening Sequence*




TYPICAL CAST SPOKE WHEEL DEMOUNTABLE RIM MOUNTINGS

*Fig. 5. Typical Rim Mountings*

The recommended procedure for torquing cast wheels is by "triangulation". The correct procedure is as follows (refer to Fig. 4):

(a) Turn nut #1 until snug.
(b) Rotate wheel-rim assembly until nut #2 in the top position. Turn the nut until snug.
(c) Rotate the wheel assembly until nut #3 is in the top position. Turn the nut until snug.

Since the entire weight of the tire and rim assembly is on the top spoke position, this procedure allows even application of force against three points of the rim for proper alignment. Now turn nuts #4, #5, and #6 until they are snug.

(d) Repeat the triangulation procedure, this time bringing all nuts to recommended torque.

| Stud Size | Torque (ft/lb.) |
|---|---|
| 1/2 inch | 90 |
| 5/8 inch | 150-175 |
| 3/4 inch | 175-200 |
| one inch | 450 |

This procedure must be followed every time a tire/rim assembly is changed.

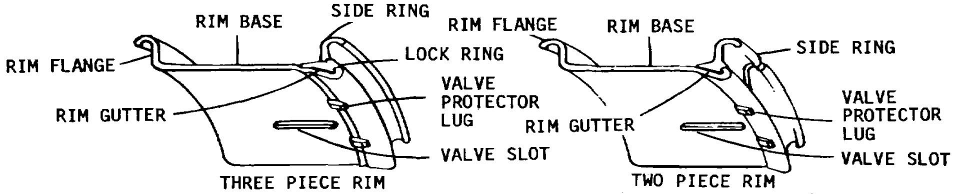
<u>Note: Even when the triangulation is used, nuts will still lose torque when the vehicle is operated. This is caused by the "seating in" of the rim assembly to the wheel. After 50 to 100 miles of travel, the nuts should be retightened to the recommended torque.</u>

2.5 Demounting

**WARNING**

Before Removing Tire And Rim Assembly From Vehicle, The Tire Must Be Completely Deflated. If Dualed, Both Tires Must Be Deflated Before Mounting Bolts Are Loosened.

Remove tire and rim assembly from truck and lay on floor with loose ring flange up. Drive wedges around tire between rim and top bead to unseat bead from rim flange. Continue this procedure until bead is free from side ring (Fig. 7).




TYPICAL CAST SPOKE WHEEL DEMOUNTABLE RIM SECTIONS

*Fig. 6. Typical Rim Sections*

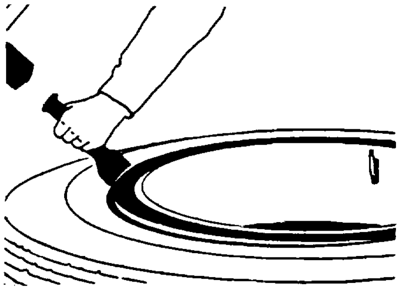


*Fig. 7. Unseat Bead From Rim Flange*

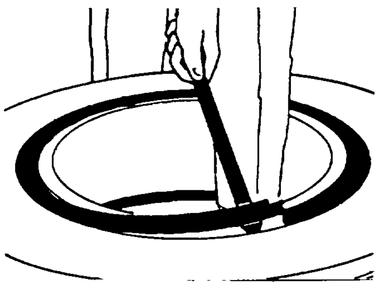


*Fig. 8. Remove Lock Ring*

Insert tapered end of tire iron into prying notch of lock ring near split in ring, and pry lock ring free from the gutter groove in which it lies (Fig. 8). Remove loose side flange. Turn assembly over, lay face down on floor, and unseat remaining bead from rim in same manner, using wedges (Fig. 9).
Lift rim from tire (Fig. 10). Remove flap and tube.

2.6 Mounting

Use only matched rim parts as specified by manufacturers handbooks. Never mix rim parts of

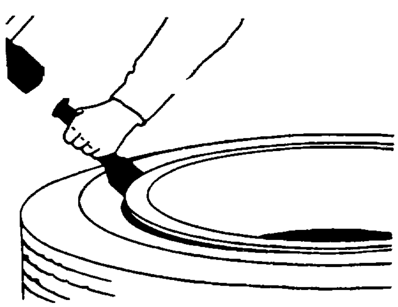


*Fig. 9. Unseat Bead From Rim*

*Fig. 9 Unseat Bead From Rim*

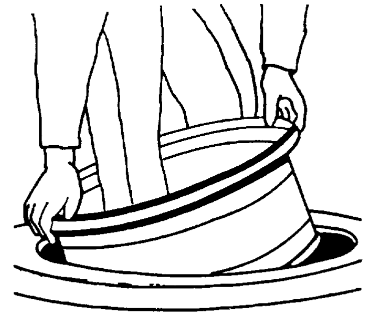


*Fig. 10. Remove Rim From Tire*

different manufacturers unless such mixing is approved by those manufacturers' handbooks. Tire, tube, flap and rim parts should be checked carefully for signs of abuse, repairs, scale, rust, or corrosion. All parts must be in good condition. Discard all parts that are cracked, welded or damaged. Clean all metal parts thoroughly by wire brushing. The inside of the casing must be free of debris, liquid and foreign material. Always use a new tube in a new tire.

2.7 General Procedure for Multi-Piece Rims

Insert tube and flap into casing, positioning valve stem at red mark on tire. Partially inflate tube to a limp, round shape. Apply RyGlyde or other approved rubber lubricant to both beads and the area of flap that lies between the beads.

Lay rim base flat on floor with valve slot up. Place tire on rim and insert valve through valve slot (Fig. 11).
Place loose side flange on rim base. Place leading end of lock ring into gutter groove of rim base. Using soft faced mallet, progressively "tap" lock ring into place (Fig. 12). Check the ring to insure that it is fully and properly seated in groove.

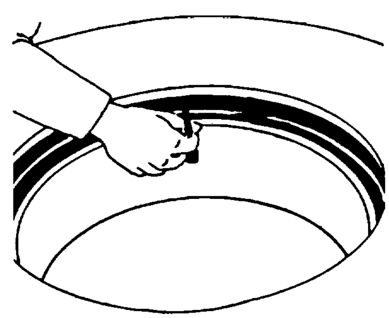
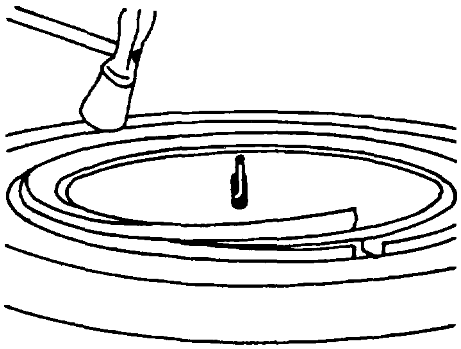


*Fig. 11. Insert Tube Valve Through Rim Valve Slot*



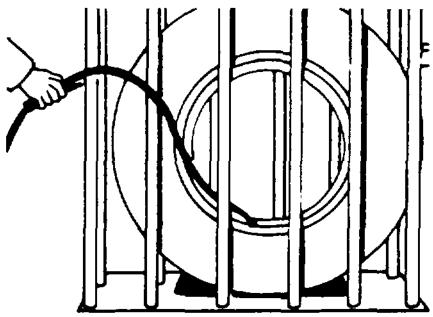


*Fig. 12 Install Lock Ring*

Fig. 13 Inflate Tire In The Safety Cage Place assembly in safety cage and attach clip-on chuck with extension hose, remote control valve and pressure gauge. Inflate to 10 psi. Check ring for proper seating by tapping it with a mallet (Fig. 13). Completely deflate tire, then reinflate to recommended psi before removal from safety cage.

2.8 Tire Inflation Chart

This chart lists inflation pressures for three situations: (1) maximum lifts on rubber (static use only); (2) five miles per hour; and (3) 50 miles per hour maximum.

The first column (maximum lifts on rubber) is the highest pressure of the three columns. The tires on a rubber tire mounted machine have to be inflated to this pressure to make lifts per the capacity chart.

Since this pressure is very high, it is for static use only. The pressures have to be reduced to those shown in the second column (5 MPH) for making slow speed moves around the job site. These pressures are generally higher than those shown in column 3 (50 MPH maximum). All tires must be inflated as shown in column 3 before driving the machine any distance, or at speeds greater than 5 MPH.

| | LOAD RANGE | PLY RATING | MAXIMUM LIFTS ON RUBBER (STATIC USE ONLY | 5 MILES PER HOUR | 5O MPH MAXIMUM |
|---|---|---|---|---|---|
| SIZE: | | | INFLATION: | INFLATION | INFLATION |
| *14:OO x 24 | L | 20 | 115 | 100 | 100 |
| *For maximum tire life, a 30-minute rest period is recommended every 50 miles of continuous travel. | | | | | |

*Fig 14*
*Tire Inflation Chart*

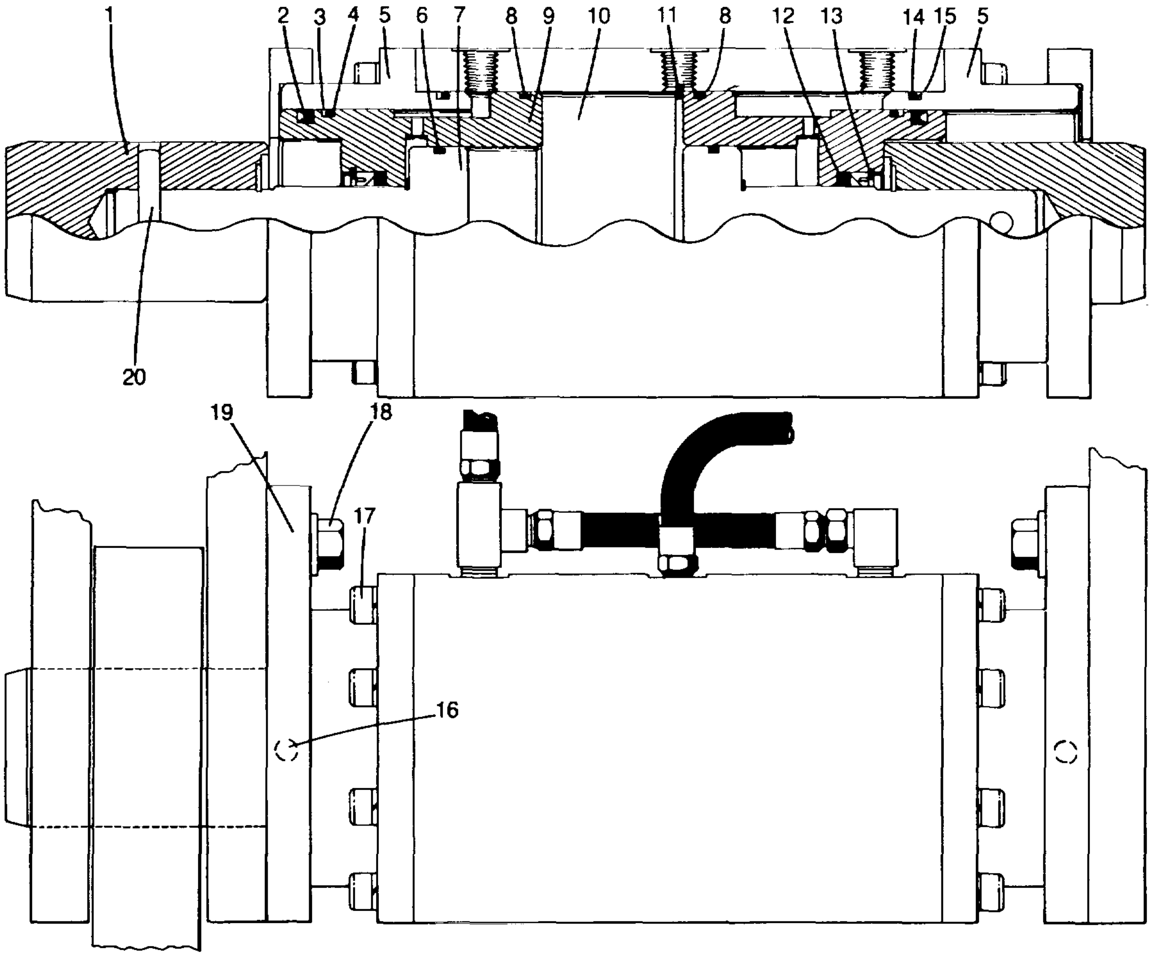



*Fig. 1. Pin Removal Cylinder*

(1) Outrigger Cylinder
(2) Outrigger Box Pin
(3) Back Up Ring
(4) "O" Ring
(5) Gland
(6) "O" Ring
(7) Inner Piston
(8) "O" Ring
(9) Outer Piston
(10) Cylinder
(11) Snap Ring
(12) Seal
(13) Snap Ring
(14) 'O' Ring
(15) Back Up Ring
(16) Roll pin
(17) Capscrew
(18) Capscrew
(19) Centering Plate
(20) Pin

## 1.1 Pin Removal System

The system provides a hydraulic means to remove the outrigger box pins to facilitate removal of the boxes. Quick disconnects are provided on the cylinder lines. These must be attached to the beam cylinder circuit before use. Refer to Section 1 of Operators Manual for more information.

## 1.2 Cylinder Removal

(a) Remove the outrigger box assembly. Refer to Section 1 in Operators Manual for instructions.
(b) Extend box pins (1). Remove pins (20) which connect inner piston (7) to box pin.
(c) Retract cylinder to withdraw inner pistons from beam pins. It may be necessary to clamp otherwise restrain the pin to hold it in position.
(d) Disconnect lines leading to the cylinder.
(e) Remove capscrews (18). Remove cylinder and centering plates from the machine. There may be shims between centering plate and frame lugs. If so, save them for later reassembly.

## 1.3 Cylinder Disassembly

(a) Thoroughly clean the exterior of the cylinder.
(b) Remove capscrews (17) from each end of the cylinder.
(c) Remove gland and piston assemblies from each end of the cylinder.
(d) Remove outer piston from gland, and inner piston from outer piston.
(e) Remove all seals. "0" rings, back up rings from the O.D. of the gland, inner piston, and outer piston.

(f) Remove snap ring (13). Remove seals (12) from I.D. of outer piston.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(g) Thoroughly clean all parts in kerosene, diesel fuel, or some other approved solvent. Inspect all metal parts for signs of scoring, wear or damage. Replace any worn or damaged parts.

## 1.4 Cylinder Reassembly

(a) Lubricate an 'O' ring (14) and back up ring (15) with Cosmolube #2 or equal. Install in groove in O.D. of gland. Back up rinq will go to outside of groove.

(b) Lubricate an "O" ring (8) with Cosmolube #2 or equal. Install in groove on O.D. of outer piston.

(c) Lubricate an "O" ring and back up ring (3 & 4) with Cosmolube #2 or equal. Install in groove in O.D. of outer piston. Back up ring goes to outside of groove.

(d) Install packing (2) in qroove in O.D. of outer piston. The notch in the face of the packing goes to the outside.

(e) Install seal assembly (12) in I.D. of outer piston. Install snap ring (13).

(f) Lubricate "0" ring (6) with Cosmolube #2 or equal. Install in aroove on O.D. of piston.

(g) Install inner piston in outer piston, and outer piston in qland. Be careful not to damage seals during installation.

(h) Install gland assembly in cylinder case. Align rollpin qroove in gland with retract port in cylinder case.

(i) Install and tighten capscrews (17).

(j) Repeat above procedure for other side of cylinder.

## 1.5 Cylinder Installation

(a) Install centering brackets on each end of cylinder assembly.

(b) Set cylinder in place in between frame luqs. Replace any shims that were removed during reassembly. Install capscrews (18) loosely.

(c) Connect all lines so cylinder can be actuated.

(d) Align inner piston extensions with holes in box retaining pins. Rotate pins and pistons as necessary to align pin holes.

(e) Extend cylinder.

(f) Install pins (20) to connect box retaining pin to inner piston extension. Tighten capscrews (18).

(g) Refer to Operators Manual, and install out-rigger assembly.

## Bearing Fits

Fits shown below are in ten thousandths of an inch. They apply to both roller and ball bearings.

Fits are designated as tight or loose. The following shows when a tight or a loose fit is produced:

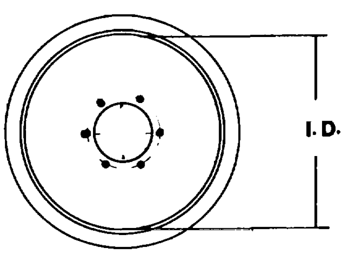
Shaft O.D. is greater than bearing I.D. - tight
Shaft O.D. is smaller than bearing I.D. - loose
Housing bore is greater than bearing O.D. - loose
Housing bore is smaller than bearing O.D. - tight

I.D. of bearing on O.D. of revolving shaft - Example: Drum shafts.
8 tight to 0 tight

I.D. of bearing on O.D. of stationary shaft - Example; Boom Head Shaft
14 loose to 3 tight

O.D. of bearing in I.D. of stationary bore - Example: Side Housing Bearings
10 loose to 0 tight

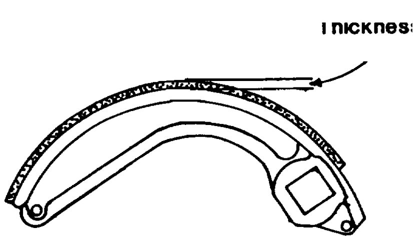
O.D. of bearing in I.D. of rotating bore - Example: Head Sheaves
19 tight to 1 tight




## Clutch Drums

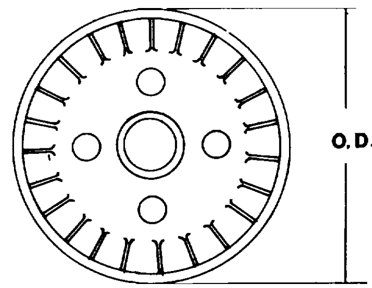
I.D. Max. 22-7/8"
Min. 23"

Clutch drums may be machines a maximum of 1/8" on the diameter to remove scoring.



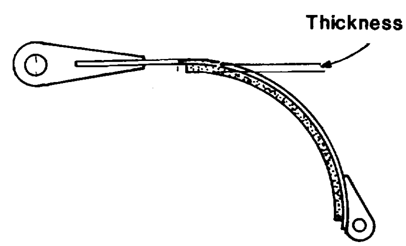

## Clutch Shoes

Lining Thickness Max. 3/8"
Min. 1/4"



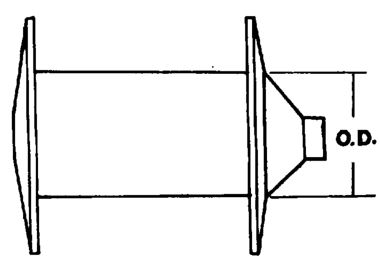

## Brake Drums

| | | |
|---|---|---|
| Swing | Max. | 20" |
| | Min. | 19-7/8" |
| Front Drum | Max. | 34-1/64" |
| | Min. | 33-61/64" |
| Rear Drum | Max. | 34-1/64" |
| | Min. | 33-61/64" |
| Boom Hoist | Max. | 28" |
| | Min. | 27-7/8" |




## Brake Linings

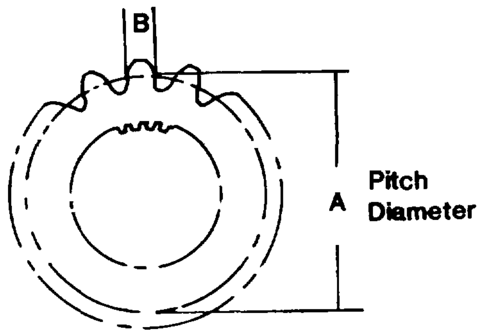
| | | |
|---|---|---|
| Swing | Max. | 1/4" |
| | Min. | 3/16" |
| Boom Hoist | Max. | 3/8" |
| | Min. | 1/4" |
| Planetary | Max. | 3/8" |
| | Min. | 1/4" |
| Front & Rear Drum | Max. | 3/8" |
| | Min. | 1/4" |



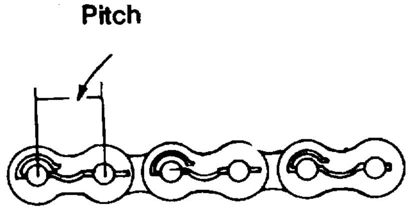

## Laggings

Boom Hoist Max. 12-1/4"
Min. 12-1/8"
Front Drum Max. 17-1/4"
Min. 17-1/8"
Rear Drum Max. 17-1/4"
Min. 17-1/8"
Rear Drum Max. 17-1/4"
Min. 17-1/8"

Laggings may be resurfaced to remove scoring. A maximum of .0125" may be removed from the diameter.

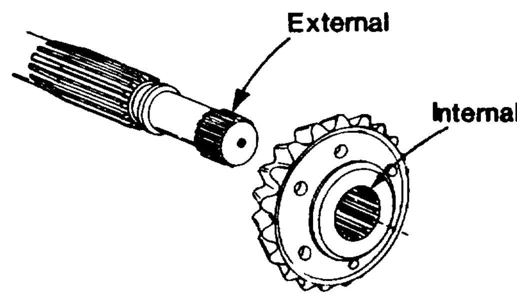



| Gear | Pitch | Tooth |
|---|---|---|
| Dia. (A) | Width (B) | |
| Boom Hoist | 25.6" | .622" Max. .585" Min. |
| Front Drum | 28.4" | .622" Max. .585" Min. |
| Rear Drum | 28.4" | .622" Max. .585" Min. |
| Upper Jackshaft Pinion | 6.4" | .622" Max. .585" Min. |
| Lower Jackshaft Pinion | 8.8" | .622" Max. .585" Min. |
| Upper L.H. Jackshaft Pinion | 6.4" | .701" Max. .664" Min. |




Engine Drive Chain

Pitch Max. .825"
Min. .75"
Roller Diameter Max. .469"
Min. .422"



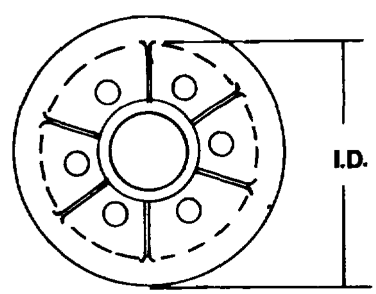

Spline Fits

Splined connections are used in various places on the upper machinery. If the splined connections do not fit tightly, motion between the components will result in wear to the splines, and damage to the components. Radial movement between components - measured at spline connection.

Max. .025"
Min. 0"

Lateral movement between components - measured at O.D. of drum or clutch spider.

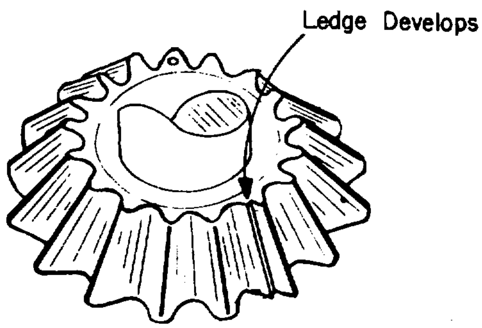
Max. .825"
Min. O"




Sheaves

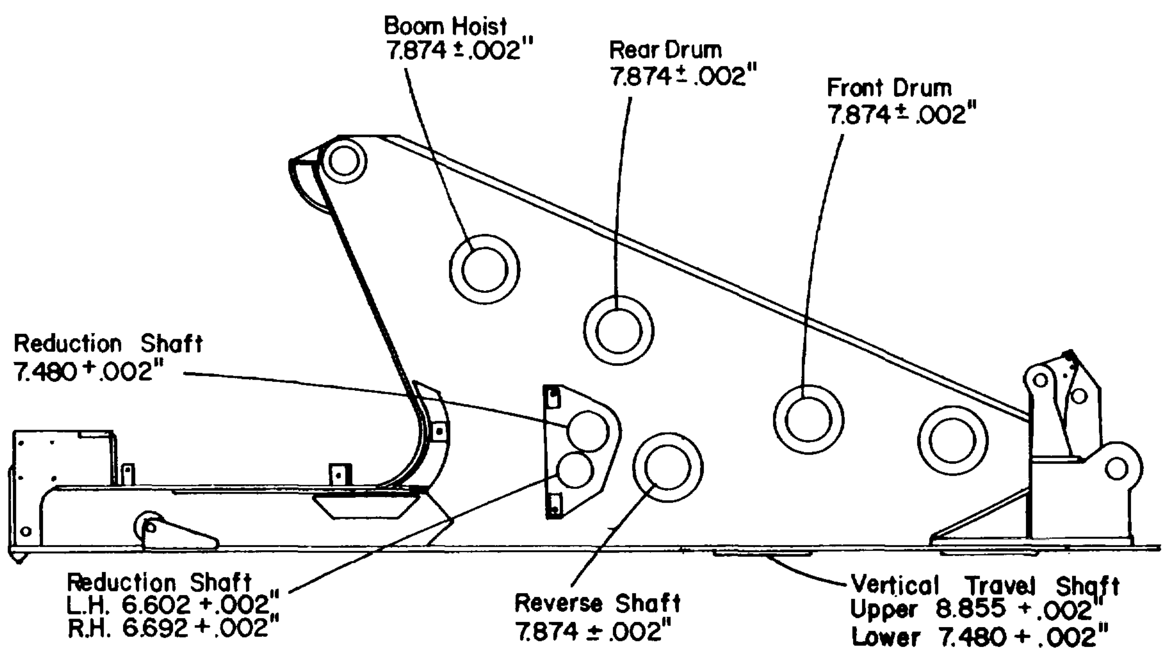
Boom Peak Max. 21"
Min. 19-7/8"
Bridle Max. 15"
Min. 14-7/8"
Bail Max. 15"
Min. 14-7/8"

Sheaves must be replaced when the wearing surface (I.D.) is worn down 1/8" from the original diameter.

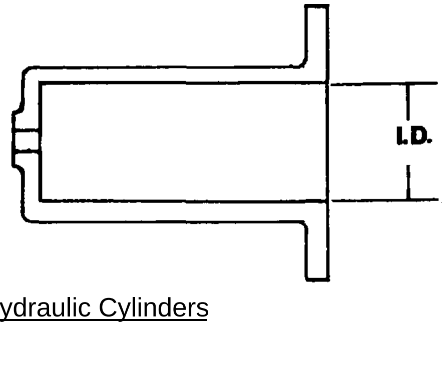



Bevel Gears

As bevel gears wear, a ledge develops on the teeth from the rubbing action of mating teeth. Gears should be replaced when this ledge is .0625" wide.




Occasionally a bearing bore will become wallowed out from high loadings, or a bearing turning in its bore. Nominal bore sizes are shown in chart above. Bores may be welded up and remachined with portable boring

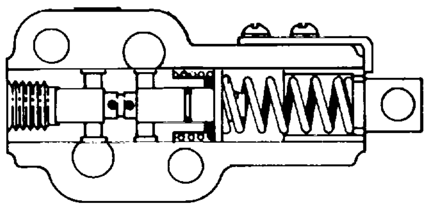



Hydraulic Cylinders

**Service Manual** Wear Limits And Replacement Chart

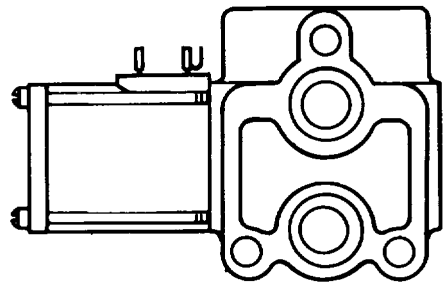
| | | |
|---|---|---|
| Clutch | Max. | 2.380" |
| | Min. | 2.375" |
| Boom Hoist | Max. | 2.005" |
| | Min. | 2.000" |
| Swing Brake | Max. | 2.255" |
| | Min. | 2.250" |
| Outrigger Jack | Max. | 9.008" |
| (Side?) | Min. | 9.003" |
| Outrigger Jack | Max. | |
| (Front) | Min. | |
| Outrigger Beam | Max. | 2.505" |
| | Min. | 2.500" |

Cylinders may be honed a maximum of .005" on the diameter to clean up scoring.



S-o-M Control Valves

Bores in these valves cannot be honed. If they are scored, or there is excessive clearance between bore and spool, valve must be replaced.



Solenoid Valves

Bores in these valves cannot be honed. If they are scored, or there is excessive clearance between bore and spool, valve must be replaced.

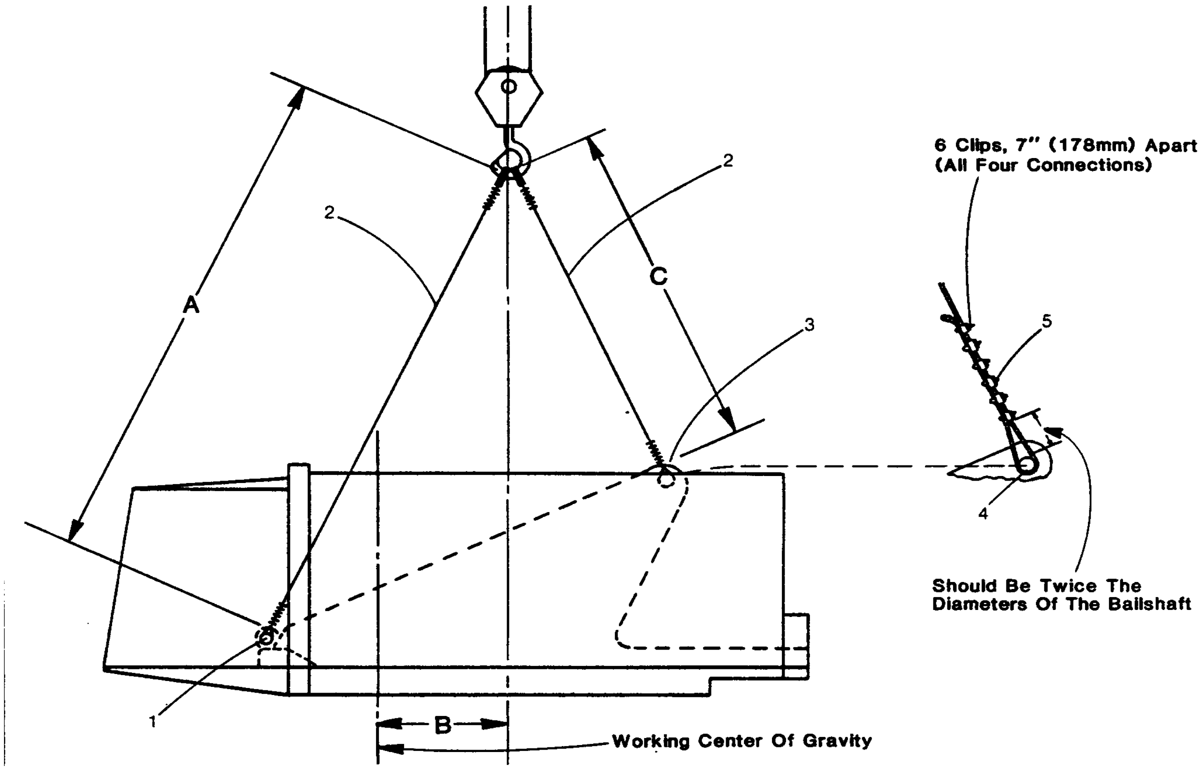



*Fig. 1. Sling Assembly*

(A) 16’9" (5.11 m)
(B) 4’ (1.23 m) to revolving frame center of gravity
(C) 10’9" (3.33 m)

(1) Boom Foot Pins
(2) Sling
(3) Boom Hoist Bail Shaft
(4) Wire Rope Thimble
(5) Wire Rope Clips (6 per connection)

Note: Center of gravity will vary due to weights of optional equipment. Sling lengths are starting point only. They may have to be adjusted to make machine hang perfectly level.

24.1 General

The basic upper weighs approximately 40,810 pounds (18,511.4 kg) without counterweight or catwalks. Addition of optional equipment will increase the weight. An upper with several options could weigh as much as 41,500 pounds (1,000 kg). Lifting equipment must be provided that can safely lift the upper. This equipment must be in good condition, properly adjusted and reeved before attempting to lift the upper. Refer to such lifting equipment’s capacity chart and make sure it can do the job before proceeding.

24.2 Preparation for Installing the Upper

When a 238A machine is shipped from the factory unmounted, the tapped holes in the truck carrier are coated with preservative to prevent rusting. The machined surface that the bearing sits on is also coated. This preservative must be removed before mounting the upper. Thoroughly remove all preservative with an approved commercial solvent.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

The threaded holes must be chased with a bottom tap before mounting the upper. A tap with an extension welded to it is available. Refer to tool list at the end of this section. This tap is driven by a ratchet or flex handle. If a tap must be obtained locally, the thread size is 1-1/2" N.C.

Install a capscrew in each threaded hole. You should be able to turn them in by hand. If no check and see why. Damaged threads, bent cap- screws, etc. will affect holding power of the capscrews and could lead to an accident.

24.3 Capscrews Must Be "Loctited" As Follows:

(1) Remove dirt, shavings, excess oil from threads.
(2) Thoroughly degrease threads with "loctite safety solvent (806006002). Allow solven to dry.
(3) Apply "locquic" primer N (806003002) to bolt threads. Allow 3 to 5 minutes to dry.
(4) Apply amount of "loctite" pipe sealant (806004002) necessary to cover thread engagement.
(5) Install capscrew.

24.4 Installing The Upper

The following procedure covers mounting the upper on a truck carrier:

(a) Park on level ground, apply parking brakes, and block wheels.
(b) Attach slings to upper (see Fig. 1). Connect one leg to each boom foot pin, and one leg to each end of the extended boom hoist bail shaft (where the boom backstops mount). Install keeper pins or cotter pins in the boom foot pins to prevent their working out. Install a large washer, or a plate with a flame cut hole in the center over the bail shaft to prevent sling slipping off. Install a cotter pin or capscrew and locknut in the hole at each end of the bail shaft to retain the washer or plate. The sling must have four legs, and be strong enough to lift the upper. If using wire rope, use a minimum 1" (25.4mm) diameter rope with a minimum breaking strength of at least 51 tons (46,266 kg). FMC type N is recommended. Use new rope straight off the reel for making up the sling. Never use used, scrapped, or damaged rope for a sling, as an accident may occur. Refer to Fig. 1 for more information. See section 10 in the Operators Manual for information on installation of wire rope clips.
(c) Remove bearing cover plates from both sides of the revolving frame to expose the bearing (item 2 and 4, Fig. 2).
(d) Install four positioning studs (5 in Fig. 2) in the tapped holes in the carrier

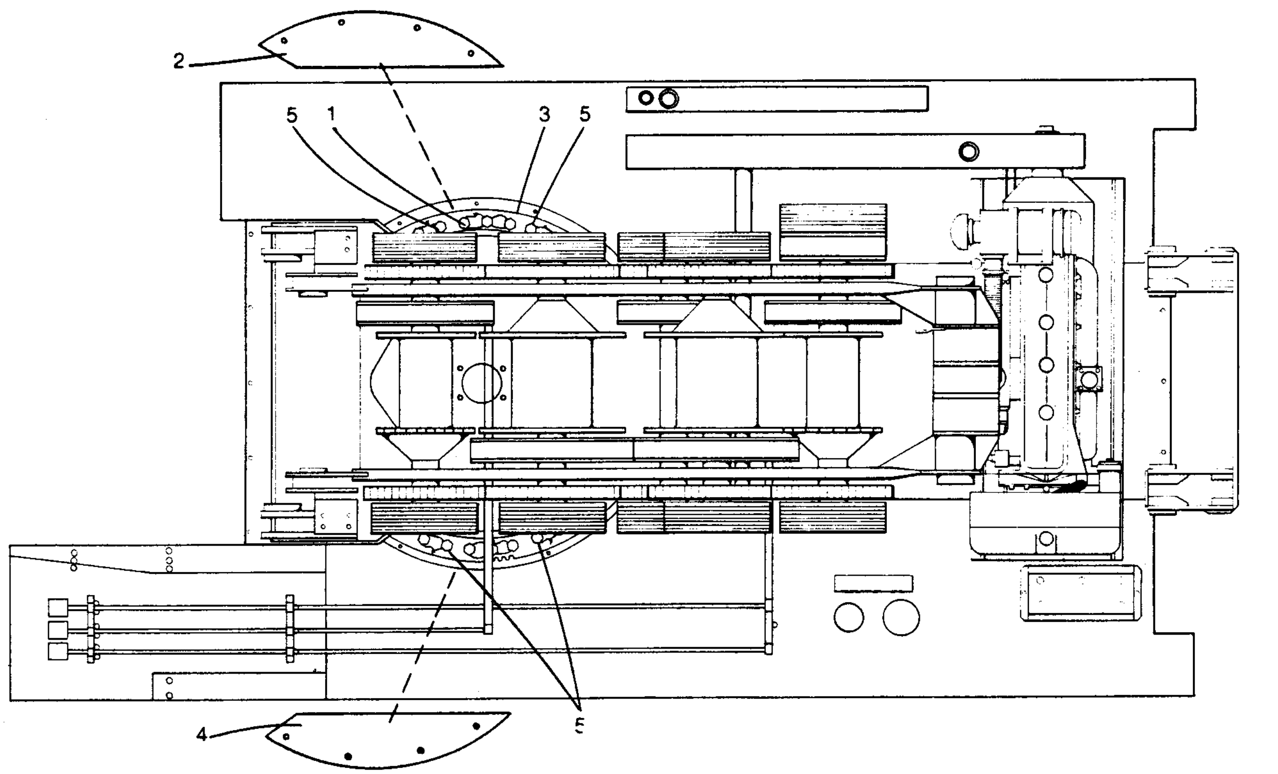



*Fig. 2. Upper Frame and Turntable Bearing*

(1) Capscrews (45 total)
(2) R.H. Cover Plate
(3) Turntable Bearing
(4) L.H. Cover Plate
(5) Positioning Stud Locations

frame.

(e) Pick the upper slightly off the ground. Check to make sure it hangs level. If not, set it back down and adjust the slings. Pick the upper and swing it into place over the truck. Stay out from under the upper.

Upper must face the rear of the carrier. Position bearing punch mark, located just below the teeth, to the front of the upper. Bearing punch mark must also align with center line of tile carrier, to allow the swing lock to hold upper in line with carrier. Carefully lower the upper into place. Engage studs with the holes in the bearing. Set the upper in place on the carrier. Maintain a strain on the sling to keep the upper from tilting.

(f) Install a capscrew on each side of each positioning stud. Remove the positioning studs. Install a capscrew in each hole that is accessible. Turn capscrews in *by* hand until the head just contacts the bearing surface. Then initially tighten each capscrew to 500 ft/lb. (669 N.m) torque.

Note: <u>All capscrews must be "loctited" as explained on page 1 before installation.</u>

(g) Start upper engine. Engage master clutch. Release swing brake. Release the lifting equipment, slowly swing upper until more capscrews can be installed. Coat all cap- screws with "loctite" as explained on page 2. Continue tnis procedure until all 45 capscrews are installed, turned in by hand until head contacts bearing surface, then initially tightened to 500 ft/lb. (669 N.m) torque.

Note: <u>Capscrews should turn in easily, by hand, until head contacts bearing surface. If not, check and see why. Damaged threads, bent cap- screws, capscrew interference, etc. will affect holding power of capscrews and may lead to an accident. Don't use a power wrench to run cap screws down. If interference does occur, it won't be noticed.</u>

(h) Now, final tighten each capscrew to 2770 - 3050 ft/lb. (3701-4075 N.m) torque. This is much easier if you use a torque multiplier. See tool list on this page. This wrench has a 1" input and 1-1/2" output drive. It multiplies the torque put on the capscrew times 4.33 the ft/lb. that are put into the torque wrench. With this multiplier, it is necessary to only put 640-704 ft/lb. (855-941 N.m) torque on the wrench to apply 2770-3050 ft/lb. (3701-4075 N.m) on tne capscrew.

(i) After final tightening the capscrews, allow the "loctite" to cure for approximately six hours.

(j) Install bearing cover plates.

(k) Assemble live mast, backstops, counter- weight, catwalks, and attachment on machine.

<u>TOOL KIT 3P175</u>

| | |
|---|---|
| 1 - | 3P112 Adaptor 1" to 1-1/2" Square Drive (1M-35) |
| 1 - | 3P119 Ratchet Wrench w/Handle 1" Drive (L-73CH) |
| 1 - | 3P120 Extension Bar 10" Long, 1-1/2" Drive(L-105) |
| 1 - | 3P121 Adaptor 3/4" to 1/2" Drive (LA-62) |
| 1 - | 3P124 Torque Wrench, 600 ft/lb. capacity, 3/4" Drive (TEC-602) |
| 1 - | 3P145 Adaptor, 1" to 3/4" Drive (LA-124) |
| 1 - | 3P158 Ratchet Adaptor, 1" Drive (L-673) |
| 1 - | 3P132 Adaptor, 1-1/2" to 1" Square Drive |
| | TOOL KIT 3P302 |
| 1 - | 3P115 (2)-1.4" Socket w/1-1/2" Square Drive |
| 1 - | 3P298 Positioning Studs |
| 1 - | 3P299 Bottom Tap with 1/2" Drive Extension |

Refer to Operators Manual for assembly instructions.

24.5 Upper Storage

If the upper is to be stored for a period of time before mounting, or will set idle for a long period of time after mounting, follow storage procedures in Operators Manual.

In addition, fully lubricate the machine at least every 60 days while in storage. Then start the machine and rotate all shafts and the turntable bearing to distribute the grease and help prevent rust. This is especially important on machines working around salt water where rust and corrosion form faster than usual. In addition, coat all unpainted metal with preservative. Store machines under cover if at all possible.

Before putting a stored unit to work thoroughly inspect it for rust, deterioration, damage, etc. Repair any damage before operating the machine.

24.6 Preparation for Undecking a Machine

Refer to Operators Manual and perform all of the following steps:

(a) Remove jib, or tip extension from machine.
(b) Remove catwalks from machine if so equipped.
(c) Remove all counterweights from the machine.
(d) Lower live mast until it is horizontal. Block securely under live mast. Remove boom hoist rope.
(e) Remove live mast from machine.
(f) Remove boom backstops from machine.

24.7 Undecking Machine

(a) If upper is mounted, park machine on firm, level surface. Apply emergency brakes and block wheels.
(b) Attach slings to upper (see Fig. 1). Connect one leg to each boom foot pin, and one leg to each end of the extended boom hoist bail shaft (where the boom backstops mount). Install keeper pins or cotter pins in the boom foot pins to prevent their working out. Install a large washer, or a plate with a flame cut hole in the center, over the bail

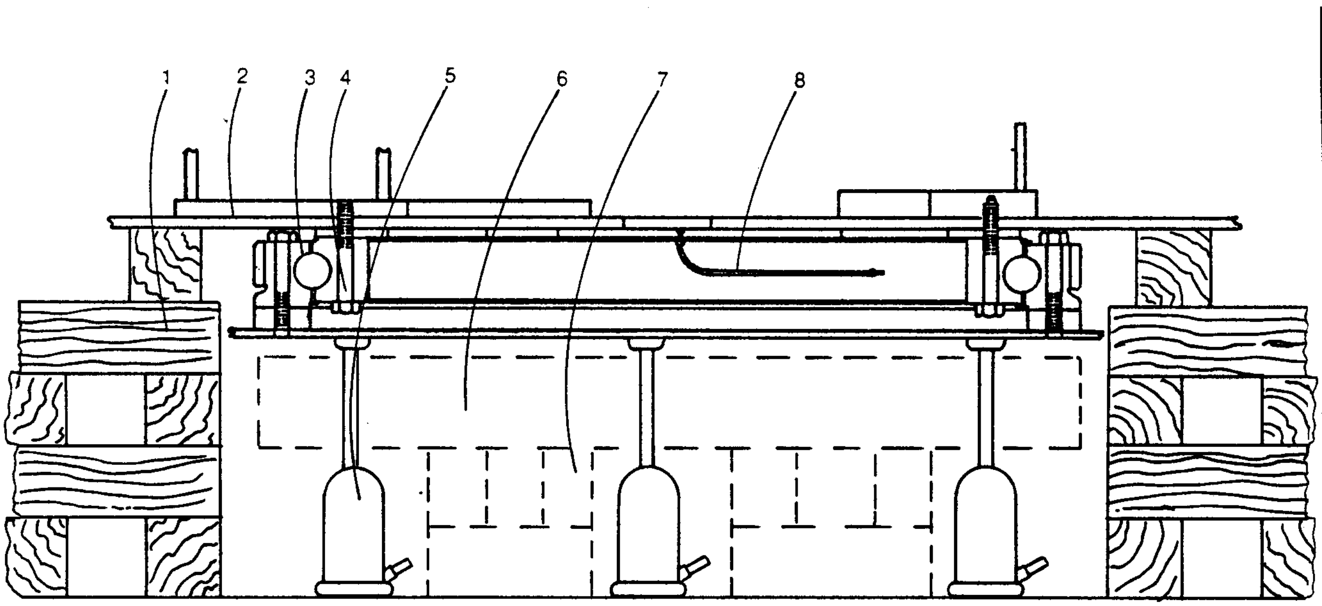



*Fig. 3. Turntable Bearing Removal*

(1) Blocking
(2) Revolving Frame
(3) Turntable Bearing
(4) Capscrews
(5) Hydraulic Jack
(6) Turntable Bearing (lowered onto blocking)
(7) Blocking
(8) Grease Line

shaft, to prevent the sling from slipping off. Install a cotter pin or capscrew and locknut in the hole at each end of the bail shaft to retain the washer or plate. Connect hook block from lifting equipment to the sling. Hoist against sling to provide some tension in the sling.

(c) Remove bearing cover plates from both sides of the revolving frame to expose the bearing and mounting capscrews.

(d) Remove the four capscrews (refer to Fig. 2, item 5) and install four positioning studs.

(e) Remove the remaining accessible mounting capscrews. With lifting equipment supporting the upper, start engine, engage master clutch, and swing slowly until all cap- screws are removed, and upper is totally supported by the lifting equipment.

Note: Capscrews are installed at the factory with "loctite" pipe sealant. Heating the cap- screws with a torch will loosen the "loctite" making capscrews easier to remove. Use a large heating tip. Apply heat to capscrew head only. Heat capscrew to a maximum temperature of 300°F (178°C). Overheating may ruin the bearing. Use a tempil stick or other means to check. WIhen replacing bearing or when machine is undecked, inspect each capscrew before reassembly. See Sr13-1-48.0 for procedure.

(f) Lift upper off the carrier cautiously. Upper must be as close to parallel to the carrier as possible to prevent binding on the alignment studs. Stay out from under the upper.

(g) Set the upper on blocking or trailer if being transported. Be careful not to damage S-o-M tubing or control linkage under the machine.

## 24.8 Tool List

Tools listed on page 3 are a big help decking or undecking 238A machines. The tools are available in tool kits 3P175 and 3P302. Con- tents of each kit are listed on page 3. Note: Number in brackets are "Snap On" tool numbers. The 3P16G tap is used to clean up threaded holes in bearing mounting.

## 24.9 Turntable Bearing Replacement (Fig. 3)

To replace turntable bearing, proceed as follows:

(a) Undeck machine as explained earlier in this section.

(b) Set the upper on blocking. Be careful not to damage S-o-M tubing or brake linkages underneath the upper. Use four piles of blocking, one under each corner of the machine. Block on main frame, not the deck plates or supports. Use a clean, dry, hard wood as blocking. Stack in a criss-cross manner as shown in Fig.3.

(c) Place three hydraulic jacks, evenly spaced, under , the bearing outer race. Jack up on each jack so the bearing will be supported when capscrews are removed.

(d) Disconnect grease lines (8) from bearings.

(e) Remove capscrews. Capscrews are installed with "loctite" and heat will make them easier to remove.

Note: Capscrews are installed at the factory with "loctite" pipe sealant. Heating the capscrews with a torch will loosen the "loctite" making capscrews easier to remove. Use a large heating tip. Apply heat to capscrew head only. Heat capscrew to a maximum temperature of 350°F (178°C).Overheating may ruin the bearing. Use a tempil stick or other means to check. When replacing bearing or when machine is undecked, inspect each cape before reassembly. See SM3-1-48. 0 for procedure.

(f) Lower bearing, slowly, onto blocking (7).

(g) Remove hydraulic jack.

(h) Skid bearing out from under machine.

(i) Slide new bearing under machine on the blocking. Align holes in bearing with mounting holes in the frame.

(j) Jack the bearing into place against the upper frame.

(k) Install mounting capscrews. Capscrews must be installed with "loctite". See page 2 for instructions. Turn each capscrew in by hand until head contacts bearing.

(l) Remove hydraulic jacks from under bearing.

(m) Final tighten each capscrew to 2770-3050 ft/lb. (3701-4075 N. m) torque. This is much easier if you use a torque multiplier. See tool list. This wrench has a 1" input and 1-1/2" output drive. It multiplies the torque put on a capscrew times 4.33 the ft/lb. that are put into the torque wrench. With this multiplier, it is necessary to only put 640-704 ft/lb. (855-941 N.m) torque on the wrench to apply 2770-3050 ft/lb. (3701-4075 N. m) on the capscrew.

(n) After final tightening the capscrews, allow the "loctite" to cure for approximately six hours.

(o) Install grease lines leading to the bearings.

(p) Install upper on carrier or mounting base.

## 48.1 General

The bolts can be reused after they have been removed. They must be thoroughly inspected before reuse. Any bolt that cannot pass the inspection must be scrapped, and not reused.

## 48.2 Inspection Procedure

(a) Remove the bolts using an accurate torque wrench of at least 6, 000 Ft.-lb. capacity.
(b) Any bolts that require more than 5, 800 Ft.-lbs. of torque to remove must be scrapped.
(c) After removal, thoroughly clean each bolt.
(d) Visually inspect each bolt for any signs of damage such as cracks, deformed threads, stretching, etc. If any damage is apparent, scrap the bolt.
(e) Check the thread pitch with a good quality thread gauge for the full thread length. Any bolt whose threads do not match the gauge for the full length of the threads must be scrapped.

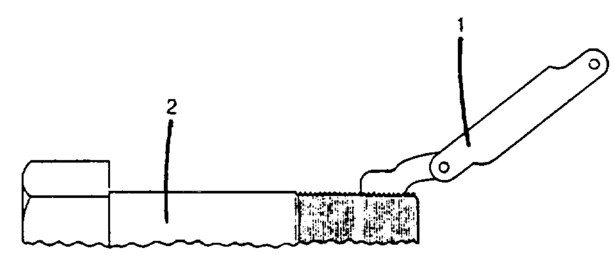



Fig. 1
Checking Thread Pitch With Gauge
(1) Thread Pitch Gauge
(2) Bearing Bolt

(f) All remaining bolts should be Wet Fluorescent Magnetic Particle inspected. See procedure later in this SM.
(g) Before installing bolts, chase the threaded holes in the frame with a bottom tap.
(h) Properly install and tighten the capscrews as described in the shop manual. See SM3-1-24.0.

## 48.3 Wet Fluorescent Magnetic Particle Inspection Procedure

The following equipment is required to perform the test.

(a) Magnetizing unit - A Magnaflux H-600 unit or equivalent with a current selection or control system and demagnetization capabilities shall be used to provide the current source. The unit shall be capable of delivering at least 3000 amperes of AC current, and shall have an ammeter that is readily observable for current flow during inspection.
(b) Liquid Penetrant - 0.20 to 0.25 concentration of 14A powder in Barton Deosene No. 487 or Apco 467 oil, or their equivalents. The suspension shall be circulated for at least 15 minutes before beginning inspection. Do not intermix different powders or materials from various manufacturers.

These materials can be flammable or emit hazardous and toxic vapors. Observe all manufacturers instructions and precautionary statements.

(c) Coil - A circular coil of sufficient size to receive the part and generate the required amperage.
(d) Lighting - A black (ultra-violet) light shall be used to perform the inspection. The black light intensity shall be a minimum of 800: '. /CMZ on the surface being inspected. This can be accomplished by holding a 100 watt black light 12 inches from the inspection surface.

The background or ambient light shall not exceed 3 foot-candles or 32 1X (Lux or Lumens per square meter). The black light shall be allowed to warm up for a minimum of 5 minutes prior to its use, or before intensity measurements are made.

## 48.4 Surface Preparation

The surface to be inspected shall be clean and dry, and free from oil, grease, sand, rust, scale, slag or paint. Wire brushing, sanding, blasting (shot or grit), detergent cleaning or solvent cleaning may be used to clean the surface.

## 48.5 Magnetizing Techniques

(a) Longitudinal magnetization - This procedure is intended to detect discontinuities primarily orientated in the circumferential direction. Connect the coil and place bolt threads against the side of the coil as shown in Figure 2, below. Flow fluid over threads of bolt for 3 to 5 seconds. Immediately energize coil upon stopping bath flow. Apply 1000 amperes of AC current for 1/2 to 1 second for magnetization. For bolts 1 inch and over in diameter, apply 1500 amperes of AC-current for 1/2 to 1 second. Repeat above procedure with bolt head against side of coil and fluid flowed-over the head and shank. Remove part from coil and inspect under black light.

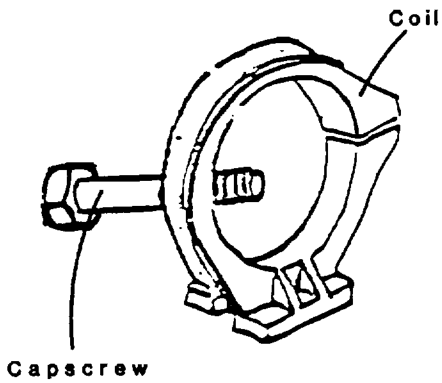



Fig. 2
Longitudinal Magnetization

(b) Circular Magnetization - This procedure is intended to detect discontinuities primarily orientated in the longitudinal direction. Place bolt longitudinally between the heads and clamp securely as shown in Figure 3, below. Flow fluid over the entire bolt for 3 to 5 seconds. Immediately energize the bolt upon stopping bath flow. Apply 2000 amperes of AC current for 1/2 to 1 second for magnetization. Remove part from heads and inspect under black light.

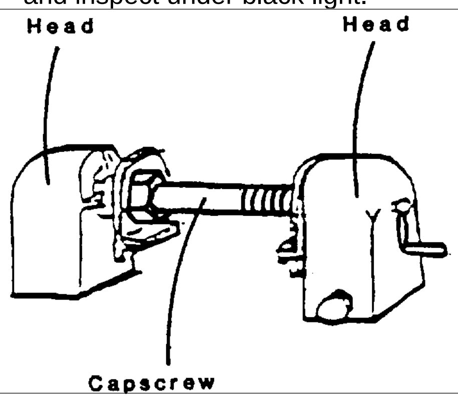



Figure 3
Circular Magnetization

48.6 Inspection

Note: Circular magnetization should be conducted before longitudinal magnetization if complete demagnetization is required.

(a) The inspection shall be performed after all machining operations, if required, are complete. Care should be taken in handling the parts to ensure that smudge marks are not placed on the areas to be inspected.

(b) Circumferential discontinuities (quench cracks, thread laps, folds or tool marks)- Fluorescent particles appear as weak or strong ragged or uniform lines of variable width. They may also appear as a single jagged or uniform line, or exist in groups. They may not have a definite line of continuity. They usually originate at the surface and generally become smaller as they go deeper, except for quench cracks. These appear as sharp, sometimes jagged surface discontinuities. Penetration can vary from minimal to almost complete penetration.

(c) Longitudinal discontinuities (seams, laps, folds or tool marks) - Fluorescent particle appearance is the same as that described in 48. 6, Step (a).

(d) Bursts, shear bursts, and forging cracks - Fluorescent particles appear as an isolated, irregular or jagged area or patch.

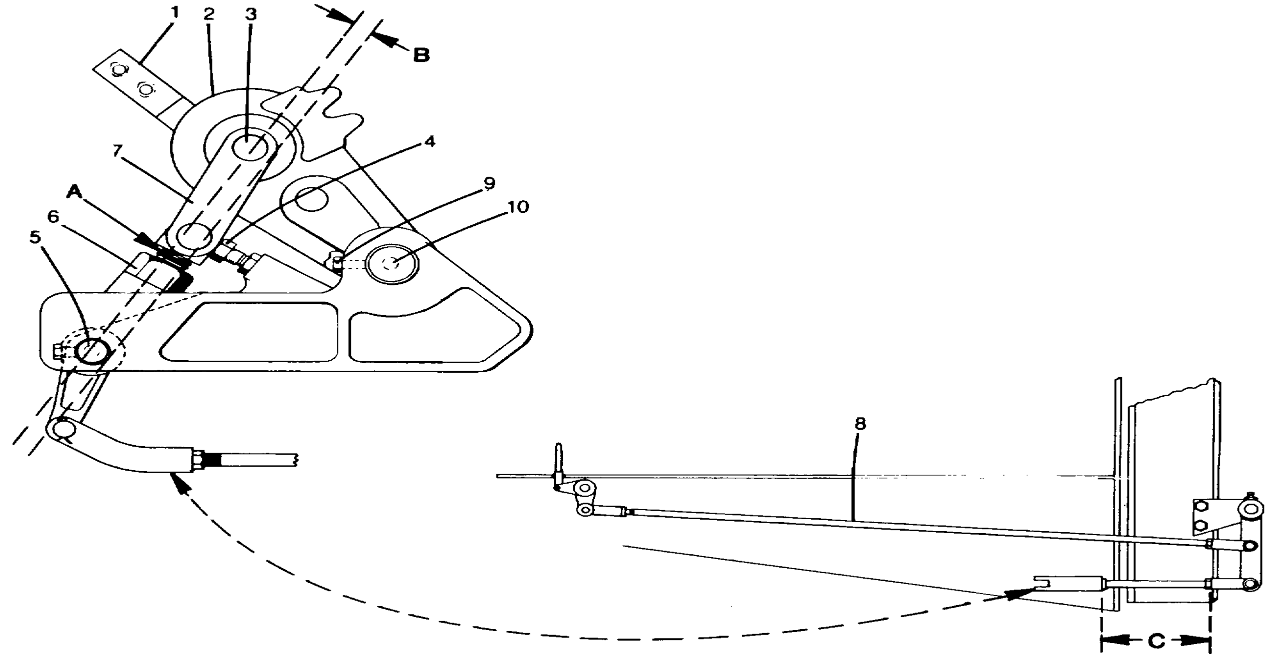
48.7 Acceptance Criteria

All bolts shall be free from quench cracks, and folds in radius corners, below the bearing surface and at the head/shank juncture. Seams, laps, bursts, shear bursts and forging cracks that exceed the requirements of SAE Recommended Practice J 1061, latest revision, are not permitted. Sharp tool marks at the head/shank juncture are not acceptable. Tool marks on the bearing surface shall not exceed the requirements of SAE J 1061, latest revision.

(a) Metallurginal examination and standard gaging techniques may be necessary to determine if seams, laps, bursts, shear bursts, forging cracks and bearing surface tool marks are rejectable.

48.8 Demagnetization

Clamp the bolt longitudinally as described earlier. Set current at 2500 amperes AC, or greater if necessary as indicated with the field inductor and depress (activate) demagnetization button or switch for approximately four seconds until current has decayed to zero as indicated on the ammeter.




NA229-C

Fig. 1
Swing Lock Assembly

| | | |
|---|---|---|
| (B) 3/8" to 1/2" (9.5 to 12.7 mm) | (3) Pin | (7) Linkage |
| (C) 8-1/4" (209. 5 mm) | (4) Stop Bolt | (8) Linkage Rod |
| (1) Pawl Bracket | (5) Pin | (9) Jam Nut |
| (2) Pawl | (6) Nut | (10) Pin |

12.1 Swing Lock Adjustment (Refer to Fig. 1)

(a) Adjust the linkage at ’A’, between pins (3) and (5), to the maximum length to provide firm tooth engagement with the control lever in its detent. Back off adjustment at ’A’ one full turn for proper clearance. Tighten nut (6).
(b) Adjust rod length at ’C’ to 8-1/4" (209.5mm).
(c) Adjust stop bolt (4) to allow linkage (5) to toggle overcenter 3/8" to 1/2" (9. 5 to 12.7 mm) when the pawl is engaged and the lever is locked in its detent.
(d) Adjust the linkage rod (8) until the pawl teeth will clear the ring gear teeth by 3/16" (4. 76 mm) with the pawl disengaged and the lever in its detent.

**WARNING**

Anchor The Upper Machinery Against Rotation By Lowering The Attachment To The Ground Before Working On Swing Lock.

12.2 Pawl Removal (Refer to Fig. 1)

(a) Anchor upper against movement (see previous caution).
(b) Remove capscrews from pawl bracket (1). Remove pawl support.
(c) Remove pin (3). Swivel connecting links out of the way.
(d) Remove jam nut and lockscrew (9). Remove pin (10). Remove pawl from machine.

12.3 Pawl Replacement

(a) Set pawl in place in brackets. Install pin (10). Install and tighten lockscrew and jam nut (9).
(b) Swivel links into place over pawl. Install pin (1). Install two shim washers on top of pin then install cotter pin.
(c) Install pawl support. Shim under pawl support to line up pawl teeth with ring gear teeth. The following shims are available for use at this point:

(1) 18J35 ...................... 14 Ga.
(2) 18J240 ..................... 18 Ga.

(d) Check adjustment of pawl as explained previously in this SM.

12.4 Swing Lock Control Adjustment (Refer to Fig. 2)

(a) Disengage swing lock lever to latched position, adjust capscrew (6) to have 1/16" ( 1. 6 mm) clearance between head and and ball joint.

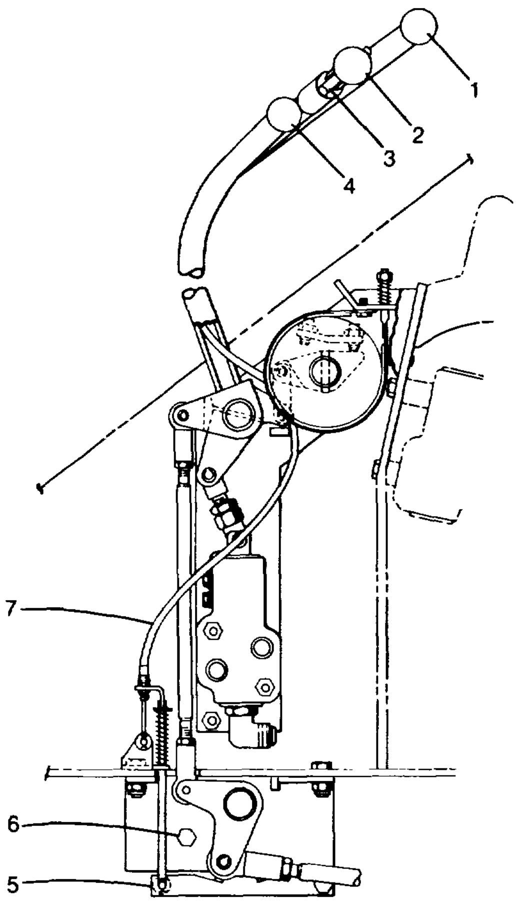



Fig. 2 NA210-D
Swing Lock Controls

(1) Swing Brake Control
(2) Swing Lock Control
(3) Detent Control
(4)Master Clutch Control
(5) Detent Lever
(6) Capscrew
(7) Push Pull Cable

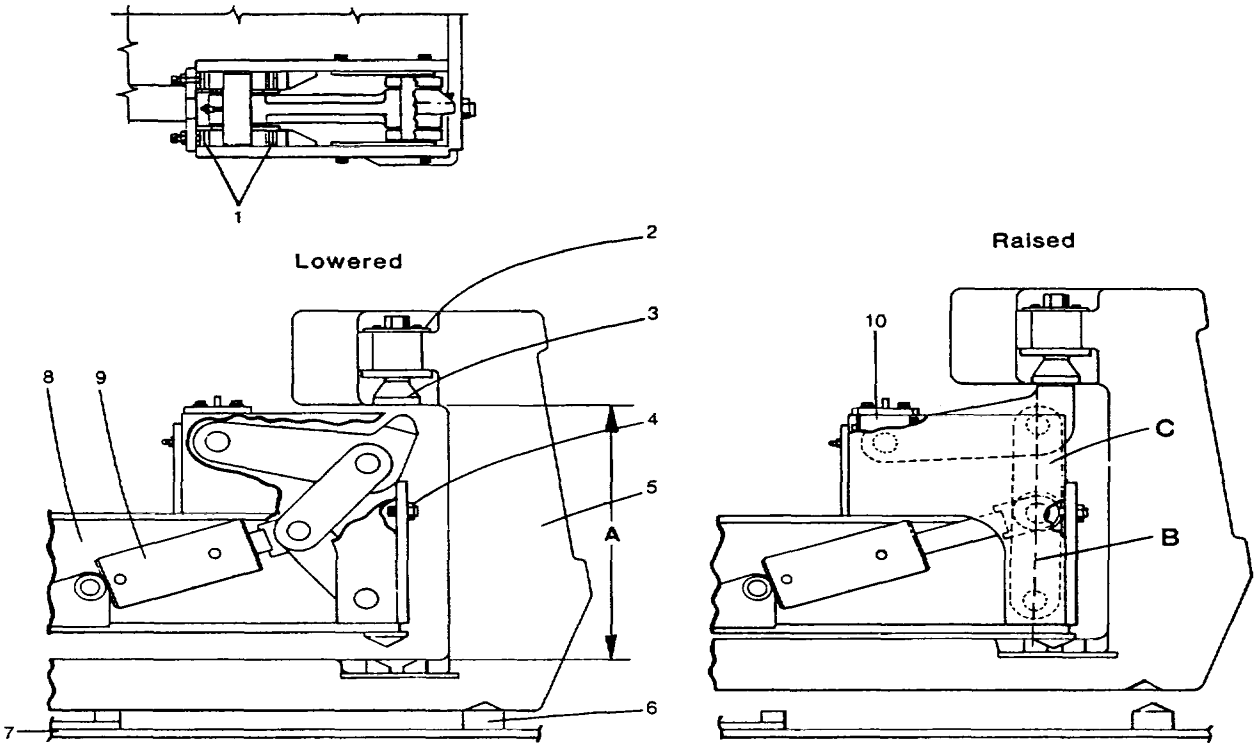



Fig. 1 NA217-C

Counterweight Remover Assembly - Early Machines Only

(A) 26-1/2" (673.1mm)

(B) Position of Linkage Toggled 1/4" (6.35mm) Over Center

(C) Position of Linkage Top Dead Center

| | | |
|---|---|---|
| (1) Shims | (5) Counterweight | (8) Upper Frame |
| (2) Lock Plate | (6) Positioning Blocks | (9) Cylinder |
| (3) Adjusting Screw | (7) Truck Frame | (10) Bearing Block |
| (4) Setscrew/Jam Nut | | |

The counterweioht remover consists of two hydraulic cylinders connected to linkaqe at the rear of the revolving frame. The remover system is used to set the counterweight on the carrier deck, or to lift it into place from the carrier deck. It also holds the counterweight in place on the machine during operation.

4.1 Counterweight Remover Adjustment - Early Machines Only

The counterweight is adjusted as follows:

4.2 Preliminary Adjustment - Early Machines Only

Must be made with counterweight off the machine.

(a) Before placing the counterweight on the positioninq blocks, fully extend the cylinders. Adjust the set screw (4) until the linkage toggles over center 1/4" (6. 35mm). Toqglinq over center provides a mechanical lock up which eliminates the requirement of hydraulic pressure to hold the counterweight in place. All down forces are transmitted into the hydraulic cylinders. Tiqhten jam nuts on the

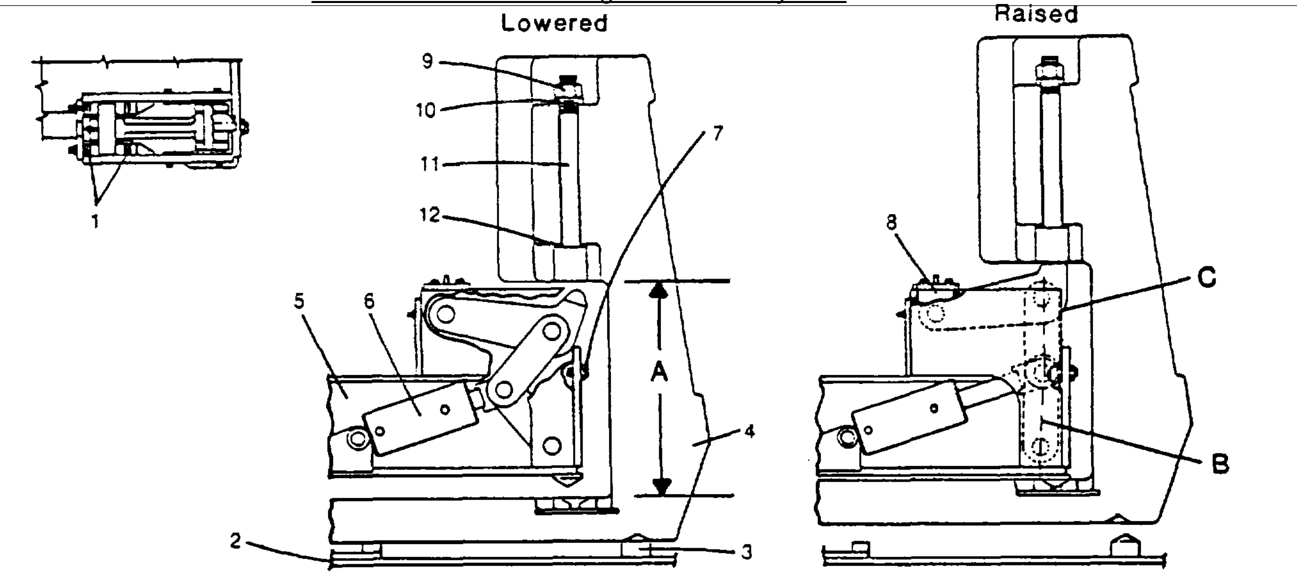



Fig. 2 NA217-C

Counterweight Remover Assembly - Later Machines Only

(A) 26-1/2" (673.1mm)

(B) Position Of Linkage - Toggled 1/4" (6.6mm) Over Center

C) Position Of Linkage - Top Dead Center

(1) Shims
(2) Carrier Frame
(3) Positioning Block
(4) Counterweight
(5) Upper Frame
(6) Cylinder
(7) Set Screw (W/Nut)
(8) Bearing Block
(9) Jam Nut
(10) Spacer
(11) Adjusting Screw
12) Shims

set screws after adjustment.

(b) The counterweight may now be positioned on the blocks (6) on the carrier bed.

(c) Remove the lock plates from adjusting screws (3).

(d) Turn the adjusting screw until dimension "A" is 26-1/2" (673.1mm).

4.3 Final Adjustment - Early Machines Only

Must be made with the counterweight on the machine. See Fig. 1.

(a) Raise up the counterweight until the linkage is at the top dead center position. (The three linkage pins are in line and the counterweight is in the maximum up position. )

(b) Tighten down both adjusting screws (3). Replace both lock plates.

(c) To level the counterweight when it is in the raised position (correct any forward or backward tilt), move shims from one side of the bearing block to the other. Adjust each bearing block as necessary. It may be necessary to readjust set screws, after changing shims.

Note: The counterweight must be lowered to the carrier bed before moving the bearing block and shims.

4.4 Counterweight Remover Adjustment - Later Machines Only

The counterweight remover is adjusted as follows:

4.5 Preliminary Adjustment - Later Machines Only

Must be made with the counterweight off the machine. See Fig. 2.

(a) Before placing the counterweight on the positioning blocks, fully extend the hydraulic cylinders. Adjust the set screws (7 in Fig. 2) until the linkage toggles over center 1/4" (6. 6mnm). See Dimension "B" in Fig. 2. This adjustment is very important. Toggling over center provides a mechanical lock up which eliminates the requirement for hydraulic pressure to hold the counterweight in place. All down forces are transmitted into the linkage and set screw instead of into the hydraulic cylinders. Tighten jam nuts on the set screws after adjustment.

(b) The counterweight may now be positioned on the blocks of the carrier bed.

(c) Check dimension "A" in Fig. 2. Dimension "A" measures 26-1/2" (673.1mm) from the bottom of the adjusting screw (11 ) to the inside surface of the counterweight. See Fig. 2. To set dimension "A", loosen the jam nuts (9). Next add or remove shims (12) on the adjusting screws (11). After you set dimension "A", tighten the jam nuts (9).

4.6 Final Adjustment - Later Machines Only

Must be made with the counterweight on the machine. See Fig. 2.

(a) Raise the counterweight until the linkage is at top dead center position (the three linkage pins are in line and counterweight is in maximum up position. ). See Fig. 2.

(b) To level the counterweight when it is In the raised position (correct any forward or backward tilt), move shims from one side of the bearing block to the other. Adjust each bearing block as necessary. It may be necessary to readjust set screws (7) after changing shims. 3

Note: The counterweight must be lowered to the carrier deck before moving the bearing block and shims.

4.7 Cylinder Removal - All Machines

To remove cylinders for repair or replacement proceed as follows:

(a) Refer to operating instructions. Lower counterweight to carrier deck, then swing out of it. Block under cylinders so they won't fall when pins are removed.

(b) Remove pins which connect cylinder rod tang to linkage. Fold linkage out of the way.

(c) Disconnect lines leading to hydraulic cylinder. Cap or plug all openings to prevent entry of foreign material.

(d) Remove pin which connects cylinder case to revolving frame lugs.

(e) Remove cylinder from machine.

4.8 Cylinder Disassembly And Repair - All Machines

Refer to SM3-10-6.0 for disassembly and repair procedures.

4.9 Cylinder Replacement - All Machines

(a) Set cylinder in place. Install pin to connect cylinder case to revolving frame lugs.

(b) Block cylinder up at appropriate angle for installing pins.

(c) Rotate linkages into position on either side of cylinder rod tang.

(d) Install pin.

(e) Connect hydraulic lines.

(f) Fully extend and retract cylinder several times while checking for leaks. If any leaks appear, repair before further use.

(g) Refer to Operators Manual and install counterweight.

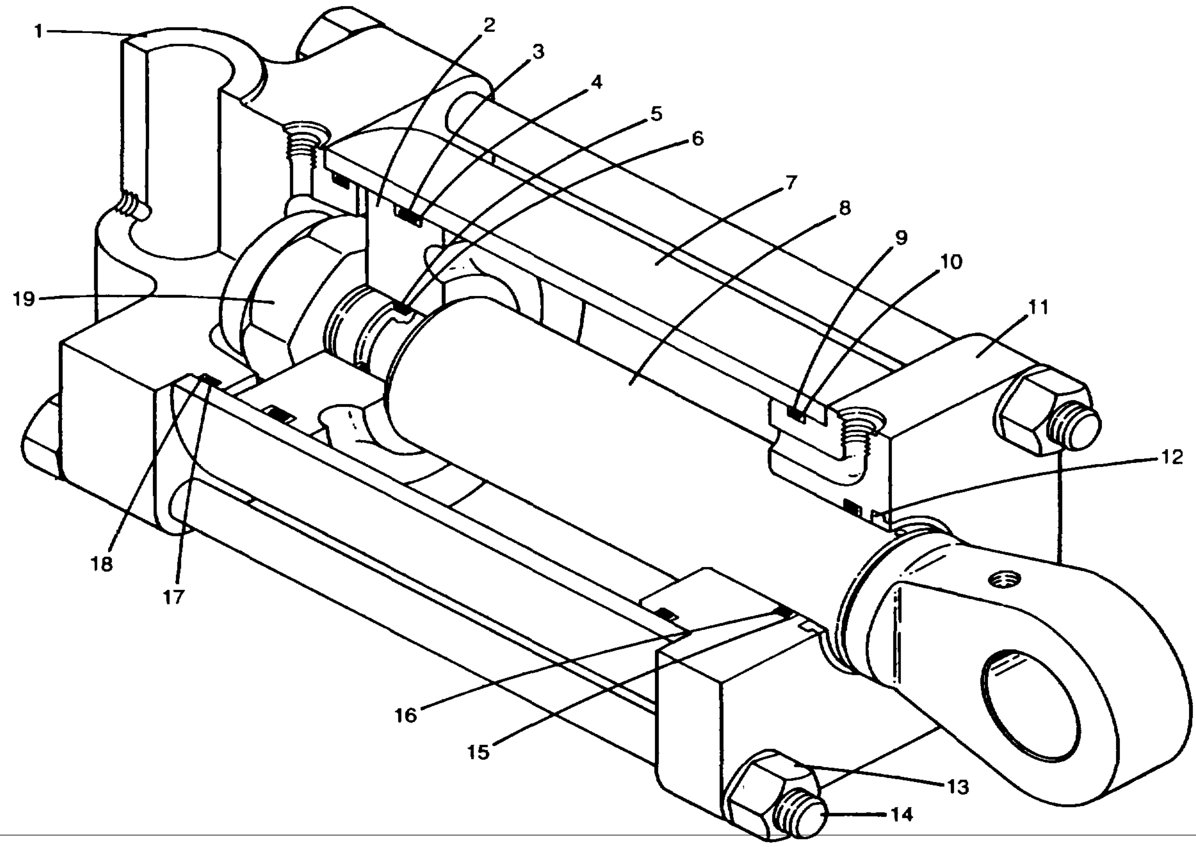



Fig. 1 L665-B

Counterweight Cylinder

| | | |
|---|---|---|
| (1) End Cap | (8) Rod | (15) Backup Ring |
| (2) Piston | (9) "0" Rinq | (16) "O" Ring |
| (3) "O" Ring | (10) Backup Ring | 17) "O" Ring |
| (4) Backup Rings | (11) Gland | (18) Backup Ring |
| (5) "0" Ring | 12) Wiper Seal | 19 Locknut |
| (6) Backup Rings | 13) Nut | |
| (7) Case | (14) Tie Bolts | |

6.1 Counterweight Cylinder Removal

See SM3-10-4.0 for removal procedure.

6.2 Cylinder Disassembly

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(a) Thoroughly clean exterior of cylinder with an approved solvent.

(b) Remove nuts (13) and washers from the bolts. Remove tie bolts from cylinder.

(c) Remove rod, gland, and piston assembly as a unit. Remove locknut (19) from rod. Remove gland and piston from rod.

(d) Remove end cap from cylinder case.

(e) Remove and discard all old "0" rings, back up rings, and seals.

6.3 Cylinder Reassembly

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(a) Thoroughly clean all parts in approved solvent. Examine all parts for scratches, nicks, or other damage. Replace any damaged parts.
(b) Install "O" ring (16) and back up ring (15) in groove in I.D. of gland. Seal is installed with lip to the outside.
(c) Lubricate I.D. of gland with Cosmolube #2 or equal. Slide gland onto rod, being careful not to damage seals.
(d) Install "O" ring (5) with a back up ring on each side of it in groove on turned down portion of rod.
(e) Lubricate I.D. Of piston with Cosmolube #2 or equal. Install piston on rod. Install locknut and tighten to 600-625 ft/lbs. (801.6-835 N.m) torque.
(f) Install "O" ring (3) with a back up washer on each side in groove in O. D. of piston.
(g) Install an "O" ring (9) and back up washer (10) in groove in O. D. of gland. Back up ring goes toward outside of cylinder.
(h) Install "O" ring (17) and back up ring (18) in groove in O. D. of end cap. Back up ring goes toward outside of cylinder.
(i) Lubricate end cap with Cosmolube #2 or equal and install on cylinder. Be careful not to damage "O" ring during installation.
(j) Lubricate O. D. of gland and of piston with Cosmolube #2 or equal. Slide piston and gland into cylinder case, being careful not to damage "0" rings.
(k) Turn gland as necessary to align inlet and outlet ports with each other.
(l) Install tie bolts, lockwashers, and nuts. Evenly tighten nuts to 280-300 ft/lbs. (374-401 N. m) torque.
(m) Install cylinder on machine as explained in SM3-6-4.0.

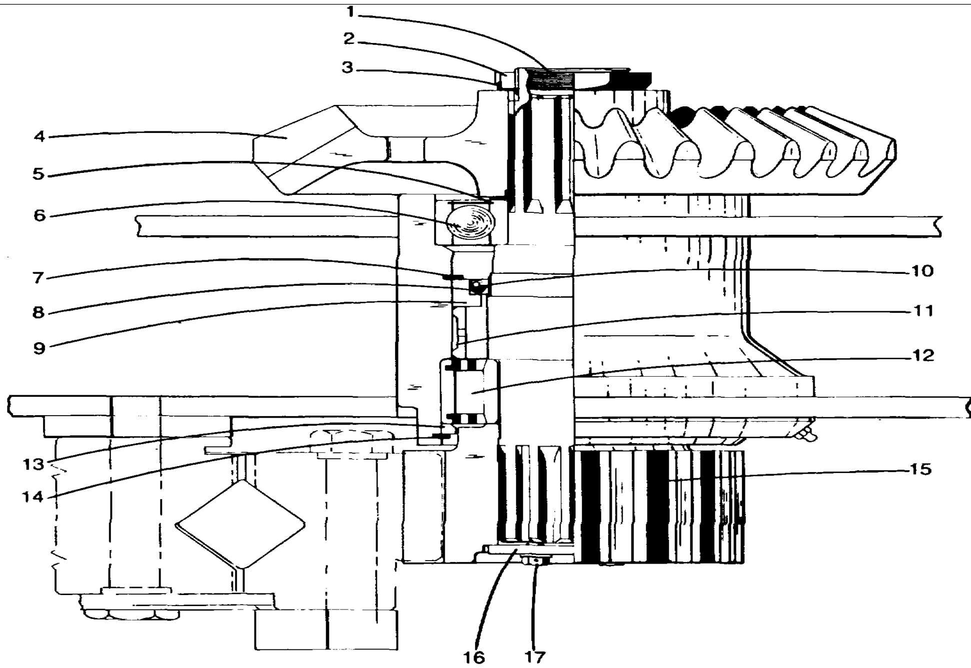



Fig. I NA3-C
Vertical Swing Shaft

| | | |
|---|---|---|
| (1) Vertical Swing Shaft | (7) Snap Ring | (13) Grease Retainer |
| (2) Locknut | (8) Seal | (14) Snap Ring |
| (3) Lockwasher | (9) Seal Retainer | (15) Swing Pinion |
| (4) Bevel Gear | (10) Wear Sleeve | (16) End Cap |
| (5) Shims | (11) Spacer( | (17) Capscrews |
| (6) Bearing | (12) Bearing | |

The vertical swing shaft is powered by the swing reverse shaft (See SMS-1-13) through a pair of bevel gears. The swing shaft swings the upper through a pinion splined to its lower end which is in mesh with the gear teeth on the turntable bearing. (See SM3-1-24.0.)

4.1 Swing Pinion Removal

The swing pinion may be removed without disturbing the swing shaft as follows:

(a) Swing the upper until swing pinion lines up with the notch in the bearing mounting plate on the truck frame.
(b) Engage the swing lock to prevent movement of the upper machinery.
(c) Unbolt and remove the pinion end cap.
(d) Remove pinion from swing shaft.

A new pinion may be installed by following removal procedure in reverse. Wire the two capscrews in end cap together after assembly.

4.2 Swing Shaft Removal

There is a hole provided in the truck fender to lower the shaft through. The hole has a cover that must be removed before removing shaft. Cover must be replaced after shaft is replaced, Remove the shaft from the machine as follows:

(a) Remove wheel and tire assemblies below cover plate.
(b) Remove swing pinion as explained previously in this section.
(c) Drain oil from bevel gear case. (See Section 2 in Operators Manual.)
(d) Remove cover plate from the bevel gear case. Remove snap ring and grease retainer from bore above swing pinion.
(f) Bend down the ears on the lockwasher on top of shaft.
(g) Alternately unscrew locknut and pry down to shaft until locknut and washer may be removed.
(h) Remove the shaft out the bottom of its

housing.

Note: Shaft weights 70 pounds. Lower it from bore with a hydraulic jack.

The lower bearing will be removed with the shaft. The upper bearing, seal, oil retainer, and spacer will remain in place. After removal of the bevel gear, these components may be removed out of the top of the bore. The horizontal swing reverse shaft must be removed to allow removal of the bevel gear. (See SM5-0-7.0 for more information.)

4.3 Swing Shaft Reassembly

(a) Examine the wear sleeve on vertical shaft. If it is scratched or damaged, replace it.
(b) If the oil retainer has been removed, it must be replaced as follows:
  (1) Thoroughly clean spacer (11) and install in bore.
  (2) Thoroughly degrease retainer, and bore where retainer fits with Loctite Safety Solvent.
  (3) Apply Locquic Primer (16M118) to retainer and bore. Allow 3 to 5 minutes to dry.
  (4) Cover contact area in bore with Loctite Pipe Sealant (16A845).
  (5) Install retainer in bore. Install snap ring (7) in bore.
  (6) Allow assembly to cure for approximately 6 hours.
(c) Install a new seal in oil retainer with lip up.
(d) Install upper bearing in bore with shield up.
(e) Install lower bearing on shaft. Make sure bearing bottom on shaft shoulder.
(f) Install the pinion, end caps, and capscrews on shaft. Tighten capscrews.
(g) Slide shaft into bore until bearing starts into housing.
(h) Slowly jack the shaft up into place with a hydraulic jack. If the bevel gear was not removed, make sure the shaft splines start through the gear properly.
(i) Install lockwasher and nut on top of shaft. Alternately tighten nut and jack up on shaft until shaft is in place and locknut is tight.
(j) Remove end cap and pinion from lower end of swing shaft.
(k) Install grease retainer and snap ring in bearing bore.
(1) Install the pinion, end cap, and capscrews. Wire capscrews heads together after tightening.
(m) Make sure shaft locknut is tight. Bend up ears on lockwasher to lock locknut in place.
(n) Install bevel gear case cover plate.
(o) Refill bevel gear case with lubricant as specified in Section 2 in Operators Manual.
(p) Replace wheels and tires.

4.4 Bevel Gear Adjustment

See "Bevel Gear Adjustment" in SM5-1-13. 0

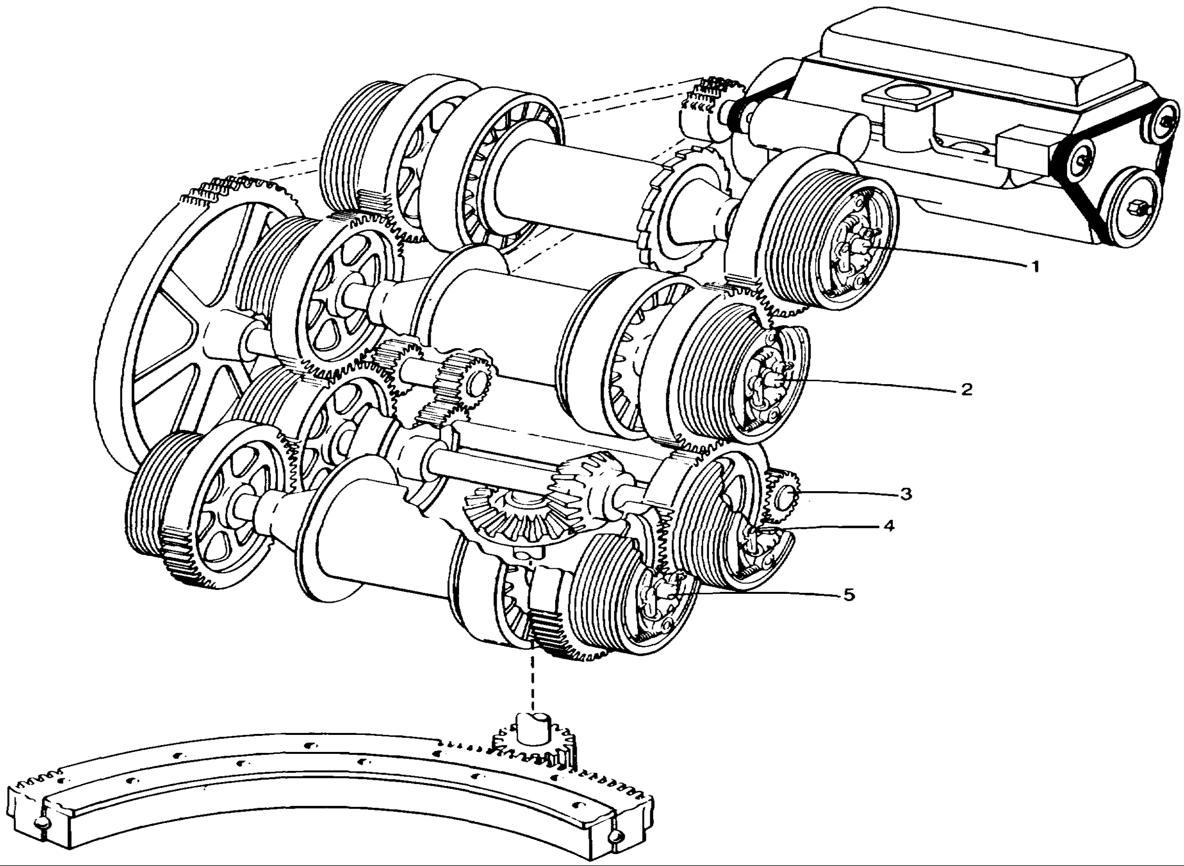



Fig. 1 NA357-C
Horizontal Shafts (General)

(1)Boom Hoist Shaft
(2)Rear Drum Shaft
(3) Reduction Shaft
(4) Reverse Shaft
(5) Front Drum Shaft

All horizontal shafts are mounted in anti friction bearings in the upper frame. When the engine is running and the master clutch is engaged, the reduction shaft, gears and clutch drums turn. The horizontal shafts do not turn until a clutch is engaged.

Power to the L..H. gear train is transferred from the L..H. reduction shaft pinion to the L..H. reverse shaft gear. The reverse shaft (4) gear transfers power into the front drum (5) and rear drum. (2). The rear drum (2) gear is in mesh with the boom hoist (1) gear and drives it.

Power to the R.H. gear train is transferred from the R.H. reduction shaft (3) pinion to the R. H. Reverse shaft (4) gear. The reverse shaft (4) gear transfers power into the rear drum (2) and front drum (5). The rear drum (2) gear is in mesh with the boom hoist (1) gear and drives it.

When a clutch, which is splined to the end of a horizontal shaft, is engaged with its mating drum, which is bolted to the side housing gear, the shaft will turn. Two directional power is obtained by rotating the gears on each end of the shaft, in opposite directions.

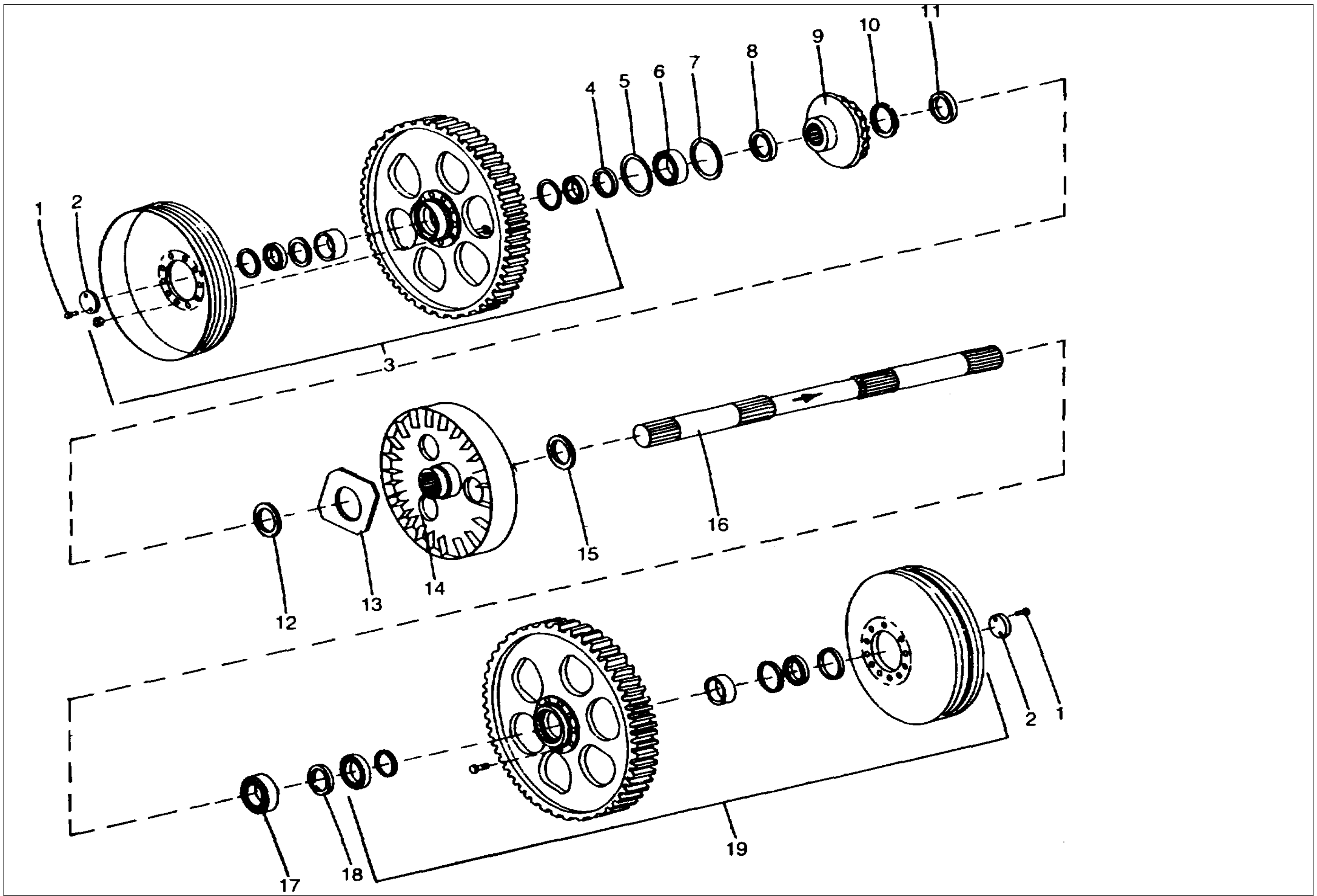



Fig. 1 NA352-C

Reverse Shaft Assembly

| | | | |
|---|---|---|---|
| 1) Capscrew | (5) Snap Ring | (10) Snap Ring | (15) Snap Ring |
| (2) End Cap | (6) Bearing | (11) Split Oil Seal | (16) Shaft |
| (3) L.H. Clutch Drum & Gear Assembly | (7) Snap Ring | (12) Snap Ring | (17) Bearing |
| (4) Shims & Spacer | (8) Shims & Spacer | (13) Hydroil Washer | (18) Shims & Spacer |
| | (9) Bevel Gear | (14) Swing Brake Drum | (19) R.H. Clutch Drum & Gear Assembly |

13.1 Reverse Shaft Removal

(a) Engage swing lock. Shut down engine. Drain oil from bevel gear case.

(b) Remove chain case and chain wheel. Refer to SM6-39-6. 0 for more information.

(c) Remove upper cover plate from bevel gear case.

(d) Remove R.H. and L. H. clutch assemblies. Refer to SM5-9-4. 0 for more information.

(e) Slide both clutch drum and gear assemblies from the shaft. The assemblies will slide off after the clutch spiders are removed.

(f) Unbolt seal retainer on side of bevel gear case. Remove split oil seal (11).

(g) Remove snap ring (10) which holds bevel gear in place on shaft, from its groove.

(h) Remove snap rings (12 & 15) which hold swing brake drum on shaft, from their grooves.

(i) Remove spacer and shims (4) from shaft.

(j) Remove shaft (16) out R. H. side of machine. It may be necessary to tap on bevel gear and swing brake drum until they slide off of shaft splines.

(k) Bearing (17) will remain on shaft. Bearing (6) will remain in its bore. Remove snap ring (5) to remove bearing (6).

(l) Retain shims (8) for later reassembly.

13.2 Shaft Reassembly

(a) Install bearing (6) in its bore with shield in. Install snap ring (5).
(b) Install bearing (17) on shaft with shield in.
(c) Temporarily install shaft through swing brake drum (14), bevel gear(9), spacer and shims (8).
(d) Push bevel gear (9) to the left as far as it will go (toward spacer). Check bevel gear backlash. It should be . 016" to . 022". The backlash is adjusted by adding or subtracting shims behind the bevel gear on the reverse shaft, and under the bevel gear on the vertical swing shaft. The following shims are available for use at this point:
(1) Reverse Shaft . . . . . . 22C26
(2) Swing Shaft .. . . . . . . 22F5

Note: All shims are 20 gauge.

(e Retract shaft (16) toward R.H. side of machine until it just clears swing brake drum (14). Install snap ring (15). Slide shaft through drum and install hydroil washer (13) and snap ring (12). Slide shaft through wall of bevel gear case and install seal retainer w/gasket, and snap ring (10).
(f) Push shaft on through bevel gear (9), spacer and shims (8), and L..H. bearing (6) until it is in place.
(g) Install spacer (4) over shaft. Install L.H. clutch drum and gear assembly (8). Check spur gear alignment with gears on front and rear drum. If necessary, shim behind spacer until full tooth contact is achieved. Use 22C26 - 20 Ga. shims. Install clutch assembly. See SM5-9-4.0.
(h) Install spacer (18) over R.H. end of shaft. Install R.H. drum and gear (19). Shim as described in Step (g). Install R.H. clutch assembly on shaft. See SM5-9-4.0.
(i) Install split oil seal (11) in seal retainer plate. Service replacement seals are split, and are installed with the split at the top. Install and tighten down seal retainer.
(j) Install bevel gear case cover and gasket. Fill bevel gear case with lubricant as specified on lubrication chart.
(k) Lubricate side housing bearings as shown on lubrication chart before operating machine.
(l) Install chain wheel and chain case on machine. Refer to SM6-39-6.0.
(m) Connect all S-o-M lines leading to clutches.

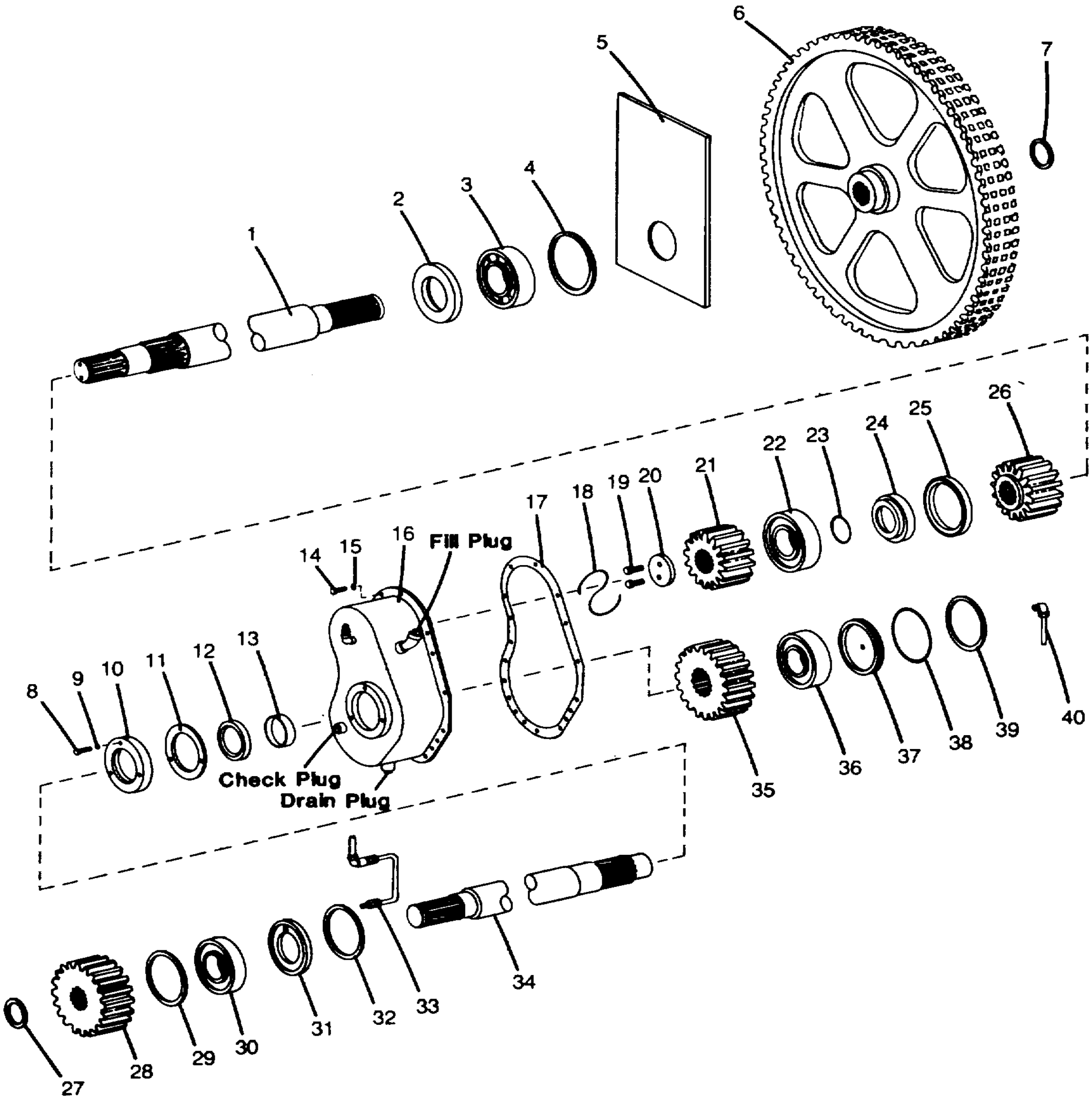



Fig. 1 NA381-C
Reduction Shaft

| | | | |
|---|---|---|---|
| (1) Upper Reduction Shaft | (11) Gasket | (21) Gear (16 teeth) | (31) Grease Retainer |
| (2) Grease Retainer | (12) Split Seal | (22) Bearing | (32) Snap Ring |
| (3) Bearing | (13) Wear Sleeve | (23) 'O' Ring | (33) Grease Line Assembly |
| (4) Snap Ring | (14) Locking Capscrews | (24)Grease Retainer | (34) Lower Reduction Shaft |
| (5) Hydroil Washer | (15) Washers | (25)Oil Seal | (35) Gear (22 teeth) |
| (6) Chain Sprocket (171 teeth) | (16) Gear Housing | (26) Gear (16 teeth) | (36) Bearing |
| *(7)* Snap Ring | (17) Gasket | (27) Snap Ring | (37) Grease Retainer |
| (8) Capscrews | (18) Lockwire | (28) Gear (22 teeth) | (38) 'O' Ring |
| (9) Washers | (19) Capscrews | (29) Snap Ring | (39) Snap Ring |
| (10) Seal Retainer | (20) End Caps | (30) Bearing | (40) Grease Line Assembly |

9.1 Lower Shaft Removal

(a) Engage swing lock. Disengage master clutch. Shut down engine.
(b) Drain oil from gear housing (16).
(c) Remove snap ring (27) and gear (28) from shaft (34).
(d) Remove snap ring (29) which retains bearing (30) in its bore.
(e) Remove snap ring (39) and grease retainer (37) from shaft.
(f) Remove capscrews (14) which hold gear housing in place on side housing.
(g) Bump shaft toward left side of machine until bearing (36), gear (35), and gear housing (16) can be removed from shaft.
(h) Remove shaft (34) out left side of machine. Remove bearing (30) from shaft.

9.2 Lower Shaft Replacement

(a) Install bearing (30) on shaft (34).

Note: Bearing is shielded and is installed with the shield out.

(b) Slide the shaft in through the left bearing bore.
(c) Inspect seal (12) and wear sleeve (13); replace if worn or damaged.

Note: A split seal is available for field replacement without removing the shaft. The split must be at the top of the shaft.

(d) Install gear housing (16) over right end of shaft. Install gear (35) and bearing (36) on shaft.

Note: Bearing is shielded, and is installed with the shield to the inside.

(e) Position gasket (17); then push gear housing and shaft into place. Install capscrews (14) with washers (15) and tighten.
(f) Install grease retainer (37). There is an 'O' ring (38) around circumference of the retainer. If 'O' ring is worn or damaged, replace it. Install snap ring (39) which holds retainer in place.
(g) Install snap ring (29) which holds bearing (36) in place. Install gear (28) and retaining snap ring (27).
(h) Before operating machine, lubricate shaft bearings and fill gear housing with lubricant as specified on the Lubrication Chart found in the Operator's Manual.

9.3 Upper Shaft Removal

(a) Engage swing lock. Disengage master clutch. Shut down engine.
(b) Remove engine fuel tank. Drain lubricant from chain case. Remove chain case cover. Remove engine drive chain.
(c) Remove mounting capscrews from chain case. Remove snap ring (7) which retains chain sprocket (6) on upper shaft (1).
(d) Slide chain sprocket (6) off shaft and remove it. Remove chain case.
(e) Remove snap ring (4) which holds bearing (3) in outboard bearing housing.
(f) Drain lubricant from gear housing (16). Remove mounting capscrews (14) from housing. Slide housing away from side housing. Remove capscrews (19) and end cap (20) which hold gear (21) on the shaft. Remove gear (21) from shaft.
(g) Bump shaft (1) toward right side of machine until bearing (22), retainer (24), and the outer gear (26) can be removed from the shaft.
(h) Remove shaft out right side of machine. Remove outboard bearing (3) from shaft.

9. 4 Upper Shaft Replacement

(a) Install bearing (22) in its bore.
Note: Bearing is shielded and is installed with shield to the inside.
(b) Install grease retainer (2) and bearing (3) on shaft.
Note: Bearing is shielded and is installed with the shield to the outside.
(c) Start the shaft through the outboard bearing support. Install gear (26) in place on the shaft. Install grease retainer (24) on shaft. Inspect oil seal (25); replace if worn or damaged. Install new '0' ring (23). Push shaft on into place in machine, being careful not to damage oil seal (25).
(d) Install gear (21) on shaft.
(e) Install end cap (20) and capscrews (19) to retain gear on shaft. Lockwire capscrews (19).
(f) Push gear housing (16) into place against side frame. Install capscrews (14) with washers (15) and tighten.
(g) Install snap ring (4) which retains outboard bearing (3) in its housing.
(h) Set chain case in place. Install hydroil washer (5). Install chain sprocket (6). Install snap ring (7) to retain chain sprocket.
(i) Finish installation of drive chain and chain case. Refer to SM6-39-6. 0 for assembly instructions.
(j) Lubricate all bearings as specified on Lubrication Chart found in Operators Manual before operating machine.
(k) Fill chain case and gear housing with lubricant as explained in the Operators Manual before operating machine.

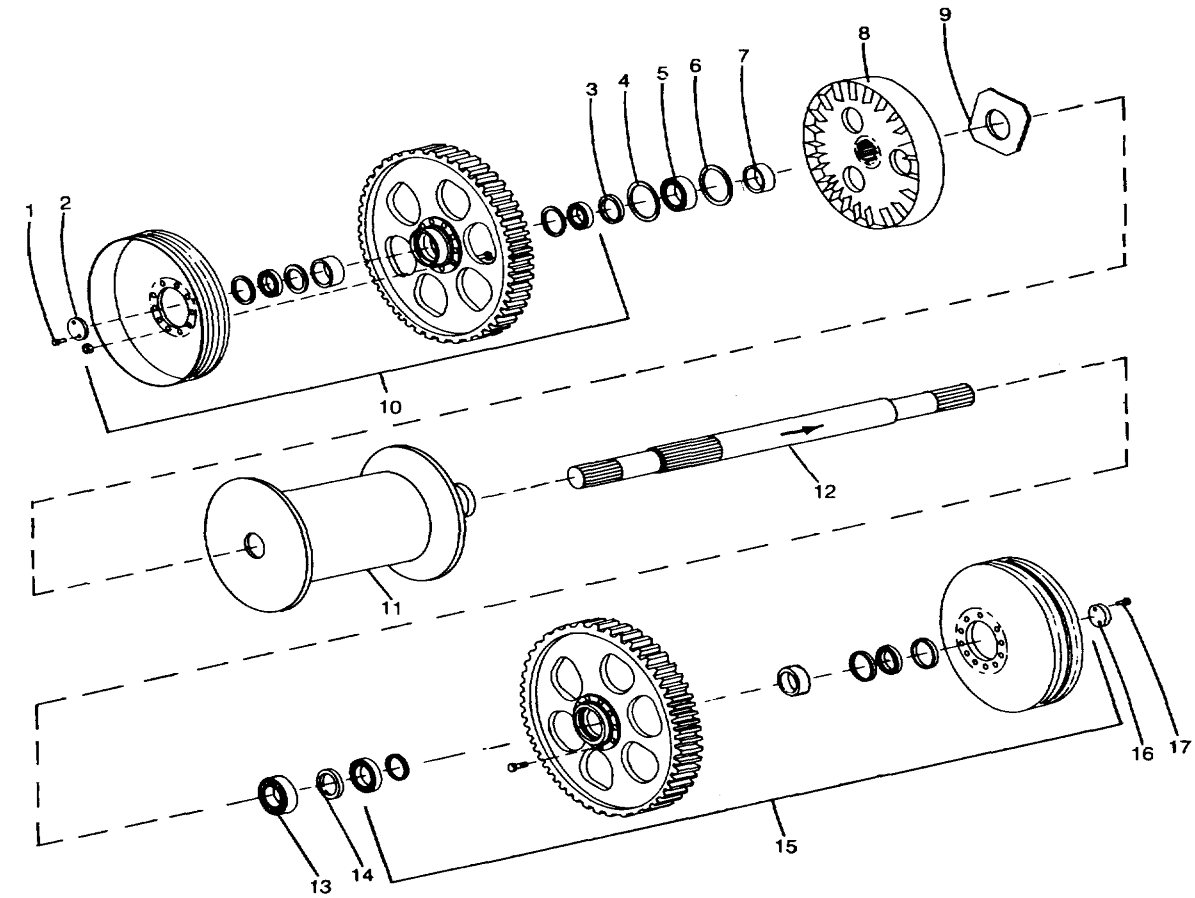



Fig. 1 NA352-C

Front Or Rear Drum Shaft

| | | | |
|---|---|---|---|
| (1) Capscrew | (6) Snap Ring | (11) Rope Drum | (16) End Cap |
| (2) End Cap | (7) Spacer | (12) Shaft | (17) Capscrew |
| (3) Shims & Spacer | (8) Brake Drum | (13) Bearing | |
| (4) Snap Ring | (9) Hydroil Washer | (14) Shims & Spacer | |
| (5) Bearing | (10) L.H. Clutch Drum & Gear | (15) R.H. Clutch Drum & Gear | |

11.1 Shaft Removal

(a) Lower any loads to the ground. Remove wire rope from the drum.

(b) Engage swing lock. Disenqage master clutch. Shut down engine. ’0

(c) If rear drum is being removed; fuel tank, chain case, and chain wheel must be removed first.

(d) Remove R.H. and L. H. clutch assemblies from shaft as explained in SM5-9-4.0.

(e) If removing front drum shaft, remove clutches from reverse shaft. If removing rear drum shaft, remove clutches from reverse shaft and boom hoist shaft.

Note: There is an overlap condition between spur gears on drum shafts, and clutch drums on reverse and boom hoist shafts.

(f) Remove clutch drum and gear assemblies from each end of the shaft. (Remove overlapping clutch drum-near assemblies on adjoining shaft assemblies. ) The assemblies will slide off of shafts after clutch assemblies are removed.

(g) Support rope drum (11) with a hoist or helper crane.

(h) Block under brake drum (8) to hold it in position.

(i) Remove shaft (12) out R.H. side of machine. R.H. bearing 13)will come out with shaft L..H. bearing (5) will remain in place. Remove snap ring (4) to remove L.H. bearing.

11.2 Shaft Replacement

(a) Install bearing (13) on shaft (12). Bearing is shielded, and is installed with shield to the inside.
(b) Install bearing (5) in its bore. Bearing is shielded, and is installed with shield to the inside. Install snap ring (4).
(c) Support rope drum (11) in place with a hoist or helper crane. Slide shaft through rope drum, and brake drum (8).
(d) Install spacers (7) over shaft. Push shaft on into place in bearings.
(e) Install shims (3 & 14) on each end of shaft.
(f) Install clutch drum and gear (10) on L..H. end of shaft. (Install overlapping drums and gears. )
(g) Check for full tooth contact between mating gears. Add or subtract shims (3) as required for full tooth contact. The following shim is available for this adjustment:

22C26 - 22 Ga.

Install clutch assemblies as explained in SM5-9-4.0.
(h) Install clutch drum and gear (15) on R.H. end of shaft. (Install overlapping drums and gears. )
(i) Shim as explained previously in Step (g) at (14). Install clutch assemblies' as explained in SM5-9-4.0.
(j) Install chain wheel, chain case, and fuel tank. Refer to SM6-39-6.0 for more information.
(k) Lubricate bearing as explained on lubrication chart before operating machine.

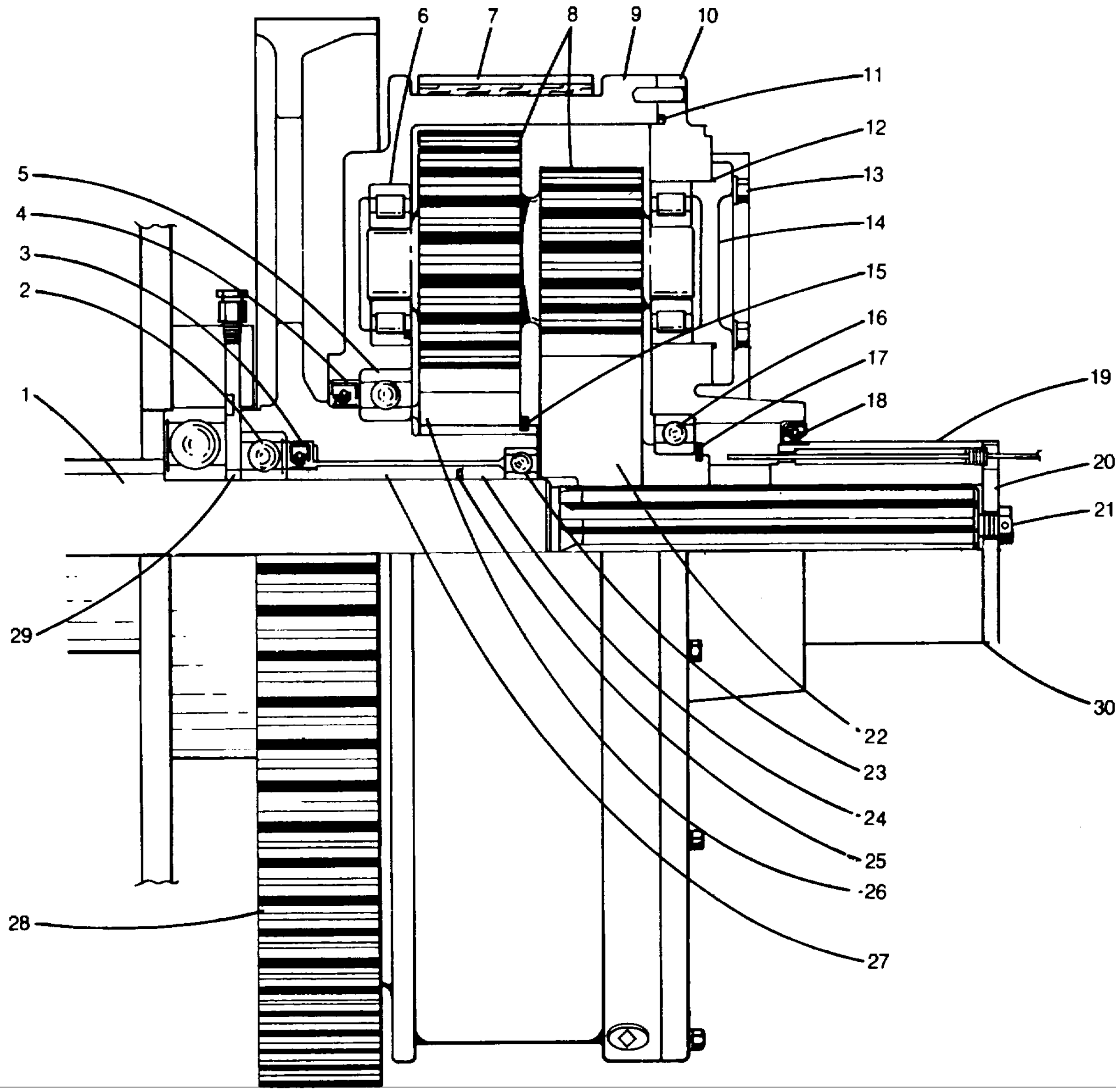



Fig. 1 N43-D
Planetary Assembly

(1) Shaft
(2) Bearing
(3) Seal & Wear Sleeve
(4) Seal & Wear Sleeve
(5) Bearing
(6) Bearing
(7) Planetary Brake
(8) Cluster Gear
(9) Planetary Housing
(10 Cover Plate
(11) 'O' Ring
(12) '0' Ring
(13) Capscrew
(14) End Cap
(15) Snap Ring
(16) Bearing
(17) Snap Ring
(18) Seal & Wear Sleeve
(19) Spacer
(20) End Cap
(21) Capscrew
(22) Driven Gear
(23) Bearing
(24) Spacer
(25) '' Ring
(26) Drive Gear
(27) Spacer
(28) Side Housing Gear
(29) Spacer and Shims
(30') Gasket

1.1 Low Speed Planetary (Fig. 1)

The unit is a low speed transmission, which gives the operator a low hoist or lowering speed.

The unit consists of a drive gear (26), which is splined to the side housing gear (28). Four sets of cluster (planet) gears (8), which are in mesh with the drive gear (26), and with a driven gear (22), which is splined to the horizontal shaft (1). When the machine is idling, with the master clutch engaged, the drive gear is rotating. It forces the cluster gears to rotate about their own axis. The cluster gears are in mesh with the driven gear, but it cannot turn, because it is splined to the horizontal shaft which is kept from turning *by* the drum brake. Since this gear cannot turn, the cluster gears are forced to walk around it, causing the entire planetary housing (9) to rotate.

To shift the planetary into gear, put the boom control lever in the lower position. This activates a valve, to direct Speed-o-Matic pressure to the planetary brake (7), instead of the standard clutch. This brake keeps the planetary housing from rotating. The side housing gear turns the driven gear, which in turn causes the cluster gears to rotate. Since the planetary case cannot rotate, the cluster gears will turn the driven gear, causing the horizontal shaft to turn.

1.2 Planetary Disassembly (Fig. 1)

(a) Drain the lubricant from the housing.
(b) Unbolt and remove the end cap (20). Remove the spacer (19).
(c) Unbolt and remove the four end caps (14). Remove cover plate mounting capscrews. Two puller holes are provided in the outer edge of the cover plate. Insert two 3/8" N. C. capscrews in the puller holes. Tighten the capscrews equally, after they make contact with the housing, to remove the cover plate (10) without binding.
(d) Remove the driven gear (22).
(e) Remove the four cluster gears (8).
(f) Remove snap ring (15) which retains the drive gear (26). Remove the drive gear.
(g) Remove the planetary brake assembly (7) from the housing (9).
(h) Remove the planetary housing (9) from the side housing gear (28).
(i) The side housing gear may be removed from the shaft (1) if desirable.

1.3 Wear Sleeve Removal (Fig. 2)

The seals within the planetary assembly all ride on wear sleeves, which provide a highly polished surface for the seal lip to ride against. These wear sleeves may be removed without damage to the hub or spacers they are mounted on, as follows:

(a) With the ball end of the ball pein hammer, tap the wear sleeve around its circumference hard enough to dent the wear sleeve. These dents will cause the metal to stretch, enlarging the diameter of the wear sleeve and allowing it to be easily removed.
(b) Install new wear sleeve by pressing them into place with an arbor press.

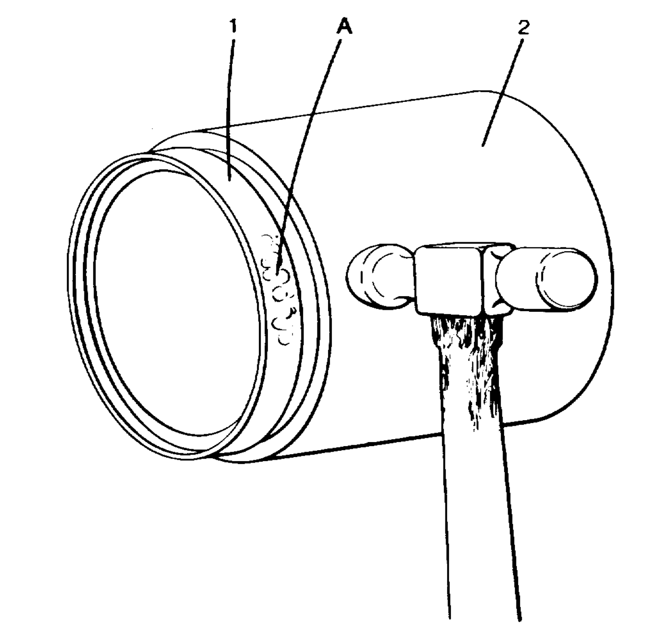



Fig. 2 Z178-A
Wear Sleeve Removal
(A) Tap here with ball of a ball pein hammer
(1) Wear Sleeve (2) Spacer

1.4 Planetary Removal (Fig. 1)

The planetary assembly may be removed from the machine as a unit as follows:

(a) Remove the end cap (20). Remove the spacer (19).
(b) Remove the planetary brake assembly (7).
(c) Remove the planetary assembly from the machine. The planetary assembly may be reinstalled on the machine by following the removal procedure in reverse. Adjust the brake as explained in this SM.

1.5 Planetary Reassembly (Fig. 1 & 3)

(a) Install a new seal (3) in the side housing gear (28) hub. The seal must be installed with the lip in. Coat the O. D. of the-? seal with Permatex before installation.
(b) Press bearing (2) in on top of the seal, with the shielded side in.
(c) Install spacer (27) through seal (3) until it contacts bearing (2). There is a wear sleeve on one end of the spacer, for the seal lip to ride on.

(d) Install 'O' ring (25) in the end of spacer (27). Install spacer (24) and bearing '(23) in the other end of the hub.
(e) Install the side housing gear (28) on the shaft (1). Shim between the inner bearing and the side housing spacer with 1C5 shims, to align the drum gear for full tooth contact between mating gears.
(f) Install seal(4), with lip in, in the bore in the center of the planetary housing. The seal must ride on a wear sleeve when the planetary is assembled.
(g) Install bearing (5) in the housing bore. Install the housing over the side housing gear hub.
(h) Install drive gear (26) and snap ring (15).
(i) Install bearing (6) on each end of each cluster gear (8). Install the four cluster gears. The gears must be installed with the match marks on the drive gear, driven gear, and cluster gear in line (see A in Fig. 3).
(j) Install driven gear (22), making sure the match marks line up. Install the bearing (16) and snap ring (17) on the driven gear.
(k) Install end cap (14) over each bearing. Permatex both sides of the gasket, then install the end cap. Tighten the capscrews (13) to 17 ft/lb. torque.
(l) Install '0'ring (11) in the groove in the planetary cover (10). Install the cover on the housing. Tighten the mounting capscrews to 50 ft/lb. torque.
(m) Install seal (18) in the hub of the planetary cover with the lip in.
(n) Install the spacer (19) over the shaft.

Note: <u>There is a wear sleeve on the spacer which the seal lips ride on.</u>

(o) Install the end cap (20). Tighten the capscrews (21) to 50 ft/lb. torque. (p) Install and adjust the planetary brake as explained in SM5-7-2.0.

Fill the case with lubricant as explained in Operators Manual before using the assembly.

1.6 Planetary Housing Bearings (Fig. 1 and 4)

The two bearings on which the planetary case ride (5 and 16 in Fig. 1) are of a special design. They are manufactured with a tapered outer race for ease of installation of the balls at the bearing factory. Because of this taper, applying a force, or thrust, against the wrong side of the bearing can cause the bearing to come apart during operation. The outer race of these bearings is stamped "thrust here". This stamp is on the thicker face of the outer race (see Fig. 4). When assembling a planetary unit, the bearings must be installed with the thrust side facing away from the cluster gears. If the bearings are installed wrong, the planetary case can move outward resulting in seal leakage, and possible damage to the planetary housing.

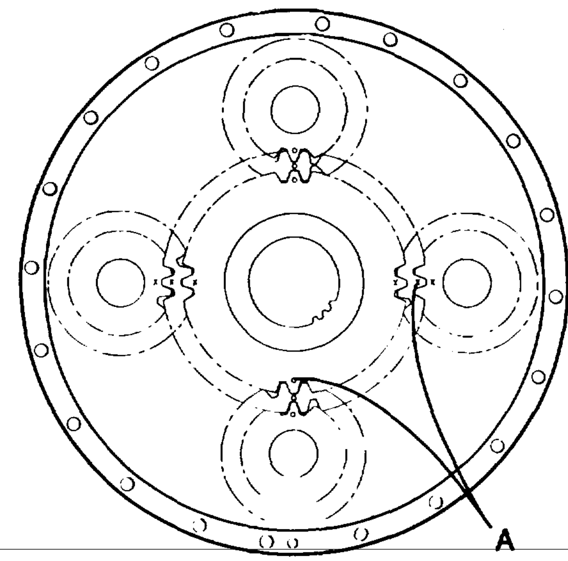



Fig. 3 Z179-8
Align Gear Match Marks
(A) Match marks

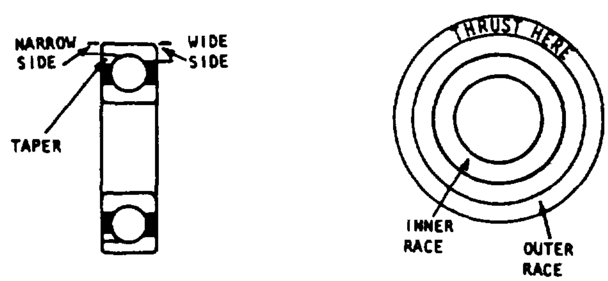



Fig. 4
Bearing Cross Sections

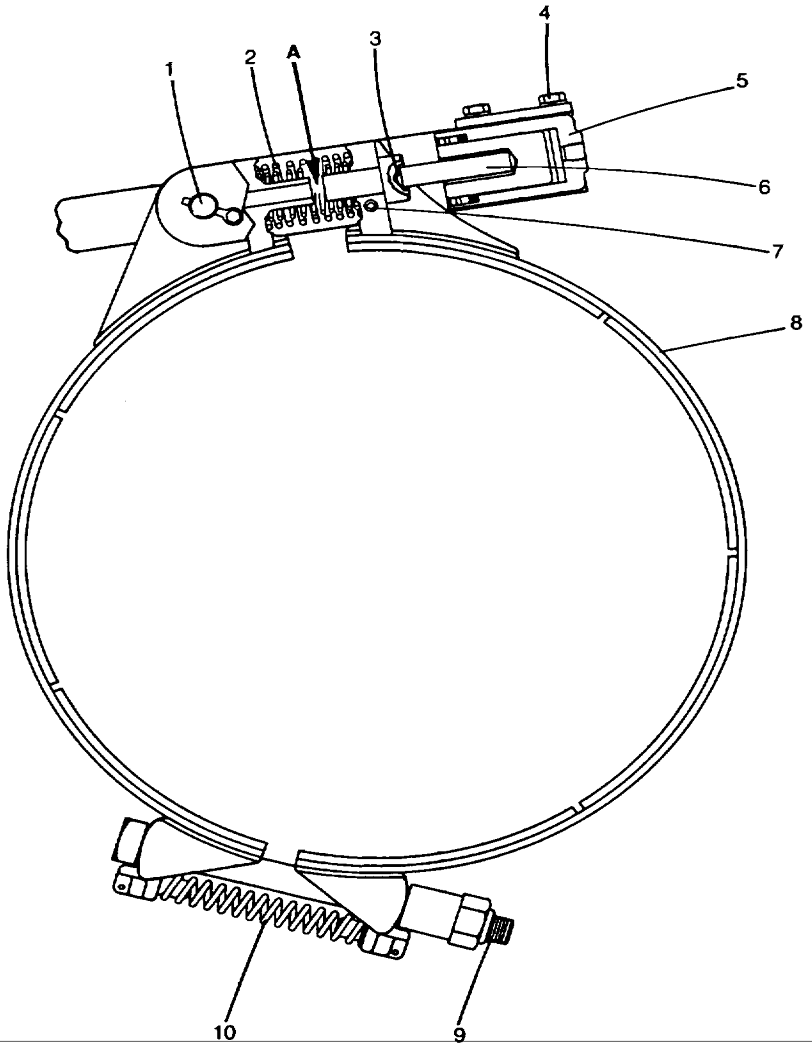



Fig. 1 W256-C
Planetary Brake

(A) Initial Clearance Measured Here (Brake Applied)
(1) Pin
(2) Spring
(3) Push Rod Seat
(4) Cyl. Mounting Capscrews
(5) Cylinder
(6) Push Rod
(7) Rollpin
(8) Brake Band
(9) Band Bolt and Nut
(10) Spring

2.1 Planetary Brake Adjustment

Maximum brake release is required for a free running planetary. Adjust the planetary brake for 3/8" clearance at point "A", with the brake applied. This clearance may be measured between the rollpin (7) and the end of the slot it rides in. The brake is adjusted with the band bolt (9). Adjust the clutch as explained in the Operators Manual.

2.2 Planetary Brake Removal

The planetary brake lining must be replaced before lining rivets score the brake drum. Remove the band as follows:

(a) Reduce S-O-M pressure to zero. Work control levers back and forth with engine off to reduce pressure.
(b) Remove hose from brake cylinder.
(c) Remove capscrews (4) which connect brake cylinder (5) to bracket.
(d) Remove cylinder (5), push rod (6), and push rod seat (3) from bracket.
(e) Insert tie bolt (2) through brake spring (3) (Refer to Fig. 2). Tighten bolt. This compresses springs (3). Remove rollpin (1).
(f) Loosen tie bolt. This releases spring tension. Remove tie bolt (2) and springs (3).
(g) Remove adjusting bolt and nut (9). Remove standoff spring (10) which fits between ends of brake bands.
(h) Remove one section of brake band.
(i) Remove capscrew and rod end from pin (1). Remove pin which connects the other section of brake to anchor rod. Remove brake band.

**WARNING**

Compress Spring With Tie Bolt Before Removing Roll Pin. If Tie Bolt Is Not Used, The Springs Can Propel Bands With Enough Force To Cause Injury When Rollpin Is Removed.

2.3 Planetary Brake Replacement

(a) Set one shoe in place over brake anchor rod. Set cylinder housing in place over shoe lug. Install anchor pin (1). Install rod end and capscrew to retain the pin.
(b) Install other band section. Install adjusting bolt, spacer, and nut (9). Install standoff spring (10).
(c) Install springs (2) between spring seats on each brake band. Install and tighten tie bolt until rollpin (7) may be installed. Install rollpin. Drive rollpin in until it is flush with housing side of bracket.
(d) Remove tie bolt. Store in machine tool box.
(e) Install push rod seat (3) and push rod (6).
(f) Install cylinder (5). Install cylinder mounting capscrews (4). Tighten capscrews.
(g) Install hydraulic hose on brake cylinder.
(h) Adjust planetary brake. See paragraph 2.1.

2.4 Cylinder Repair (Fig. 3)

(a) Reduce S-O-M pressure to zero. Work control levers back and forth with engine off to reduce pressure.
(b) Remove hose from brake cylinder.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

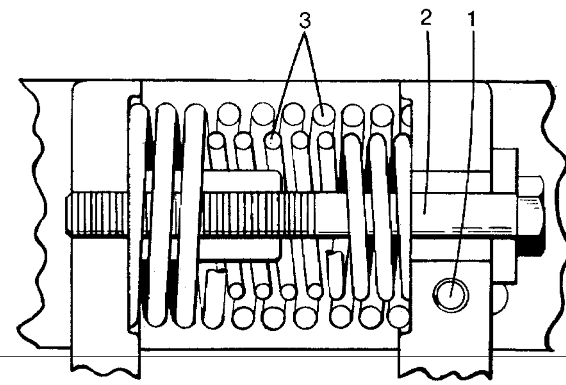



Fig. 2 L251 -A
Tie Bolt Installation

(1) Rollpin
(2) Tie Bolt
(3) Spring

(c) Remove capscrews (5) which connect brake cylinder to bracket. Remove cylinder. Clean outside of cylinder with kerosene or diesel fuel.
(d) Remove piston (4) from cylinder. Remove snap ring (1) from cylinder. Remove seal (2) from cylinder.
(e) Clean all parts. Examine piston and cylinder for scoring or other damage. Replace damaged parts.
(f) Install new oil seal and wiper ring assembly. Install snap ring. Lubricate piston with clean S-O-M oil. Install piston in cylinder case.
(g) Install cylinder over push rod. Install and tighten mounting capscrews (5). (h) Connect hose to brake cylinder.

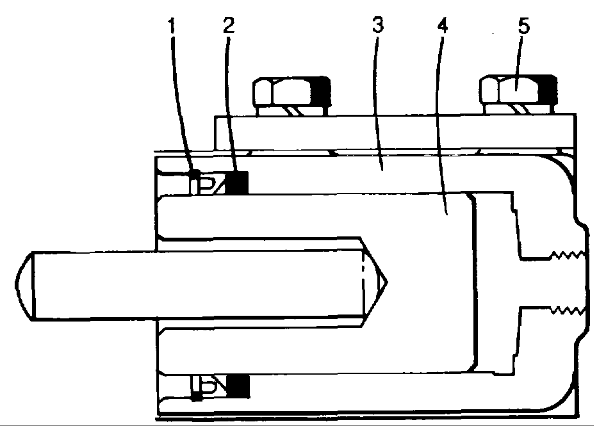



Fig. 3 A1 028-C
Planetary Brake Cylinder

(1) Snap Ring
(2) Oil Seal & Wiper Ring
(3) Cylinder Case
(4) Piston
(5) Mounting Capscrews

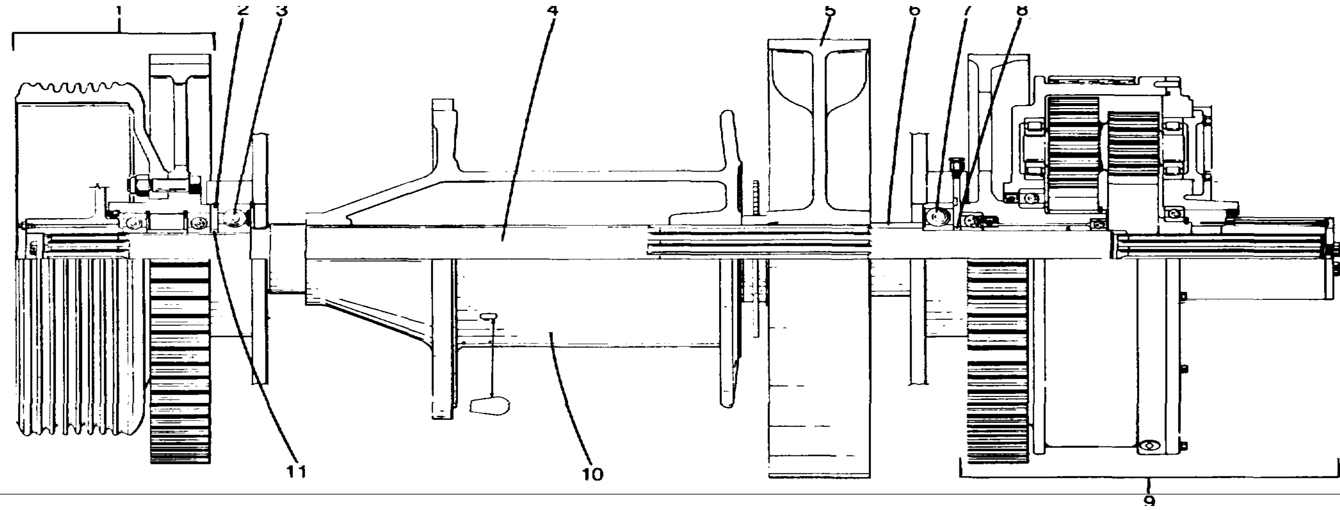



Fig. 1 N43-D

Boom Hoist Shaft

(1) Clutch Drum & Gear Assy.
(2) Snap Ring
(3) Bearing
(4) Shaft
(5) Brake Drum
(6) Spacer
(7) Bearing
(8) Spacer & Shim
(9) Low Speed Planetary Assy.
(10) Rope Drum
(11) Spacer & Shim

14.1 Shaft Removal

(a) Swing upper over rear of carrier. Lower boom to the ground. Continue to lower until live mast standoffs contact boom. Remove wire rope from B.H. drum (10).
(b) Engage swing lock. Disengage master clutch. Shut down engine.
(c) Remove clutch assemblies from shaft. Refer to SM5-9-4. 0 for more information. Remove clutch drum and gear assembly (1) from L.H. end.
(d) This machine has a low speed planetary on the R.H. end of the shaft. Remove planetary (9) as explained in SM5-7-1.0.
(e) Remove spacers and shims (8 & 11) from each end of shaft.
(f) Support rope drum (10) with a hoist or helper crane. Block up under B.H. brake drum (5).
(g) Remove snap ring (2). Remove shaft (4) out L.H. side of machine.
(h) Remove bearing *(3)* from shaft.
(i) Remove bearing *(7)* from its bore.

14.2 Shaft Replacement

(a) Install bearing (3) on shaft. Bearing is shielded, and is installed with shield to the inside.
(b) Install bearing (7) in bore. Bearing is shielded and is installed with shield to the inside.
(c) Support rope drum (10) in place with a hoist or helper crane. Slide shaft (4) in through rope drum (10), brake drum (5), spacer (6), bearing (7), and on into place.
(d) Install snap ring (2).
(e) Install spacers and shims (8 & 11) which were removed earlier, on each end of the shaft.
(f) Install L..H. drum and gear assembly (1) on shaft. Check alignment between mating gears. Add or subtract shims as necessary until full tooth contact is achieved. The following shim is used for this purpose:

 22C26 - 22 Ga.

(q) Install L..H. clutch assembly. See SM5-9-4.0 for more information.
(h) Install planetary assembly (9) on R. H. End of shaft. Shim if necessary as explained in step (f). Refer to SM5-7-1.0 for more information.
(i) Lubricate bearings as shown on lubrication chart before operating machine.

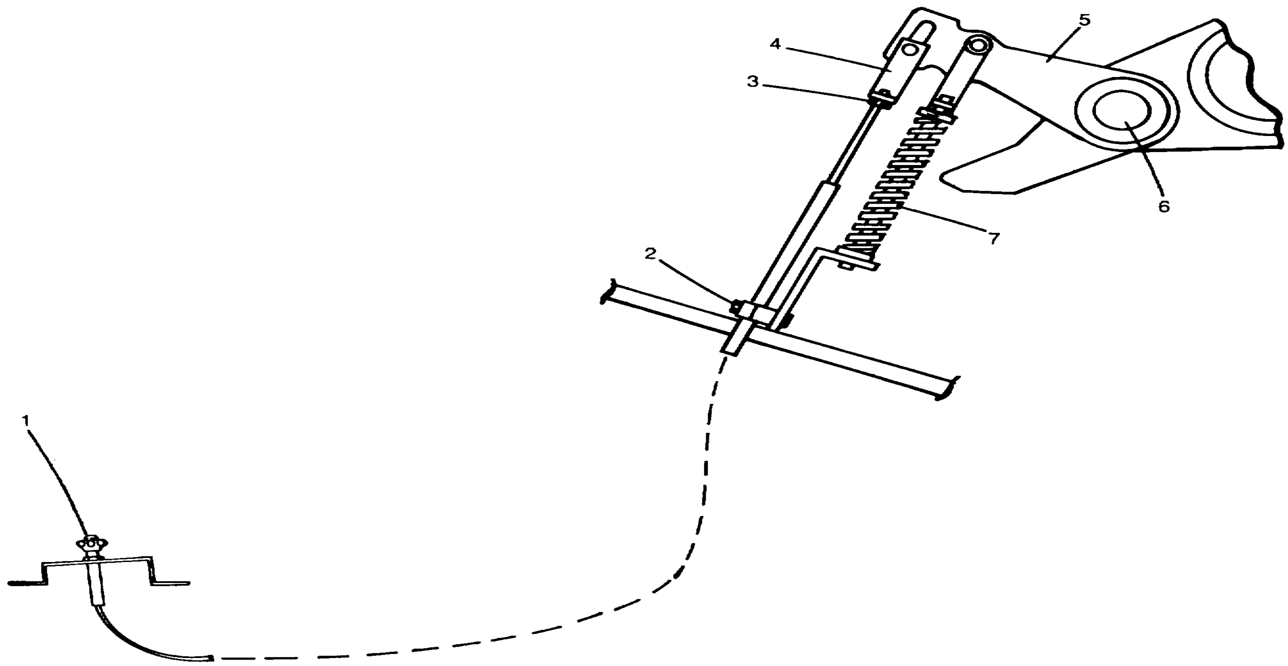



Fig. 1 N201-C
Boom Hoist Pawl Control

| | | |
|---|---|---|
| | | (5) Pawl |
| (1) Control Handle | (3) Jam Nut | (6) Pin |
| (2) Clamp | (4) Clevis | (7) Spring |

On the boom hoist laggings, ratchet teeth are cast into the lagging flange. A spring loaded pawl rides against these teeth to provide a positive means to lock the boom hoist drum lagging against rotation. See Section 1 in the Operators Manual for operating instructions.

17.1 Pawl Adjustment

(a) Adjust the clevis (4) on the pawl end of the cable to fully disengage the pawl when the control cable bottoms out on the outer housing of the cable assembly.
(b) Adjust the tension in the spring to hold pawl snugly against the lagging teeth when the pawl is engaged.

17.2 Control Cable Replacement

(a) Lower the boom to the ground. Lower live mast onto boom. Slack off on boom hoist rope.
(b) If replacing cables on machine equipped with tower attachment, lower tower and boom to ground. Lower mast onto boom. Slack off on the boom hoist ropes.
(c) Remove pin which connects clevis to pawl(5).
(d) Remove capscrews from clamp (2). Remove clamp.
(e) Thread nut off of the threaded portion of the control. Remove the control from the machine.
(f) Install new cable through the hole in control panel. Install nut over cable. Thread it onto the threaded portion of the control, and tighten.
(g) Route the cable back to the pawl.
(h) Install clamp to hold end of cable station-
(i) Install clevis (4) and jam nut (3) on the cable. Pin clevis to pawl assembly. Adjust as explained earlier in this SM.

17.3 Pawl Removal

(a) Lower the boom, or tower and boom if so equipped, to the ground. Lower the live mast until it contacts the boom. Slack off on the boom hoist ropes.
(b) Remove anchor pin which connects clevis (4) to pawl assembly.
(c) Remove the pin which connects the spring (7) to the pawl assembly.
(d) Slide pin (6) out of bracket until pawl and shims can be removed.

17.4 Pawl Replacement

(a) Install pin (6) in brackets. Slide shaft over and install pawl (5). Determine the number of spacers that will be necessary to center pawl with teeth of lagging flange. The shims are: JA1021 .16 Ga. (. 51 m)
(b) Anchor pin (6).
(c) Connect spring (7) to pawl (5). Connect clevis (4) to pawl (5).
(d) Adjust pawl assembly as explained earlier in this SM.

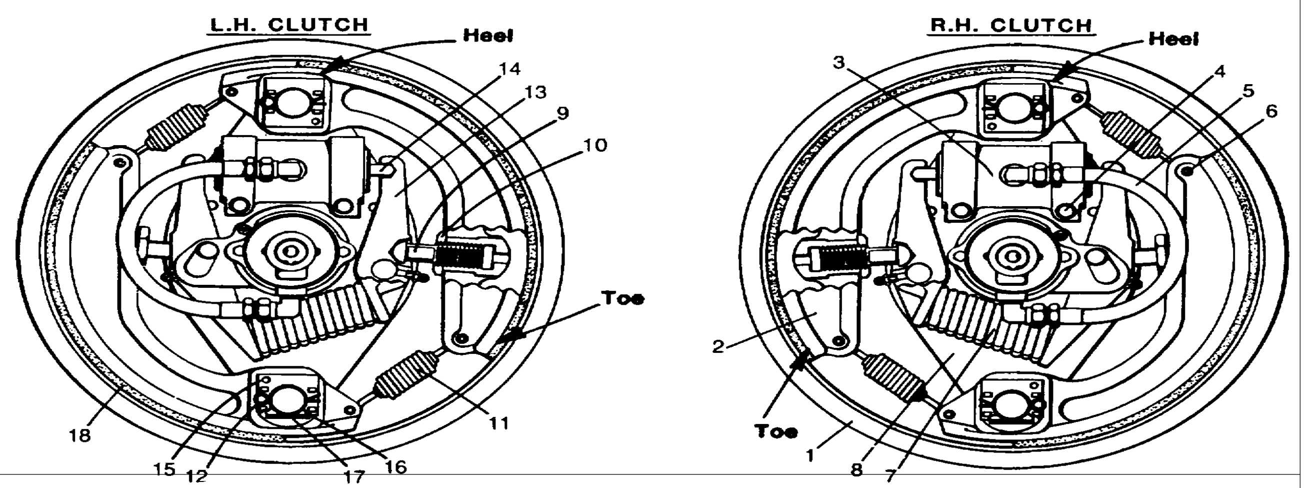



Fig. 1 B351-C

Clutch Assembly

| | | |
|---|---|---|
| (1) Clutch Drum | (7) Spring | (13 Clutch Arm |
| (2) Live or Toe End | (8) Spider | (14) Piston Rod |
| (3) Cylinder | (9) Adjusting Bolt | (15) Shim Cover |
| (4) Bolts | (10) Locknut | (16) Dead Or Heel End |
| (5) Hose | (11) Return Spring | (17) Shims |
| (6) Rollpin | (12) Cotter Pin | (18) Clutch Shoe |

2.1 Clutches (General Information)

All clutches used on Link-Bel1lmachines operate in the same way. Each has two shoes which are hydraulically applied, and spring released. The clutches are controlled by a hand lever on the operator's control stand. Actuating the lever opens a control valve allowing Speed-o-Matic oil under pressure to flow to the clutch cylinder and apply the clutch. When the control lever is returned to neutral, porting is opened in the valve allowing oil in the clutch cylinder to flow back to sump tank. The clutch return springs then disengage the clutch.

The clutch drum and clutch gear are mounted on a shaft on bearings and revolve independent of the shaft when engine master clutch is engaged.

The clutch assembly is splined to the shaft, and when applied will cause the shaft to rotate with the drum and gear.

The clutch assemblies on any given machine may be assembled for right or left hand rotation depending upon their use on the machine. Clutch assemblies of the same size and type are interchangeable from one location to another, but may or *may* not be assembled for the right rotation. Also in some cases, a L..H clutch may be changed to a R. H. and vice-versa by changing parts around on the clutch spider. For this reason, it is a good idea to tag a clutch for location and rotation when one is removed. (Refer to chart on next page if in doubts)

To define L.H. and R.H. clutches two other terms must be defined: toe and heel end. The toe is the end of the clutch shoe which first engages the clutch drum. The heel is the pivoting point of the clutch shoe and engages after the toe.

A R.H. clutch may now be defined as one, which when assembled and an arrow drawn from toe of shoe to heel of shoe, the arrow will point in a clockwise direction. A L.H. clutch is one where an arrow drawn from toe to heel would point in a counter-clockwise direction.

To further clarify proper clutch installation, all clutches must be installed in an energized position. That is, so the drum rotates from the "toe" or live end of the clutch shoe to the "heel" or dead end of the clutch shoe. In this way the clutches will be self energized (energized by clutch drum rotation).

There are several applications where the load is actually the driving force and acts to energize the clutch. In this case, the clutch must be installed with the drum rotating from heel to toe. These applications are:
(a) Front drum lowering clutch when used in crane work.
(b) The rear drum lowering clutch.

| HC238A Machines | L.H. Clutch | R.H. Clutch |
|---|---|---|
| Swing Reverse Clutch (Left Side) | | * |
| Swing Reverse Clutch (Right Side) | | * |
| Front Drum Clutch (Left Side) | | * |
| Front Drum Clutch (Right Side) | * | |
| Rear Drum Clutch (Left Side) | | * |
| Rear Drum Clutch (Right Side) | * | |
| B.H. Clutch (Left Side) | | * |

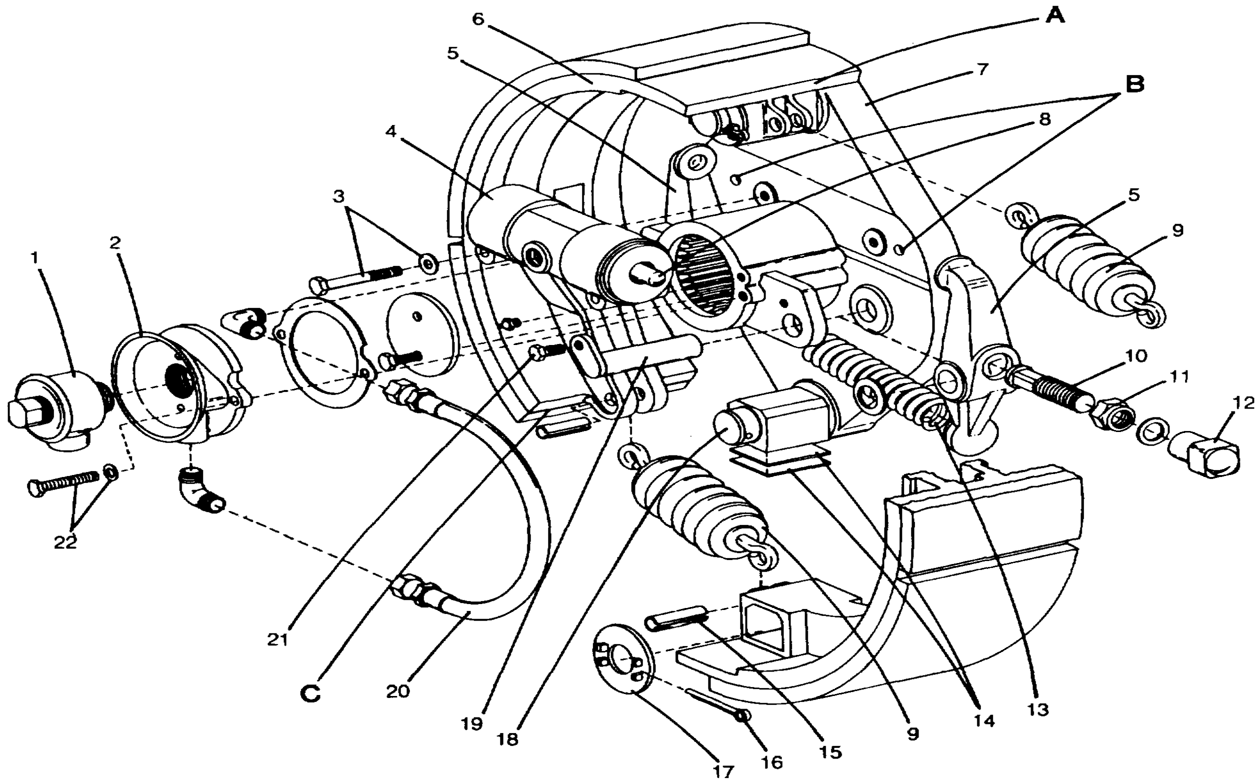



Fig. 1 Z1026-B
Clutch Assembly

(A) Toe End(
(B) Holes to Facilitate Cylinder Removal
(C) Heel End

(1) Rotating Joint
(2) Rotating Joint Adapter
(3) Locking Capscrew and Washer
(4) Clutch Cylinder
5) Clutch Arm
(6) Clutch Shoe
(7) Clutch Spider
(8) Piston Rod
(9) Shoe Spring
(10) Adjusting Bolt
(11) Jam Nut
(12) Locknut
(13) Compression Spring
(14) Shim
(15) Rollpin
(16) Cotter Pin
(17) Cover
(18) Heel Block Pin
(19) Clutch Arm Pin
(20) Hose
(21) Capscrew
(22) Capscrew and Washer

4.1 General Information

See SM5-9-2. 0

4.2 Clutch Removal (Refer to Fig. 1)

(a) Exhaust hydraulic pressure in S-O-M system by working control levers back and forth with the engine shut down. Disconnect S-O-M line leading to clutch rotating joint. Cap or plug all openings to prevent entry of foreign material.

(b) Remove the two capscrews (22) which attach the rotating joint adaptor (2) to the clutch spider (7). Remove the rotating joint (1) and adaptor (2) as a unit.

(c) Remove lock wire from two capscrews in shaft end cap.

(d) Remove clutch assembly from shaft.

4.3 Clutch Drum And Gear Removal

The clutch drum and gear rides on the shaft on two bearings. After the clutch assembly is removed, the drum and gear may be slid off the shaft, except in a case where one drum or gear overlaps another. The clutch drum is attached to the gear with capscrews. Remove the capscrews to remove the drum.

The drum gear bearings are pressed in, one from each end, against a pair of snap rings. There is a spacer in between the bearings. Always inspect the bearing spacer for wear or damage. A worn or damaged spacer will contribute to bearing failure. There is a seal in the outer gear hub. Inspect the seal for wear or damage and replace if necessary. The seal is installed with the lip in.

4.4 Clutch Replacement (Refer to Fig. 1)

(a) Slide the clutch assembly onto the shaft. Align the splines and push the clutch on into place in the drum.
(b) Install shaft end cap and capscrews. Tighten capscrews and lockwire heads together.
(c) Install rotating joint (1) and adaptor (2)on clutch spider (7). Install and tighten capscrews (22).
(d) Connect S-O-M line. Start engine and check line for leaks. If any, repair before using.
(e) Adjust clutch as explained later in this SH before using.

4.5 Clutch Cylinder Removal (Refer to Fig. 1)

(a) Engage control lever for clutch being worked on to force the clutch shoes out against the clutch drum.
(b) Insert 1/2" pins into holes (B) provided in the clutch spider (7) to hold clutch arms (5) in engaged position.

Note: It may be necessary to back off on the adjusting bolt to allow the clutch arms sufficient travel to insert pins.

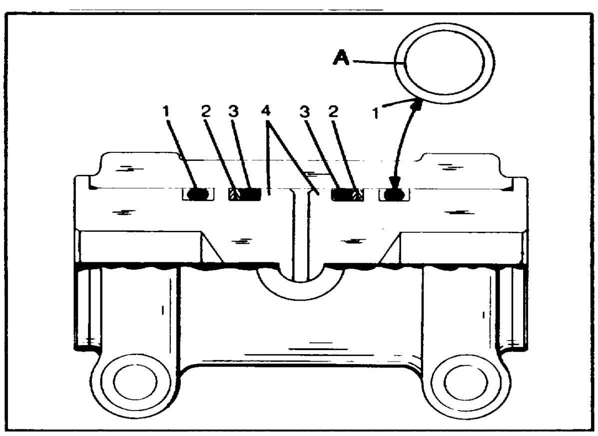



Fig. 2 A126-A
Clutch Cylinder
(A) Knife Cut
(1) Wiper Ring
(2) Back-Up Rings
(3) 'O' Rings
(4) Piston

(c) Return control lever to neutral, shut off engine, and exhaust S-O-M pressure to zero by working control levers back and forth.
(d) Remove cylinder piston rods (8).
(e) Remove hydraulic hose (20) leading from rotating joint (1) to clutch cylinder (4). *J*
(f) Remove mounting capscrews (3) and clutch cylinder (4).

4.6 Cylinder Repacking (Refer to Fig. 2)

(a) Remove pistons (4) from cylinder.
(b) Remove old 'O' ring (3), back up rings (2), and wiper rings (1) from pistons.
(c) Thoroughly clean and inspect all parts. Replace any worn or damaged parts.
(d) Install new '0' rings (3) in inner groove on pistons. Slide the rings into place --don't roll them.
(e) Install back up rings (2), two per piston, in groove next to 'O' ring (3) (toward outside of cylinder).
(f) The wiper rings (1) are actually knife cut '0' rings. If cut wiper rings are not available, knife cut an 'O' ring as shown in Fig. 2.
(g) Lubricate both piston assemblies with #2 petrolatum or equivalent and install in cylinder.

4.7 Cylinder Replacement (Refer to Fig. 1)

(a) Install cylinder (4) on clutch spider (7). Tighten capscrews (3) just enough to flatten lock washers. Overtightening may distort cylinder and cause pistons to bind.
(b) Install piston rods (8) in pistons. Make sure piston rods line up properly with holes in pistons and clutch arms (5). If not, remove arms (see procedure later in this SM). Shim between the lugs at the spider and the clutch arms to align properly. The following shim is available for this adjustment: 5Z491 . . . 22 Ga.
(c) Install hose (20) leading from rotating joint to clutch cylinder.
(d) Start engine, build up hydraulic pressure, and engage clutch. Remove pins from holes in spider.
(e) Disengage clutch. Adjust clutch as explained later in this SM before using.

4.8 Clutch Shoe Removal (Refer to Fig. 1)

(a) Loosen jam nut (11) and back off on adjusting bolt (10) to release spring tension.
(b) Remove rollpins (15) which connect shoe springs (9) to clutch shoes.
(c) Remove cotter pin (16) and cover (17) from heel block pin (18).
(d) Remove adjusting bolts (10).
(e) Remove clutch shoes by sliding them out.

4.9 Clutch Shoe Replacement (Refer to Fig. 1)

(a) Check clutch drum to make sure it is free of oil.
(b) Slide clutch shoes into place, making sure they are replaced the same as before removing.

**Service Manual**

SM5-9-4.0 Clutch Assembly

(c) Set adjusting bolt (10) in place in clutch arm (5).
(d) Install rollpin (15) which connects toe end of shoe (A) to spring. There is a right and a wrong way to install rollpins. The open portion of the rollpin must face the open portion of the spring eye. Improper installation may result in premature failure of the spring eyes.
(e) Install dead end block over block pin.
(f) Adjust the clutch as explained later in this SM before using.

4.10 Clutch Arm Or Spring Removal (Refer to Fig. 1)

(a) Exhaust hydraulic pressure and remove hose that leads from end cap to clutch cylinder.
(b) Turn adjusting bolts (10) to force shoe into contact with drum.
(c) Remove capscrews (21) and clutch arm pins (19).
(d) Back off on adjusting bolts, which will gradually reduce spring tension. Remove the spring (13) when it becomes slack.
(e) Back off adjusting bolts until bolt assem- bly can be removed from shoe.
(f) Remove clutch arms (5).

4.11 Clutch Arm or Spring Installation (Fig. 1)

(a) Set clutch arms (5) in place in spider (7). Install adjusting bolts (10) in shoes.
(b) Set spring (13) in place between the two arms-.
(c) Turn out on adjusting screws to compress spring until holes (A) in spider and arms line up to allow installation of pins.
(d) The arms must be aligned with piston rods (8) and pistons. The arms are aligned by shimming between the clutch spider ears and the arms with the following shim: 5Z491 22 Ga.

Note: Alignment of the clutch arm and cylinder pistons is very important. Misalignment may cause cylinder scoring and seal damage. It can also cause incomplete disengagement of the clutch.

(e) Install clutch arm pins (19) and retaining capscrews (21).
(f) Install hose (20) leading from end cap to clutch Cylinder.
(g) Adjust clutch as explained later in this SM.

4.12 Clutch Adjustment (Fig. 1)

(a) Turn adjusting bolt (10) until toe of shoe contacts the drum.
(b) Remove cotter pin (16) and shim cover (17) from dead end block.
(c) Add shims (14) as required until the heel of the shoe contacts the drum. The following shims are available for making this adjustment:

22C51 ................................12 Ga.
22C52 ................................16 Ga.
22C53 ................................28 Ga.

(d) Back off on adjusting bolt until a clearance of .015 to .025 inch is obtained between clutch lining and drum at the toe end of the shoe. It may be necessary to add or subtract shims in conjunction with turning the bolt to obtain an even clearance of .015 to .025 inch the length of the shoe.
(e) Oil dead end pin. Be careful not to get oil on clutch shoes.
(f) Replace the cover (17) and cotter pin (16).
(g) Tighten the locknut (12).
(h) Repeat the above procedure on each shoe in each clutch assembly.

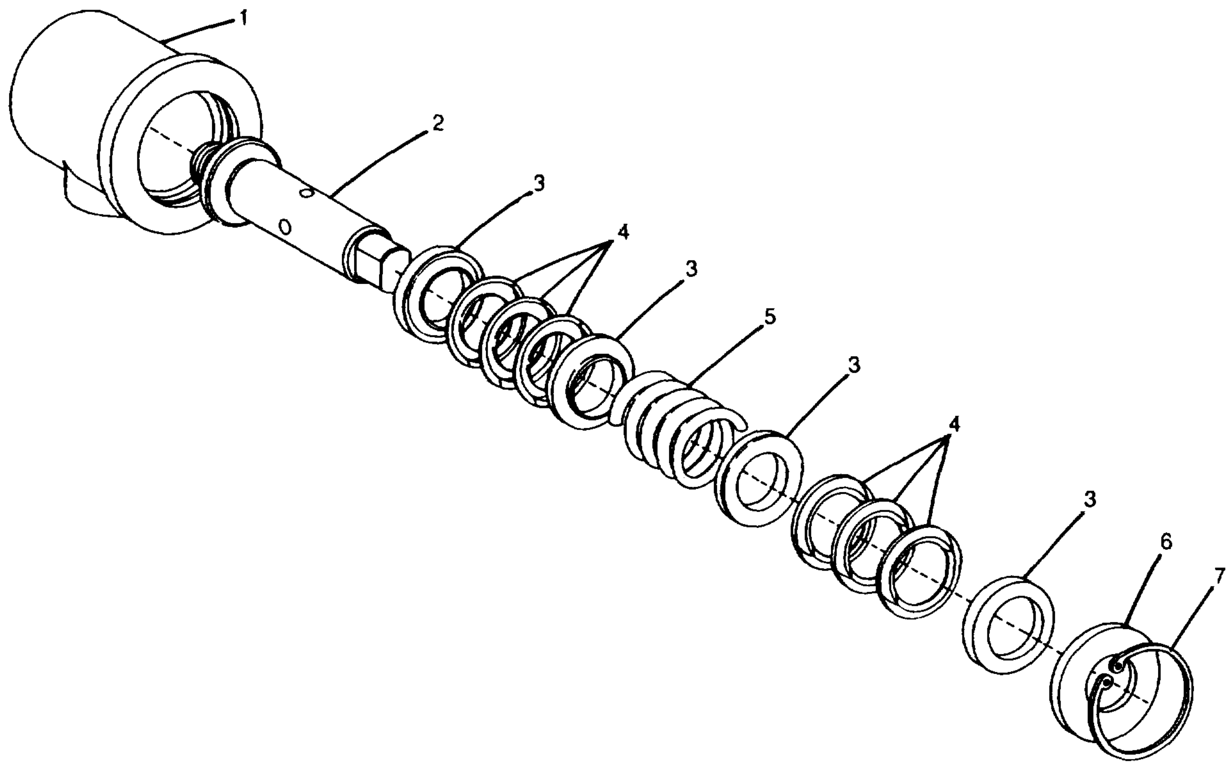



*Fig. 1*
*Clutch Rotating Joint Assembly*

D404-B

(1) Housing
(2) Rotor
(3) Adaptor Ring
(4) 'V' Packing
(5) Spring
(6) Retainer Ring
(7) Snap Ring

Rotating joints are used to transfer hydraulic pressure from stationary tubes to the revolving clutch. The rotating joint stem is screwed into the clutch end cap, while the body is attached to the stationary tube leading from the control valve.

9.1 Rotating Joint Disassembly
The unit is not adjustable in any way. The 'V' packing may eventually become worn enough to allow an excessive amount of oil seepage. The unit may be disassembled and the 'V' packing replaced as follows:

(a) Remove the snap ring (7) from the outer end of the rotating joint body.

(b) Remove the retainer ring (6).

(c) Remove the adaptor rings (3), 'V' packing (4), and spring (5) from the housing (1).

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(d) Wash all parts in kerosene or approved solvent. Install new packings and reassemble.
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The complete rotating joint assembly may be removed from the clutch by disconnecting the tube leading to the housing and unscrewing the rotor from the clutch end cap.

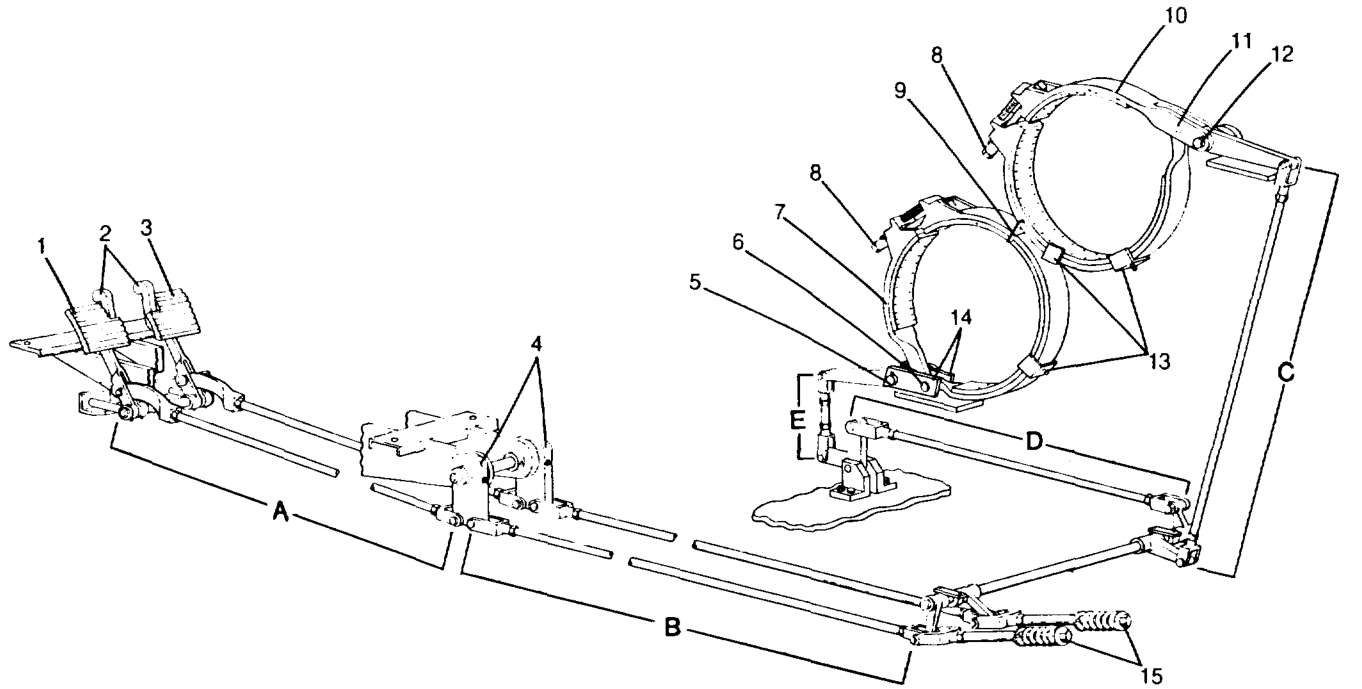


*Fig. 1*
*Front and Rear Drum Brakes*

LA71 O-D

| REACH ROD | DIMENSIONS | |
|---|---|---|
| (A) | 1'11-5/16" | 59.2 cm) |
| (B) | 10'2-3/8" | (3.10 M) |
| (C) | 4'1-5/16" | (1.29 M) |
| (D) | 6'1-7/16" | (1.87 M) |
| (E) | 10-1/4" | (260.35 mm) |

(1) Front Drum Pedal
(2) Pedal Latches
(3) Rear Drum Pedal
(4) Bellcranks
(5) Dead End Pins
(6) Live End Pins
(7) Front Drum Brake
(8) Band Bolts and Nuts
(9) Centering Bracket
(10) Rear Drum Brake
(11) Live End Pins
(12) Dead End Pins
(13) Standoff Bolts
(14) Connecting Link
(15) Return Springs

The foot operated front and rear drum brakes are of the mechanical type. Two pedals beneath the operator's control stand actuate the brake bands. The right pedal controls the rear drum brake, while the left pedal controls the front drum brake. A latch is built into each pedal to hold the brake in the applied position. Since both brakes are similar in construction and operation, the following instructions apply to both.

Note: <u>Every 500 hours of operation, remove the front and rear drum brake bands and all related parts for a visual inspection. If any of the parts show signs of cracks, undue wear, etc., replace them. If the linings are worn thin, or the rivets are close to contacting the drum, replace the lining. Readjust as explained later in this section.</u>

7.1 Front and Rear Drum Brake Adjustment

The brake adjustment must be checked upon delivery, and every 50 hours afterward. Adjust the brake as follows:

(a) Check the length of each reach rod, from center of clevis pin to center of clevis pin. Make sure they are adjusted to the dimensions shown in Fig. 1.

(b) Brake lining wear is taken up by means of an adjusting bolt and Out (8) located at the split in the band. Tightening this bolt will take up on the band, while loosening will increase clearance between the drum and the band. The band should be adjusted tight enough to hold the load when the pedal is operated in the lower half of its travel. By adjusting the band in this manner, the maximum available leverage is being used. Over-tightening the band will result in a much harder working brake, improper brake release, abnormal lining wear, and will make it difficult to lock the pedal in the fully applied position.

(c) Adjust the standoff bolts (13) to provide even clearance between the band and the brake drum when the brake is released, all the way around the drum. This is required for maximum brake band cooling, and to prevent brake band drag when powering down a load.

(d) The brake band should be centered with the brake drum. The middle area of each band is centered with the drum by means of a centering bracket (9). The rest of each

band is centered with the brake drum by shimming between the dead end lug, and the dead end mounting bracket on the frame. The following shims are available for use at this point:
1D144 10................Gauge (3.41 mm)
J218 16 .................Gauge (1.51 mm)
1D14522.................Gauge (.759 mm)

(e) Adjust the pedal return spring (15) to return the pedal (1 or 3) to its extreme upward position when unlatched. This will completely release the brakes if the band and standoffs are in correct adjustment. Adjust the stop nut on the pedal return spring bolt to limit spring stroke to: 1-27/32 inch (46.83 mm).

7.2 Brake Band Removal
Periodic inspections of the linings should be made so they may be replaced before wearing to the point that the rivets contact the drum. To remove brake band for relining or replacement, do the following:

(a) Land any loads, and/or the hook block that may be on the drum line.
(b) Fully release brake.
(c) Remove adjusting bolt, nut, spacer, and standoff spring.
(d) Remove the band centering bracket.
(e) Remove standoff bolt brackets.
(f) To remove rear drum brake:
    (1) Remove dead end pin (12).
    (2) Remove short band section.
    (3) Remove live end pin (11).
    (4) Rotate long band section around drum until it can be removed.
(g) To remove front drum brake:
    (1) Remove dead end pin (5).
    (2) Push short band section forward. Rotate long band section around drum to gain access to live end pin (6). Remove live end pin (6).
    (3) Remove short band section.
    (4) Rotate long band section around drum until it can be removed.

Install new band assemblies by following removal procedures in reverse.

Note: Use only bands or replacement linings from FMC Corporation. They have been tested for use on these machines and will provide the best operating and wear characteristics.

New bands may be installed or new linings can be riveted to the old band. Thoroughly inspect the band for damage or cracked welds. Discard the band if damage is apparent.

For best operation, bands may have to be shaped to properly fit the curvature of the brake drum. Don't heat brake bands when shaping; do it cold. Place a small piece of bar stock between the brake band and drum, then apply the brake to bend the band slightly and shape it better.

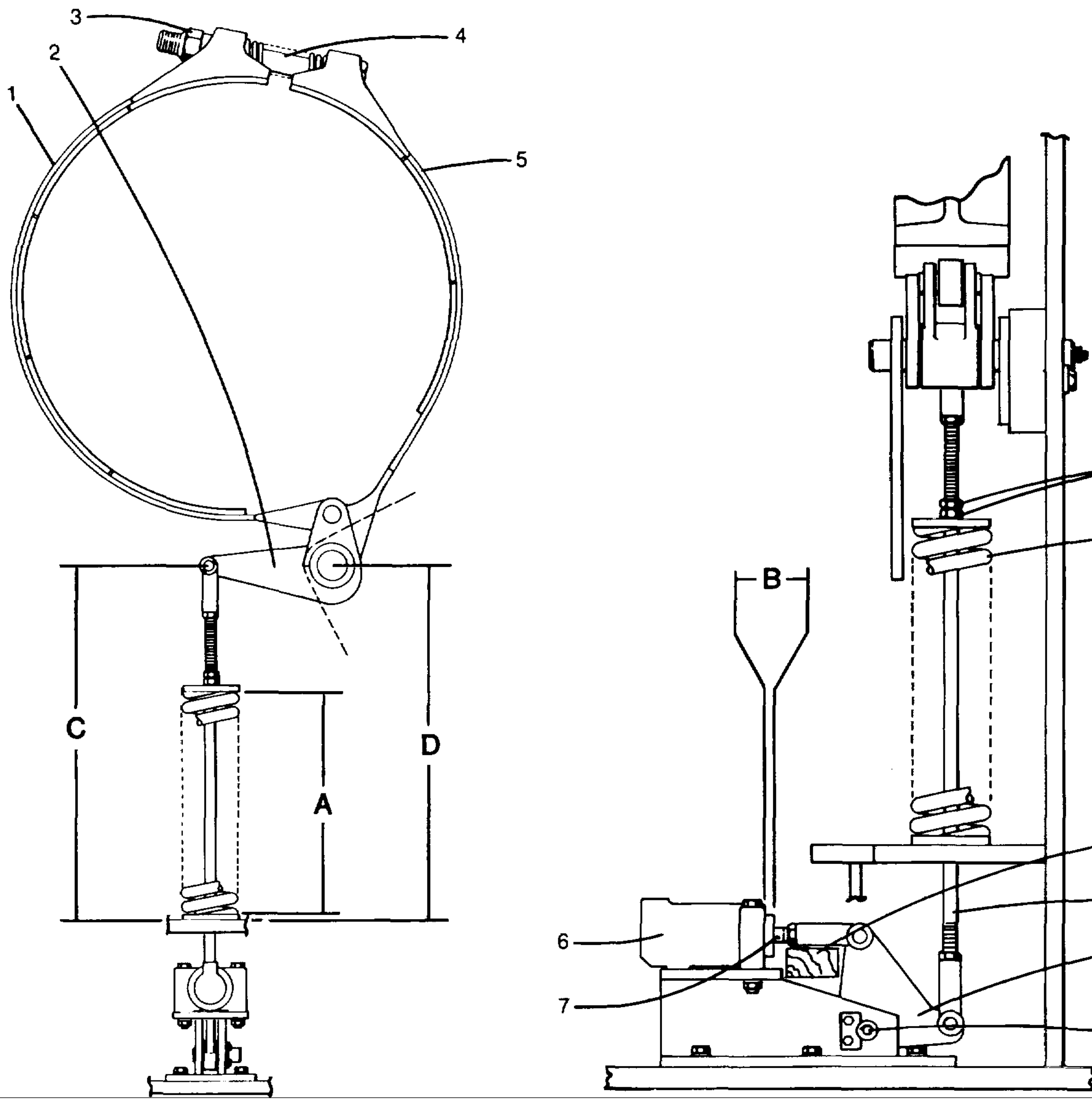


*Fig. 1I*
*Boom Hoist Brake*

(A) 14-5/8 inches (371.5 mm) - Brake applied
B) 7/16 inch (11.1 mm) - Brake applied (adjust when flush or less)
(C,D)23-1/4 inches (590.5 mm) - Brake applied

| | | | | | |
|---|---|---|---|---|---|
| | | | | (9) | Bell Crank |
| (1) | Long Band Section | (5) | Short Band Section | (10) | Spring Rod |
| (2) | Bellcrank | (6) | Cylinder Blocking | | |
| (3) | Adjusting Nut | (7) | Push Rod | 12) | Spring |
| (4) | Band Bolt | (8) | Grease Fitting | (13) | Adjusting Nut & Jam Nut |

The boom hoist brake is spring applied and hydraulicly released. If S-o-M pressure should be lost, and the boom hoist brake was adjusted properly, it would automatically apply.

When the boom hoist control is actuated to raise or lower the boom, oil under pressure is admitted to the boom hoist brake cylinder to release the brake-. When the control lever is returned to neutral, the oil in the cylinder flows directly to the S-o-M sump tank. The spring then applies the brake.

11.1 Boom Hoist Brake Adjustment (Fig. 1)

Check the boom hoist brake adjustment on deli- very of a new machine, and every 50 hours thereafter as follows:

(a) Boom down until boom is lying on ground, and boom hoist ropes are slack before working on boom hoist brake.
(b) The band must be centered with the boom hoist brake drums by adding or subtracting shims between the dead end lug and the

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dead end bracket on the revolving frame. The following shims are available for use at this point:
VB92........................... 16 Ga. (1.51 mm)
1A1275....................... 22 Ga. (.759 mm)

(c) With brake applied, the bellcrank (2) arm must be parallel to the upper frame horizontal members as shown by these dimensions (C) and (D). These dimensions must be equal. If not, adjust brake band bolt until they are.
(d) The brake must be adjusted when dimension (B) (the amount the piston protrudes from the cylinder) is zero (piston flush with cylinder). Tighten the band bolt until dimension (B) equals 7/16 inch (11.1 mm).
(e) Check the spring (12) length. It must equal 14-5/8 inch (371.4 mm) measured inside the spring seats. If not, adjust the spring length with the adjusting nut and jam nut (13).

Note: Adjustments made necessary by lining wear should be made with the adjusting nuts on the band bolt only providing step (c) has been established. The centering adjustment and the adjustment of the spring bolt nut are ordinarily necessary only when the band has been removed.

11.2 Brake Band Removal (Fig. 1)

Every 500 hours of operation, remove the boom hoist brake band and all related parts for visual inspection. If any of the parts show signs of cracks or undue wear, replace them. To remove the brake band, do the following:

(a) Before working on the boom hoist brake, boom down until the boom is lying on the ground and the boom hoist ropes are slack.
(b) Engage the boom hoist pawl and swing lock, disengage the master clutch, and shut the engine down.
(c) With the master clutch disengaged, move the boom hoist control lever until the boom hoist cylinder releases the boom hoist brake. Insert a small piece of blocking between the cylinder and bellcrank to hold bellcrank in extended position. Refer to item 11. Return boom hoist control lever to neutral position. Bleed remaining S-o-M pressure down to zero.
(d) Unscrew the brake band bolt (4). Remove bolt, nut, and spacer.

Note: Do not disturb the spring rod, spring rod nuts, and brake cylinder spring.

(e) Remove dead end pin. Remove the short brake band section (5).
(f) Remove the live end pin. Remove the long brake band section (1).

11.3 Brake Band Installation

Install new brake band assemblies by following removal procedures in reverse.

Use only FMC Corporation brake bands or replacements linings. They have been tested for use on these machines and will provide the best oper-

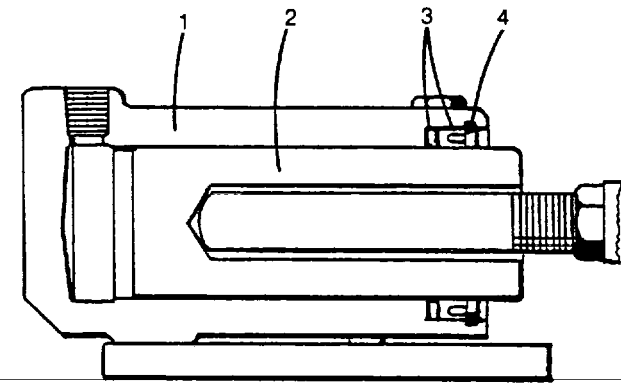


*Fig. 2*
*Cylinder Assembly*

(1) Cylinder (3) Seal Assembly
(2) Piston (4) Snap Ring

ating and wear characteristics.

New bands may be installed or new linings can be riveted to the old band. Thoroughly inspect the band for damage or cracked welds. If damage is detected, discard the band.

11.4 Cylinder Removal (Fig. 1 and 2)

(a) Shut engine down. Work control levers back and forth to reduce S-o-M pressure to zero.
(b) Disconnect hydraulic line from cylinder.
(c) Remove cylinder mounting capscrews. Remove cylinder from machine.

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(d) Thoroughly clean the outside of the cylinder with an approved solvent.
(e) Remove snap ring (item 4 in Fig. 2). Remove seal assembly (3). Remove piston from cylinder.
(f) Thoroughly clean cylinder and piston. Examine for scratches or nicks; replace if damaged.

11.5 Cylinder Replacement (Fig. 1 and 2)

(a) Lubricate O.D. of piston (item 2 in Fig. 2). My with clean S-o-M oil. Insert in cylinder.
(b) Install seal assembly (3); and snap ring (4).
(c) Install cylinder on machine. Install and tighten capscrews.
(d) Connect hydraulic lines to the cylinder.
(e) Engage and disengage the brake several times and check for leaks. Repair any leaks before operating.

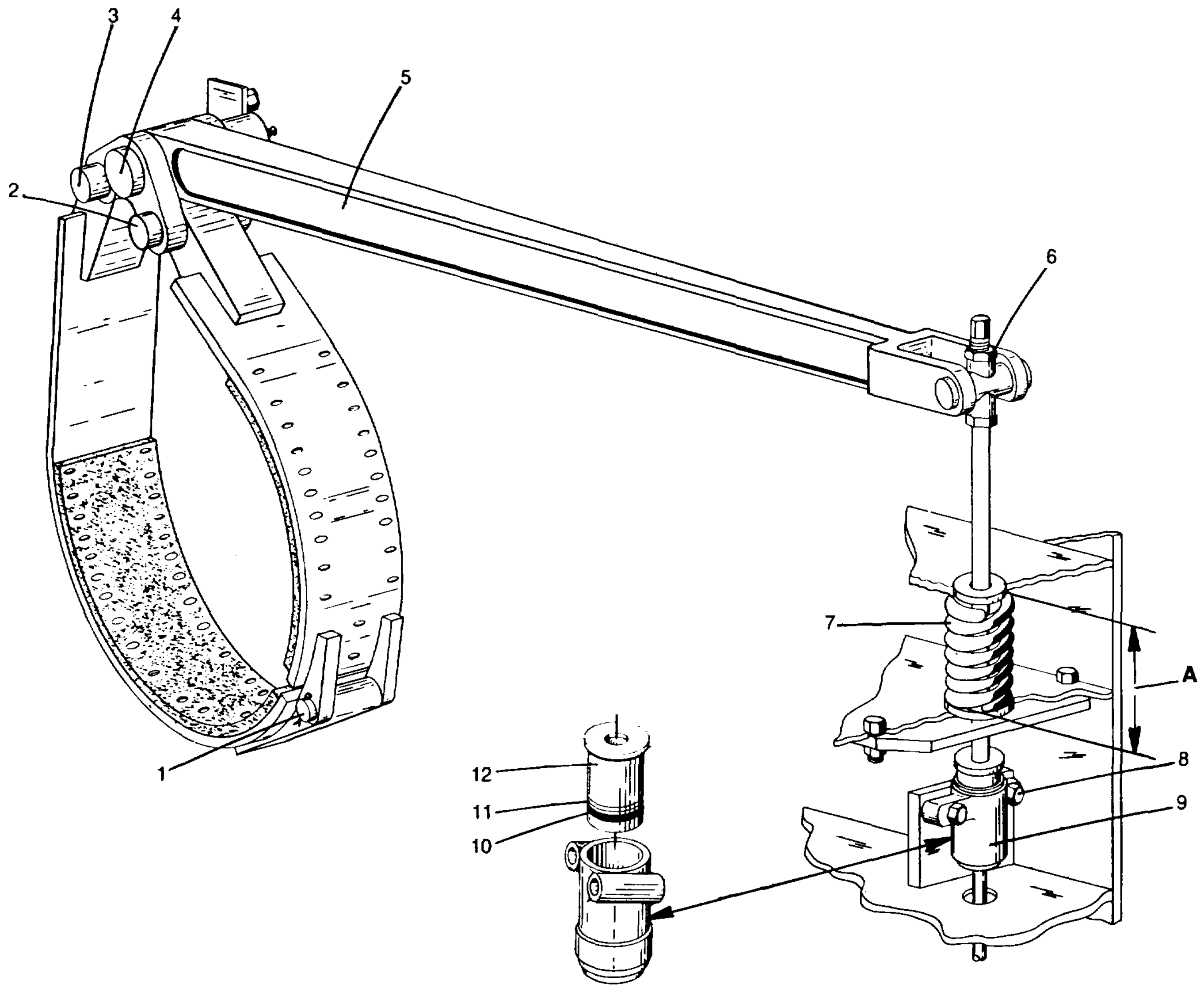


*Fig. 1*
*Swing Brake*

L118-D

(A) 13-5/8" (346.1 mm) Brake Applied
(1) Connecting Pin
(2) Pin (Short Band Section)
(3) Pin (Long Boom Section)
(4) Pivot Pin
(5) Lever Arm
(6) Adjusting Nut
(7) Spring
(8) Capscrews
(9) Cylinder Body
(10) 'O' Ring
(11) Back-up Ring
(12) Cylinder Piston

The swing brake is a two-piece external band which rides on a brake drum splined to the reverse shaft. It is spring applied, and hydraulically released by a lever on the operator's control stand. If control pressure should be lost. and the brake is in proper adjustment, it would automatically apply.

Sometimes it is advisable to swing against a partially applied swing brake, for greater accuracy when spotting a load with a long boom. To make this possible, a small brake drum and spring loaded band is attached to the swing brake control lever. With this arrangement, the lever may be partially engaged and the brake will hold it in position.

Note: Never use the swing brake as a house lock when traveling, transporting, or when leaving the machine. Use the swing lock for this purpose. Avoid using the swing brake or lock to make a sudden swing stop. Boom damage or loss of load may result.

Note: <u>Every 500 hours of operation, remove the brake band and all related parts for a visual inspection. If any of the parts show signs of cracks, undue wear, etc., replace them. If the linings are worn thin, or the rivets are close to contacting the drum, replace the lining. Readjust as explained later in this SM</u>.

2.1 Brake Adjustment

The brake adjustment must be checked upon delivery, and every 50 hours after that. Adjust the brake as follows:

(a) The brake must be adjusted if the cylinder piston (12) is flush with the edge of the cylinder when the brake is applied. To adjust the brake, back off on the locknut and tighten the adjusting nut (6) until the spring length (A) is as shown in Fig. 1 with the brake applied. This dimension is spring length, and does not include the spring guides.

*2.2* Brake Band Removal (Refer to Fig. 1)

Periodic inspections of the linings should be made so they *may* be replaced before wearing to the point that the rivets contact the drum. The brake band may be removed as follows:

(a) Engage swing lock.
(b) Reduce S-o-M pressure to zero by working control levers back and forth.
(c) Remove the hydraulic cylinder from the machine.
(d) Remove the adjusting nut, spring rod, spring, etc.
(e) Remove the connecting pin (1) from between the two halves of the bank.
(f) Raise the lever arm (5) until the pin (2) may be removed from the short band section.
(g) Remove the short band section.
(n) Remove the lever arm pivot pin (4).
(i) Pull the lever arm to the rear of the machine until the long band section pin (3) may be removed.
(j) Remove tile long band section.

The new or relined band may be installed by following removal procedure in reverse.

Use only bands or linings supplied by FMC Corporation. They have been tested for use on these machines and will provide the best lining life.

2.3 Swing Brake Control Adjustment (Refer to Fig. 2)

The brake band tension may be adjusted by tightening or loosening the nuts (2) on the band. The control valve linkage is adjusted as explained in SM7-12-1.0. 2.4 Swing Brake Cylinder Repair (Refer to Fig. 1)

(a) Work control levers back and forth with engine shut down to reduce S-o-M pressure to zero.
(b) Disconnect line from cylinder.
(c) Remove mounting capscrews (8) from cylinder. Remove cylinder from machine.

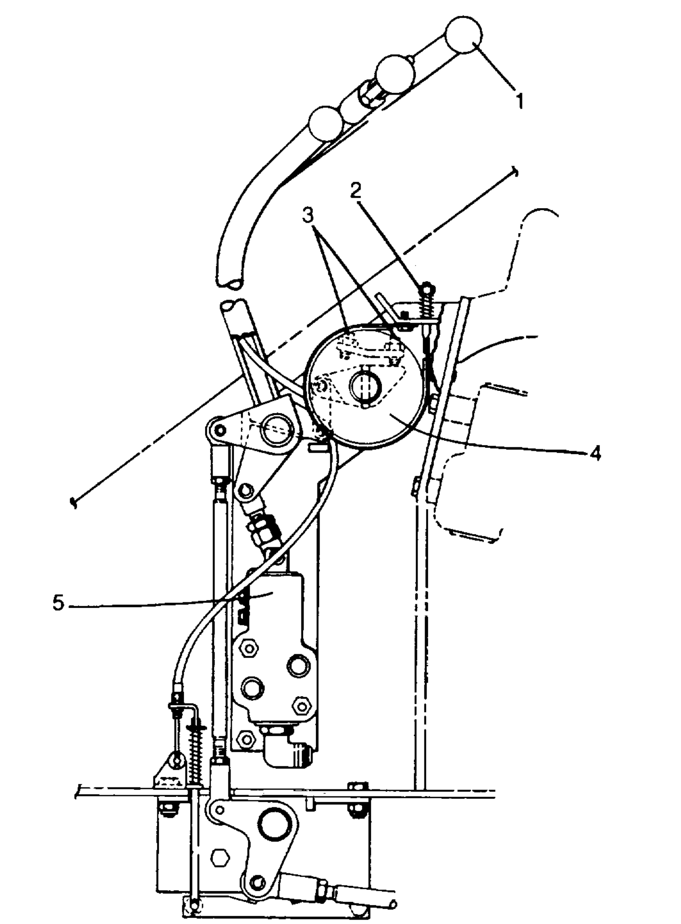


*Fig. 2*
*Swing Brake Control*

NA210-D

(1) Swing Brake Control Lever
(2) Locknut
(3) Set Screws
(4) Brake Drum
(5) Control Valve

(d) Remove piston (12) from cylinder. Remove old 'O' ring (10) and back-up ring (11) from piston.

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(e) Thoroughly clean parts in approved solvent. Examine parts for wear or damage. Replace parts if necessary.
(f) Install new '0' ring and backup ring on piston.
(g) Lubricate O.D. of piston with #2 Cosmolube or equal. Install piston in cylinder.
(h) Install cylinder on machine. Connect hydraulic lines.
(i) Engage and disengage swing brake several times, and check for leaks. If any, repair before using machine.

**Service Manual**

SM6-5-2.0-Engine Upper; Main

The cylinder block (Figs. 1 and 2) serves as the main structural part of the engine. The cylinder block is made of cast iron. Transverse members, cast in tegrally, provide rigidity and strength and ensure alignment of the block bores and bearings under load. The two ends of the block are similar, so the flywheel housing and gear train can be assembled to either end.

The block is bored to receive replaceable cylinder liners. Water jackets, which extend the full length of the bores, are divided into upper and lower sections which are connected by hollow struts (Fig. 2). Coolant from the pump enters at the bottom of each water jacket and leaves at the top of the block through holes which register with corresponding openings in the cylinder head.

An air box (Fig. 2) surrounding the water jackets conducts the air from the blower to the air inlet ports in the cylinder liners. Air box openings (Fig. 3) on the side of the block opposite to the blower provide access to the air box and permit inspection of the pistons and compression rings through the air inlet ports in the cylinder walls. The six-cylinder block has two additional air box openings on the blower side.

The camshaft and balance shaft bores are located on opposite sides near the top of the block.

The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping.

The perimeter of the top surface of the cylinder block is grooved, outside of the cam pockets, to accommodate a block-to-head oil seal ring. The top surface of the block is also counterbored at each water or oil passage to accommodate individual seal rings (Fig. 4).

Each cylinder liner is retained in the block by a flange at its upper end. The liner flange rests on a cast iron insert located in the counterbore in the block bore. An individual compression gasket Is used at each cylinder.

When the cylinder head is installed, the gaskets and seal rings compress sufficiently to form a tight metal-to-metal contact between the head and block.

New service replacement cylinder block assemblies include the main bearing caps and bolts, dowels, and the necessary plugs.

Since the cylinder block is the main structural part of the engine, the various sub-assemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand (Fig. 5) provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction 90° or 180° where it is locked in place and then, if desired, tipped back with either end or the oil pan side up.

2.1 Remove And Disassemble Engine

Before mounting an engine on an overhaul stand, it must be removed from its base and disconnected from the drive mechanism. Details of this procedure will vary from one application to another. However, the following steps will be necessary.

(1) Drain the cooling system.
(2) Drain the lubricating oil.
(3) Disconnect the fuel lines. Remove the air silencer or air cleaner and mounting bracket.
(5) Remove the turbocharger, if used.
(6) Disconnect the exhaust piping and remove the exhaust manifold.
(7) Disconnect the throttle controls.
(8) Disconnect and remove the starting motor, battery-charging generator and other electrical equipment.
(9) Remove the air compressor, if used.
(10) Remove the radiator and fan guard or the heat exchanger and other related cooling system parts. 6
(11) Remove the air box covers.
(12) Disconnect any other lubricating oil lines, fuel lines or electrical connections.
(13) Separate the engine from the drive mechanism.
(14) Remove the engine mounting bolts.
(15) Use a sling with a spreader bar (Fig. 6) and lift the engine from its base.

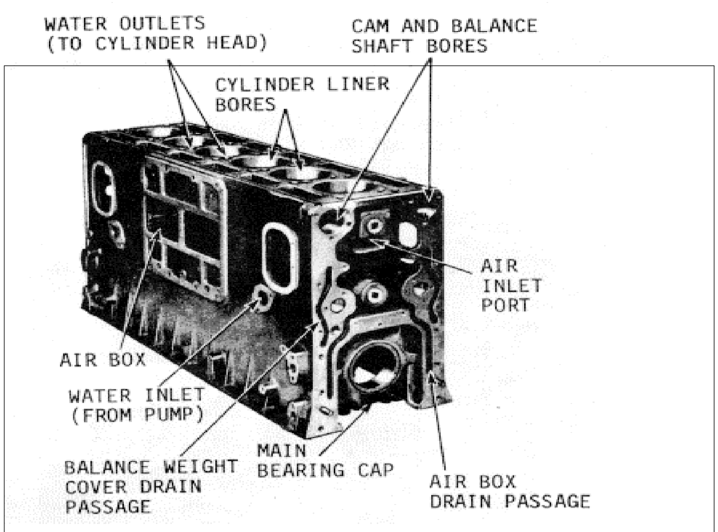



*Fig. 1*
*Typical Cylinder Block*

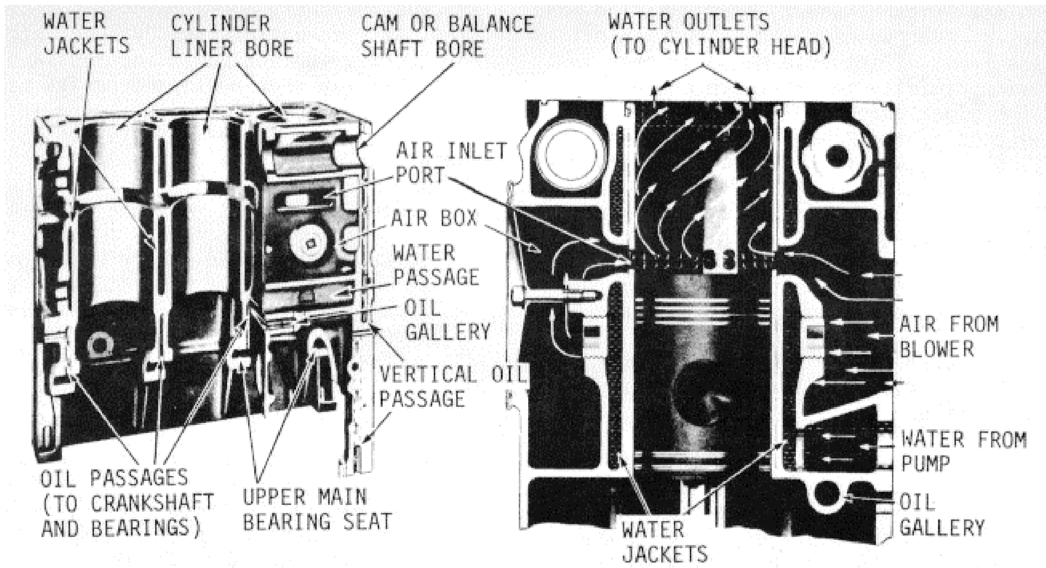



Fig. 2
Cutaway View Of Cylinder Block Showing Air And Water I

(16)Locate the center lug of the overhaul stand adaptor plate in the proper air box opening on the side of the block opposite the blower. The center lug is located in the number four opening of six cylinder engines.

The adaptor plate, used with the hydraulic engine overhaul stand, must be attached to the mounting plate on the overhaul stand with six spacers and bolts (Fig. 5). Short spacers and bolts are used with the six cylinder engines. The spacers provide the necessary clearance for the front balance weight cover and the flywheel housing when the engine is tipped on its side and rotated.

(17)Loosen the lock nuts on the two holding lugs on the adaptor plate and lower the engine while guiding the lugs into the air box openings.

(18)Turn the holding lugs crosswise in the air box openings and tighten the lock nuts, drawing the engine tight against the adaptor plate.

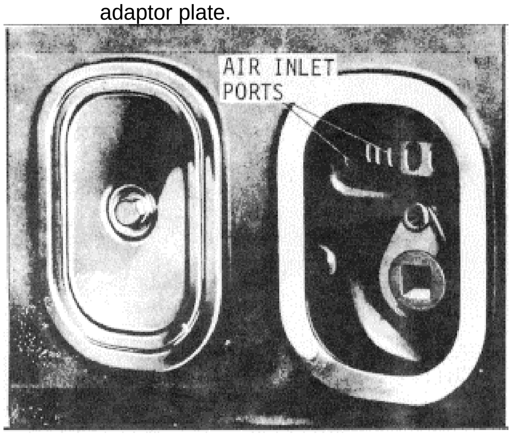



Fig. 3
Air Box Covers And Air Inlet Ports

(19)To be sure the engine does not shift on or break away from the overhaul stand, insert a 7/16" -14 X 2" bolt, with a plain washer under the head of the bolt, through the hole in the adaptor plate and into the pad on the cylinder block.

**WARNING**

Be Sure The Engine Is Securely Mounted To The Overhaul Stand Before Releasing The Lifting Sling. Severe Injury To Personnel And Destruction Of Engine Parts Will Result If The Engine Breaks Away From The Overhaul Stand.

(20)With the engine mounted on the overhaul stand, remove all of the remaining sub-assemblies and parts from the cylinder block. The procedure for removing each sub-assembly from the cylinder block, together with dis-

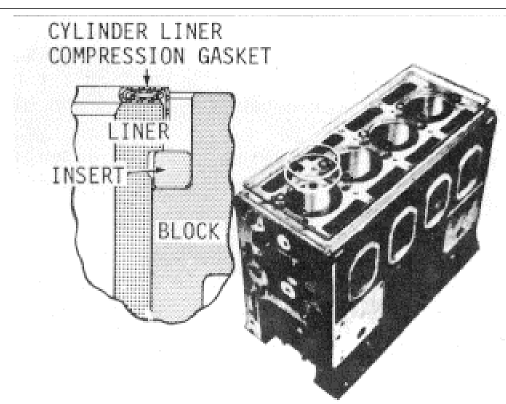



*Fig. 4*
*Sealing Arrangement Of Cylinder Block*

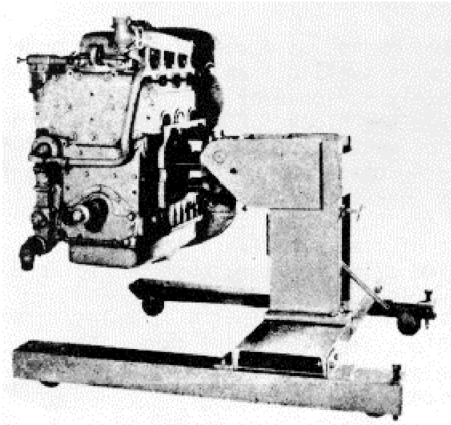


*Fig. 5*
*Engine Mounted On Overhaul Stand*

assembly, inspection, repair and re-assembly of each, will be found in the various sections of this manual.

After stripping, the cylinder block must be thoroughly cleaned and inspected.

2.2 Clean Cylinder Block

Scrape all gasket material from the cylinder block. Then remove all oil gallery plugs and core hole plugs (except cup plugs) to allow the cleaning solution to contact the inside of the oil and water passages. This permits more efficient cleaning and eliminates the possibility of the cleaning solution attacking the aluminum core hole plug gaskets.

If a core hole plug is difficult to remove, hold a 3/4" drift against the plug and give it a few sharp blows with a one-pound hammer. With a 1/2" flexible handle and a short extension placed in the countersunk hole in the plug, turn the plug slightly in the direction of tightening.

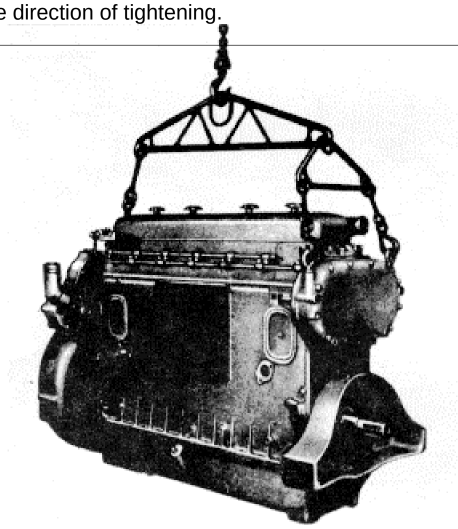


Fig. 6.
Lifting Engine With Sling

Then turn it in the opposite direction and back the plug out.

Clean the cylinder block as follows:

(1) Remove the grease by agitating the cylinder block in a hot bath of commercial heavy-duty alkaline solution (Fig. 7).
(2) Wash the block in hot water or steam clean it to remove the alkaline solution.
(3) If the water jackets are heavily scaled, proceed as follows:
  (a) Agitate the block in a bath of inhibited commercial pickling acid.
  (b) Allow the block to remain in the acid bath until the bubbling action stops (approximately 30 minutes).
  (c) Lift the block, drain it and re-immerse it in the same acid solution for 10 minutes.
  (d) Repeat step "c" until all scale is removed.
  (e) Rinse the block in clear hot water to remove the acid solution.
  (f) Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.
  (g) Wash the block in clean water or steam clean it.

**Warning**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(4) Dry the cylinder block with compressed air.
(5) Make certain that all water passages, oil galleries and air box drain holes have been thoroughly cleaned.

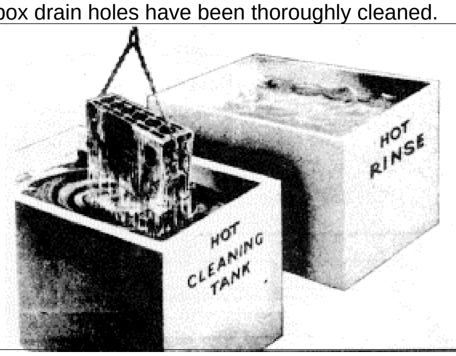



*Fig. 7*
*Cleaning Cylinder Block*

Note: The above cleaning procedure may be used on all ordinary cast iron and steel parts of the engine. Mention will be made of special cleaning procedures when-ever necessary.

2.3 Pressure Test Cylinder Block

Extremely tight fitting cylinder liners, severe scoring of the liners and overheating of the engine may result in cracks in the cylinder bores. Overheating of the engine may also result in cracks between the water Jackets and the oil passages.

The cylinder block may be pressure tested for cracks or leaks by either one of two methods. In either method, it will be necessary to make plates (Fig. 8) to seal the water openings in the top of the block. Main bearing caps may be used to secure the plates to the block with the cylinder head bolts or studs and nuts. Cylinder head seal rings may be used as gaskets between the plates and the block. It will also be necessary to use water hole cover plates and gaskets to cover the water pump inlet openings in the block. Drill and tap one cover plate to provide a connection for an air line (Fig. 9).

With the cylinder block prepared in the above manner, the core hole plugs installed and the plugs removed from the oil passages, test the block as follows:

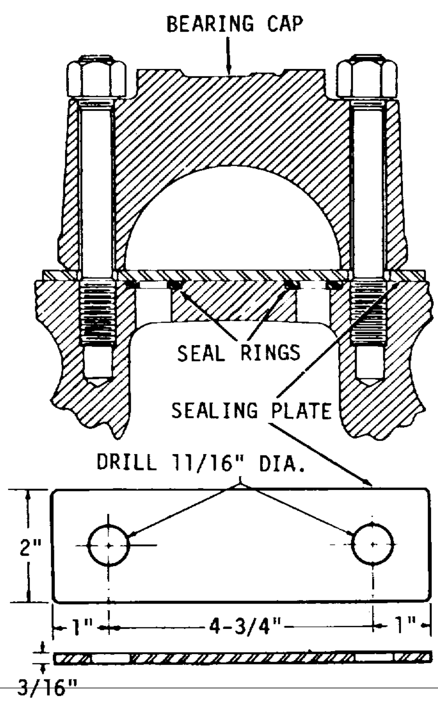


Fig. 8
Sealing Plate Details For Pressure Testing Cylinder Block

2.4 Method "A"

This method may be used when a large enough water tank is available and the cylinder block is completely stripped of all parts.

(1) Immerse the block for twenty minutes in a tank of water heated to 180-200° F (82-930C)
(2) Apply 40 psi (276 kPa) air pressure to the water jacket and observe the water in the tank for bubbles which indicate the presence of cracks or leaks in the block. A cracked cylinder block must be replaced by a new block.
(3) After the pressure test is completed, remove the block from the water tank. Then remove the plates and gaskets and dry the block with compressed air.

2.5 Method "B"

This method may be used when a large water tank is unavailable, or when it is desired to check the block for cracks without removing the engine from the equipment which it powers. However, it is necessary to remove the cylinder head, blower, oil cooler, air box covers and oil pan.

(1) Attach sealing plates and gaskets as in Method "A". However, before attaching the last sealing plates, fill the water jacket with a mixture of water and one gallon of permanent type antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.
(2) Install the remaining sealing plate and tighten it securely.
(3) Apply 40 psi (276 kPa) air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks which may exist.
(4) At the end of the test period, examine the cylinder bores, air box, oil passages, crank-case and exterior of the block for presence of water and antifreeze mixture which will indicate the presence of cracks. A cracked cylinder block must be replaced by a new block.

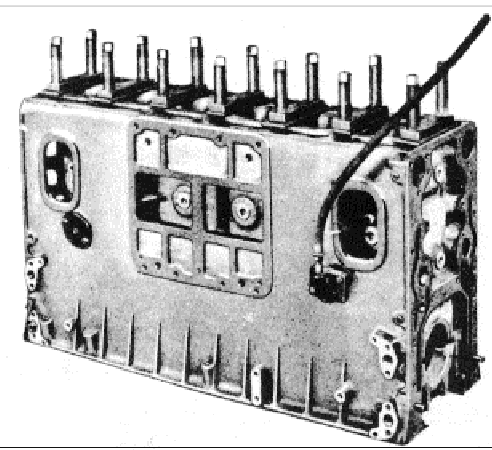


*Fig. 9*
*Cylinder Block Prepared For Pressure Test*

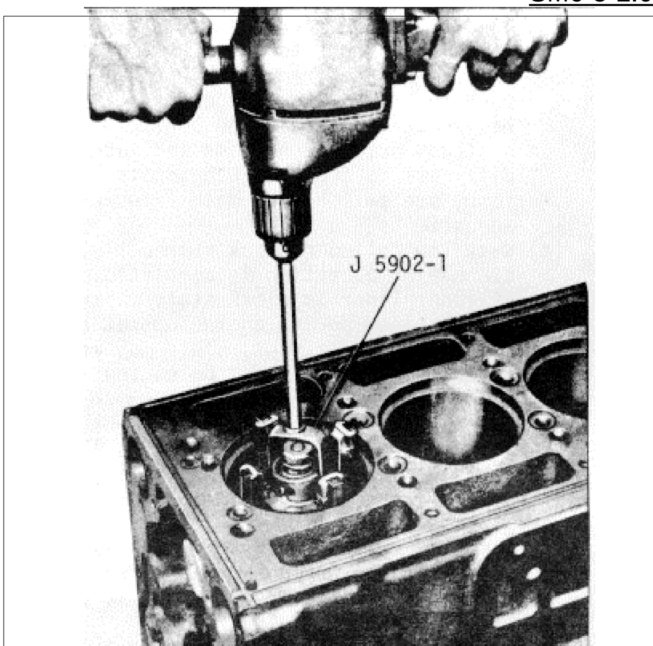



*Fig. 10*
*Honing Bore Of Cylinder Block*

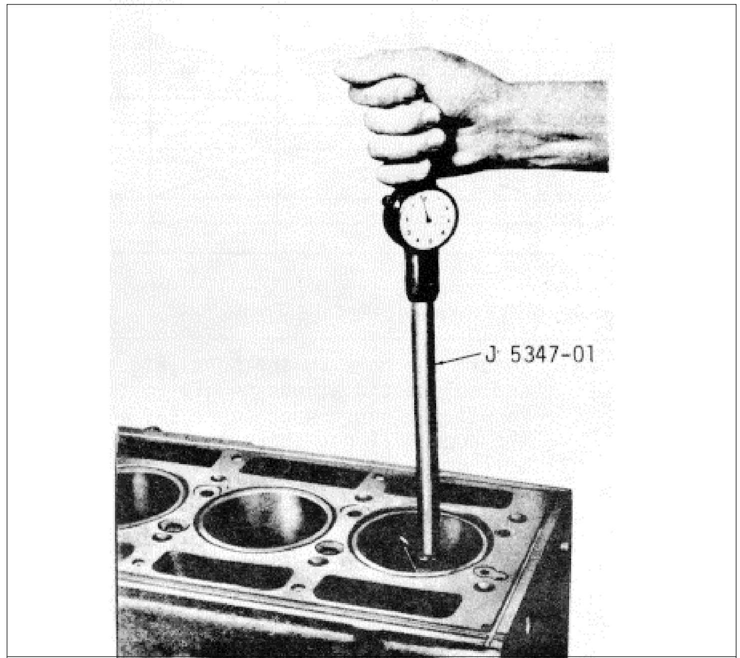



*Fig. 12*
*Checking Bore Of Cylinder Block*

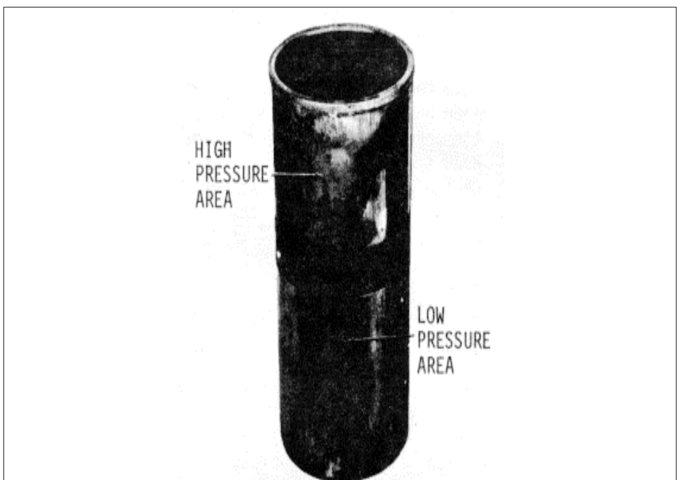



*Fig. 11*
*High Pressure Areas On Cylinder Liner*

(5) After the test is completed, remove the plates, drain the water jacket and blow out all of the passages in the block with compressed air.

2.6 Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block.

Since most of the engine cooling is accomplished by heat transfer through the cylinder liners to the water jacket, a good liner-to-block contact must exist when the engine is operating. Whenever the cylinder liners are removed from an engine, the block bores must be inspected.

Note: <u>Before attempting to check the block bores, hone them throughout their entire length until about 75% of the area above the ports has been "cleaned-up "</u> 6

(1) Hone the block bores as follows:

(a) Use a hone in which the cutting radius of the stones can be set in a fixed position to remove irregularities in the bore rather than following the irregularities as with a spring-loaded hone. Clean the stones frequently with a wire brush to prevent stone loading. Follow the hone manufacturer' s instructions regarding the use of oil or kerosene or the stones. Do not use such cutting agents with a dry hone. In a cast iron cylinder block, use 120 grit stones J 5902-14.

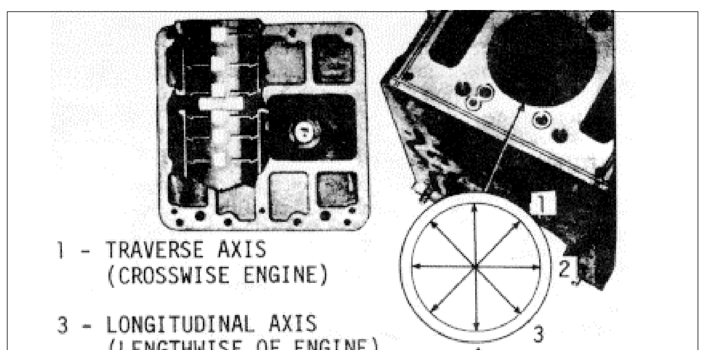



*Fig. 13*
*Cylinder Bore Measurement Diagram*

| | Trans. 1 | 45° 2 | Long. 3 | 45° 4 |
|---|---|---|---|---|
| A | | | | |
| B | | | | |
| C | | | | |
| D | | | | |
| Part Belt | | | | |
| E | | | | |
| F | | | | |

Fig. 14
Block Bore Measurement Record Form

(b) Insert the hone in the bore (Fig. 10) and adjust the stones snugly to the nar rowest section. When correctly adjusted, the hone will not shake in the bore, but will drag freely up and down when the hone is not running.

(c) Start the hone and "feel out" the bore for high spots which will cause an increased drag on the stones. Move the hone up and down the bore with short overlapping strokes about 1" long. Con centrate on the high spots in the first cut. As these are removed, the drag on the hone will become lighter and smooth er. Do not hone as long at the air inlet port area as in the rest of the bore because this area, as a rule, cuts away more rapidly. Feed lightly to avoid an excessive increase in the bore diameter Some stones cut rapidly even under low tension.

(d) When the bore is fairly clean, remove the hone, inspect the stones and measure the bore. Determine which spots must be honed most. Moving the hone from the top to the bottom of the bore will not

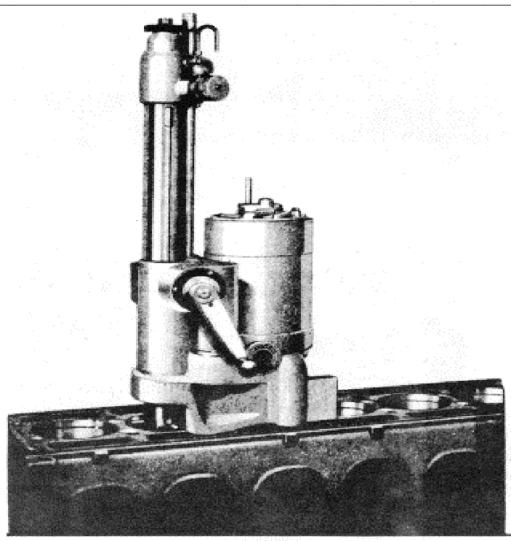


*Fig. 15*
*Boring Cylinder Block With Portable Boring Bar*

correct an out-of-round condition. To remain in one spot too long will cause the bore to become irregular. Where and how much to hone can be judged by feel. A heavy cut in a distorted bore produces a steady drag on the hone and makes it difficult to feel the high spots. Therefore, use a light cut with frequent stone adjustments.

(e) Wash the cylinder block thoroughly after the honing operation is completed.

(2) The cylinder liner is alternately expanding and contracting, during engine operation, due to temperature variations. This may result in irregularities in the block bores (out-of-round and taper), the effects of which will be seen as high pressure areas on the outside diameter of the cylinder liner (Fig. 11). A slight increase in block bore size is normal with high mileage or long periods of engine operation.

(a) Visually check the contact area as revealed by the honed surface. There must not be any low spots which are larger in area than a half dollar.

(b) Measure the entire bore of each cylinder with cylinder bore gauge J 5347-01 (Fig. 12) which has a dial indicator calibrated in .0001" increments. The standard block bore is 4.6260" to 4.6275" (cast iron block). Place the bore gauge in the master ring gauge J 8386-01 which has an I.D. of 4.6270" and set the dial to zero. Take measurements on the cleaned-up surface only at positions A,B,C,D,E and F in the bore on axes 450 apart (Fig. 13). Read the measurements from the zero mark on the gauge. The readings may be recorded on a form similar to the one illustrated in Fig. 14.

Note: Dial bore gauge setting master tool J 23059-01 may be used in place of the master ring gauge.

(3) The liner-to-block clearance with new parts is zero to .0015" (cast iron block). With used parts, the maximum clearance is .0025" (cast iron block). After measuring the block bores, measure the outside diameter of the cylinder liners (SM6-5-22.0). Then determine the block-to-liner clearances (refer to SM6-5-70.0for the specified clearances) and whether it will be necessary to bore the block for oversize cylinder liners.

(4) If necessary, bore the cylinder block as follows:

(a) Each bore in a used block must not be out-of-round or tapered more than .002". If the average block bore is over 4.6285", the block should be bored oversize (refer to Tables 1 and 2).

(b) A typical commercially available portable boring bar is illustrated in Fig. 15. Instructions on correct use of the boring bar are provided by the manufacturer.

(c) After boring the block or an oversize cylinder liner, check the bore finish to be sure it is smooth (120 RMS). Heat transfer from the cylinder liner.

| For Average Block Bore I.D. Size | Use Liner O.D. Size | For Liner-to-Block Clearance |
|---|---|---|
| | CAST IRON BLOCK | |
| 4.6260" 4. 6275" | Standard | .000" to .0025" |
| 4.6270" 4.6285" | .001" Oversize | .000" to .0025" |

TABLE 1

| Block Boring Dimensions | Liner O.D. Size | Max. Block Bore I.D. on Used Block |
|---|---|---|
| | CAST IRON BLOCK | |
| 4.63120 4. 6320" | .005" Oversize | 4.6325" |
| 4.6370" 4.6370" | .010" Oversize | 4.6375" |
| 4.6460" 4.6470" | .020" Oversize | 4.6475" |
| 4. 6570" | .030" Oversize | 4.6575" |

TABLE 2

to the block will be adversely affected if the block bore isn't smooth.

(d) Wash the block thoroughly after the boring operation.

(e) When an oversize liner is used, stamp the size of the liner on the top deck of the block adjacent to the liner counterbore. An oversize liner is used (SM6-5-22.0).

(5) Check the top of the block for flatness with an accurate straight edge and a feeler gauge (Fig. 16).

(a) The top surface of the block must not vary more than .003" transversely and not over .009" longitudinally. It will be difficult to prevent water, oil and compression leaks if the top surface of the block exceeds these tolerances.

(b) If it is necessary to machine the top surface of the block to correct for the above conditions, do not remove more than .008" of metal. Stamp the amount of stock removed on the face of the block. The distance from the centerline of the crankshaft to the top of the block must not be less than 16.176" (Fig. 17).

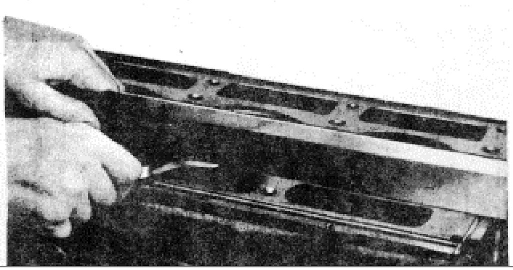


*Fig. 16*
*Checking Top Face Of Cylinder Block*

(c) If stock is removed from the top surface of the block, check the depth of the seal ring grooves and counterbores. The cylinder head seal strip grooves must be .092"-.107" deep. The large water hole counter-bores (between the cylinders) must be .109"-.120" deep, and the combination water and oil hole counterbores and small water hole counterbores must be .087"-.098" deep. If necessary, deepen the grooves or counterbores to the specified limits to retain the proper "crush" on the seal rings. It is not necessary to deepen the counterbores for the cylinder liners since .004" and .008" undersize thickness inserts are available for ad- justing the liner position as outlined in SM6-5-22.0 under Fitting Cylinder Liner In Block Bore.

(6) Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth (Fig. 18). The depth must be .4770" to .4795" and must not vary more than .0015" throughout the entire circumference. The counterbored surfaces must be smooth and square with the cylinder bore within .001" total indicator reading. There must not be over .001" difference between any two adjacent cylinder counterbores when measured along the cylinder longitudinal centerline of the cylinder block.

(7) Check the main bearing bores as follows:

(a) Check the bore diameters with the main bearing caps in their original positions. Apply a small quantity of International Compound No. 2, or equivalent, to the threads on the bolts or studs and nuts and to the bolt head (or nut) contact area. Then install and tighten the bolts to 165-175 ft/lb (224-238 N-m) torque or stud nuts to 140-155 ft/lb (190-211 N.m) torque. The specified bore diameter is 3.812" to 3.813". If the bores do not fall within these limits, the cylinder block must be rejected.

**CAUTION**

Main Bearing Cap Bolts Are Especially Designed For This Purpose And Must Not Be Replaced By Ordinary Bolts.

Note: <u>Bearing caps are numbered to correspond with their respective positions in the cylinder block. It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The number of the front main bearing cap is stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 19, regardless of engine rotation or accessory arrangement. As originally manufactured, the main bearing caps are installed with the numbered side facing the blower side of the engine. Machining of the cylinder block and main bearing caps is such that the mating parts are</u>

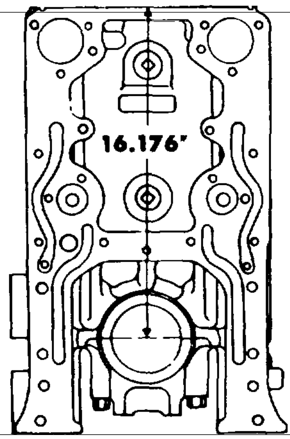



*Fig. 17*
*Minimum Distance From Center Line Of Crankshaft To Top Of Cylinder Block*

"offset" to prevent installation of the bearing caps 180° from their correct position. However, if an engine has been converted for a new application and the cylinder and bearing numbering sequence has been reversed, the bearing caps must be reinstalled in the original positions regardless if the block and bearing caps have or have not been re-numbered.

(b) Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a finished replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap.

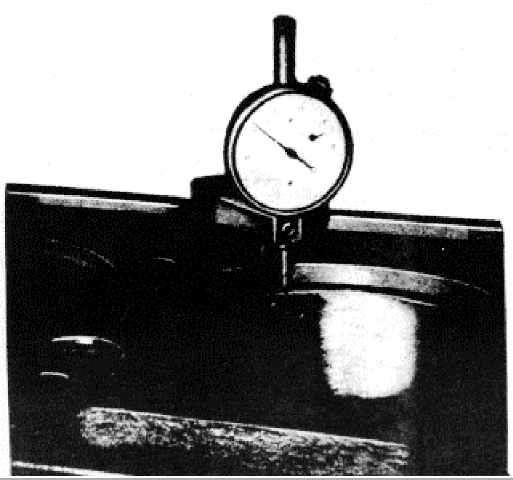


*Fig. 18*
*Checking Depth Of Counterbore For Cylinder Liner With Tool J 22273*

Note: Use the unfinished bearing caps for the front and intermediate bearing positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the rear bearing position.

(c) If the main bearing bores are not in alignment or a replacement bearing cap is used, the block must be line-bored. Install the bearing caps in their original positions and tighten the bolts to 165-175 ft/lb. (224-238 N.m) torque (or tighten the nuts, if used, to 140-155 ft/lb.(190- 211 N.m) torque. Line-bore the block, but do not remove more than .001" stock. After boring, all bores must be within the specified limits of 3.812" to 3.813".

(d) Main bearing bores are line-bored with the bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured in place and the bolts tightened as specified in SM6-5-12.0. If a main bearing bore is more than .001" out of alignment, the block must be line-bored or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat or other damage.

(8) Refer to the Cylinder Block Plugging Charts at the end of this manual and install the necessary plugs and dowels.

(9) Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .625" from the face of the block.

The dowels used to retain the crankshaft thrust washers on the rear main bearing cap must extend .110" to .120" from the surface of the bearing cap.

Note: A stepped dowel pin is available to replace-loose pins in the rear main bearing cap. Before installing the stepped pins, rebore the dowel holes in the bearing cap with a No. 11 (.1910") or No. 12 (.1890") drill. After pressing the pins into the bearing cap, remove all burrs from the base of the dowel pins to ensure proper seating of the thrust washers.

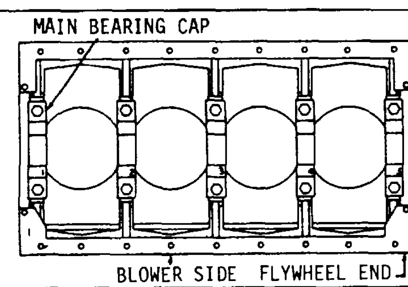



Fig. 19
Cylinder Block Markings

Fig. 19
Cylinder Block Markings

(10) Replace main bearing cap studs, if used, which a re damaged or broken. Install new studs to a height of 4" + 1/32" above the upper bearing seat at a Torque of 35-75 ft/lb. or 47-102 N m.

(11) If used, replace damaged or broken cylinder head studs. Install and drive a new stud to a height of 4-3/8" $\pm$ 1/32" at minimum torque of 75 ft/lb. or 102 N.m.

(12) Examine the tapped bolt holes for the cylinder head or main bearing cap bolts and, if the threads are damaged, "clean-up" the threads or install a helical thread insert. The tapped holes may be tapped with a 5/8" -11 UNC3B tap. All cylinder head bolt or stud holes must have the threads extending 1.84" below the block surface.

Note: The current service replacement cast iron cylinder blocks use a special cylinder head bolt in all positions.

(13) Check the drive pins (which plug the vertical oil galleries) in the corners of the block to be sure they are flush with or below the top surface of the block.

(14) Check the remaining cylinder block surfaces and threaded holes. Check all of the mating surfaces, or mounting pads, for flatness, nicks and burrs. The flatness of the blower mounting pad must not vary more than .004". Clean-up damaged threads in tapped holes with a tap or install helical threads inserts, if necessary.

(15) After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil. If the block is to be stored for an extended period of time , spray or dip it in a polar type rust preventive such as Valvoline Oil Company's "Tectyl 502-C", or equivalent. Castings free of grease or oil will rust when exposed to the atmosphere.

2.7 Assemble And Install Engine

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

Note: Before a reconditioned or new service replacement cylinder block is used, steam clean it to remove the rust preventive and blow out the oil galleries with compressed air.

(1) Mount the cylinder block on the overhaul stand.

(2) If a new service replacement block is used, stamp the engine serial number and model number on the pad located in the upper right-hand corner on the blower side of the block. Also stamp the position numbers on the main bearing caps (Fig. 19) and the position of the No. 1 bearing on the oil pan mounting flange of the block.

(3) Install all of the required cylinder block plugs and drain cocks. Use a good grade of non-hardening sealant on the threads of the plugs and drain cocks. Install the plugs flush with or below the surface of the block.

(4) Clean and inspect all engine parts and subassemblies and, using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. The procedures for inspecting and installing the various parts and sub-assemblies are outlined in the following SMs in this manual.

(5) Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.

(6) Complete the engine build-up by installing all remaining accessories, fuel lines, electrical connections, controls etc.

(7) Operate the engine on a dynamometer, following the RUN-IN procedure outlined in SM6-5- 67.0.

(8) Reinstall the engine in the equipment which it powers.

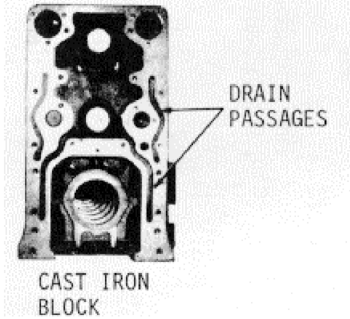



*Fig. 1*
*Drain Passages In Cast Iron Cylinder Blocks*

A flat steel plate, one bolted to each end of the cylinder block, provides a support for the flywheel housing at the rear and the balance weight cover and crankshaft cover at the front of the engine. Since the blower drive gear assembly is supported on the rear end plate, this plate has a different contour than the one used at the front. Gaskets are used between the block and each end plate.

3.1 Inspection

When an end plate is removed, it is essential that all of the old gasket material be removed from both surfaces of the plate and the cylinder block. Clean the end plate as outlined under Clean Cylinder Block in SM6-5-2.0.

Inspect both surfaces of each end plate for nicks, dents, scratches or score marks and check the end plates for warpage. Also check the tapped holes in the end plates at this time. If nicks or scratches on the sealing surfaces of the end plates are too deep to be cleaned up, replace the end plates.

3.2 Install End Plates

With all of the necessary plugs properly installed, the end plate-to-cylinder block dowels in place, attach the cylinder block front and rear end plates as outlined below.

(1) Affix a new gasket to each end of the cylinder block, using a non-hardening gasket cement. Also apply an even coating of gasket cement to the outer surface of each gasket (the surface next to the end plate).
(2) Use guide studs J 1927-01 as shown in Fig. 2 to set the front end plate next to the cylinder block and install the bolts and lock washers. Do not tighten the bolts at this time. Wipe the excess gasket cement from the bores in the end plate and the cylinder block.
(3) Insert a camshaft end bearing through the SMALL bearing bore in the end plate and into the bore of the block to accurately align the end plate as shown in Fig. 3.
(4) With the bearing in place, tighten the 3/8" -16 end plate retaining bolts 30-35 ft/lb. (41-47 N-m) torque. Tighten the 1/2" -13 bolts to 71-75 ft/lb. (96-102 N-m) torque.

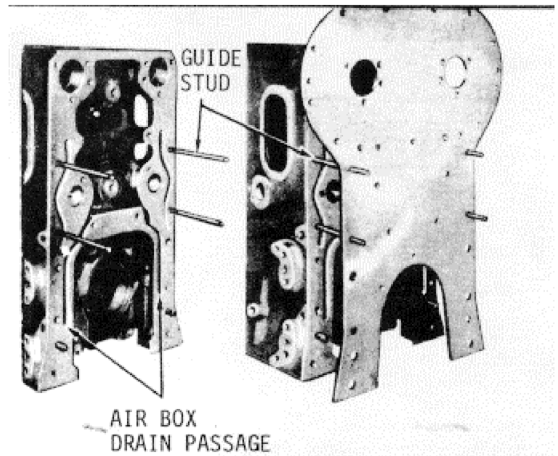



*Fig. 2*
*Installing Front End Plate*

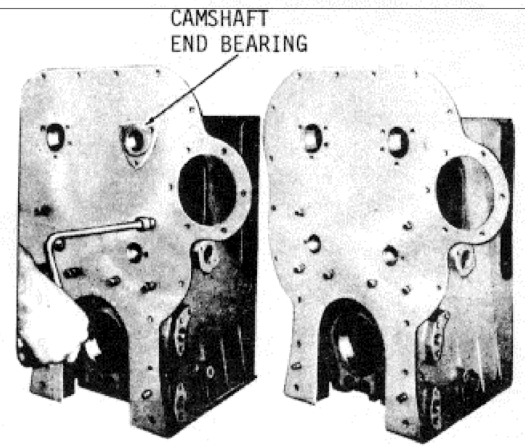



*Fig. 3*
*Installing Rear End Plate*

Remove the camshaft bearing which served as a pilot while attaching the end plate.

(5) Use the guide studs J 1927-01 and the camshaft end bearing to install the rear end plate in the same manner as outlined above.

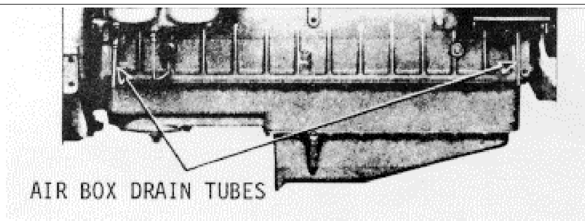


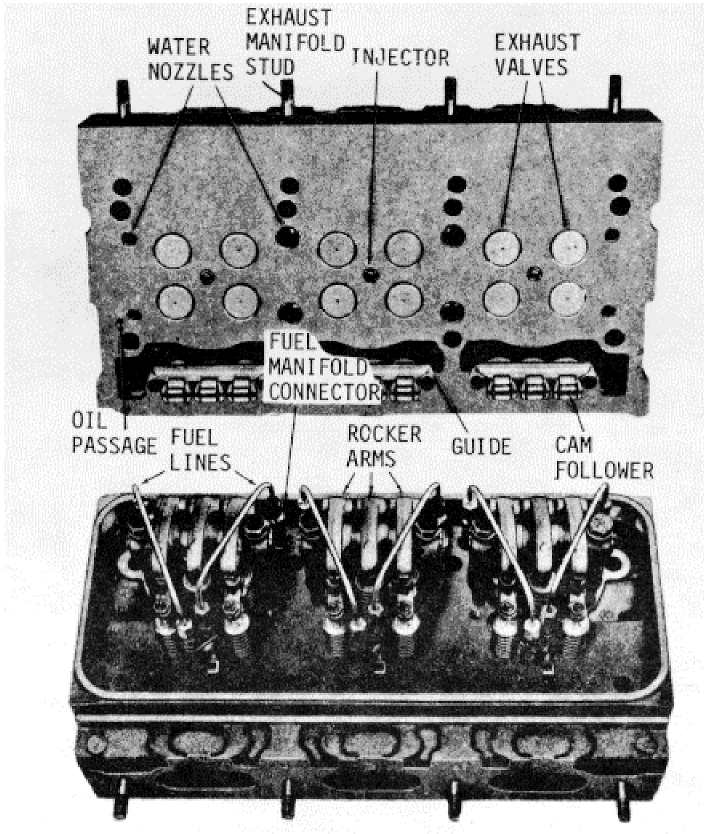

*Fig. 1*
*Air Box Drain Tubes*

During normal engine operation, water vapor from the air charge, as well as slight amount of fuel and lubricating oil fumes, condenses and settles on the bottom of the air box. This condensation is removed by the air box pressure through cored passages located at the front and rear of the cylinder block with drain outlets (Fig. 1) in the side of the block.

Air box drains must be kept open at all times, otherwise water and oil that may accumulate will be drawn into the cylinders.

4-1 Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Operator's Manual ).




6

*Fig. 1*
*Cylinder Head Assembly (Four-Valve)*

The cylinder head (Figs. 1 and 2) is a one-piece casting securely held to the top of the cylinder block by special bolts.

The exhaust valves, fuel injectors and the valve and injector operating mechanism a)J located in the cylinder head.

Four exhaust valves are provided for each cylinder.

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of valves under varying conditions of temperature and materially prolong the life of the cylinder head.

To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube (Fig.4 ) which passes through the water spacer in the cylinder head. The lower end of the injector tube is pressed into the cylinder head and flared over; the upper end is flanged and sealed with a neoprene seal. The sealed upper end and flared lower end of the injector tube prevent water and compression leaks.

The exhaust passages from the exhaust valves of each cylinder lead through a single port to the exhaust manifold. The exhaust passages and the injector tubes are surrounded by engine coolant.

In addition, cooling of the above areas is further ensured by the use of water nozzles (Fig.5 ) pressed into the water inlet ports in the cylinder head. The nozzles direct the comparatively cool engine coolant at high velocity toward the sections of the cylinder head which age subjected to the greatest heat.

The fuel inlet and outlet manifolds are cast as an integral part of the current cylinder heads. Tapped holes are provided for connection of the fuel lines at various points along each manifold.

The water manifold is also cast as an integral part of the cylinder head.

To seal compression between the cylinder head and the cylinder liner, separate laminated metal gaskets are provided at each cylinder. Water and oil passages between the cylinder head and cylinder block are sealed with synthetic rubber seal rings which fit into counterbored holes in the block. A synthetic rubber seal fits into a milled groove near the perimeter of the block. When the cylinder head is drawn down, a positive leakproof metal-to-metal contact is assured between the head and the block.

To make the cylinder heads more tolerant of abnormal coolant temperature, relief areas have been cast

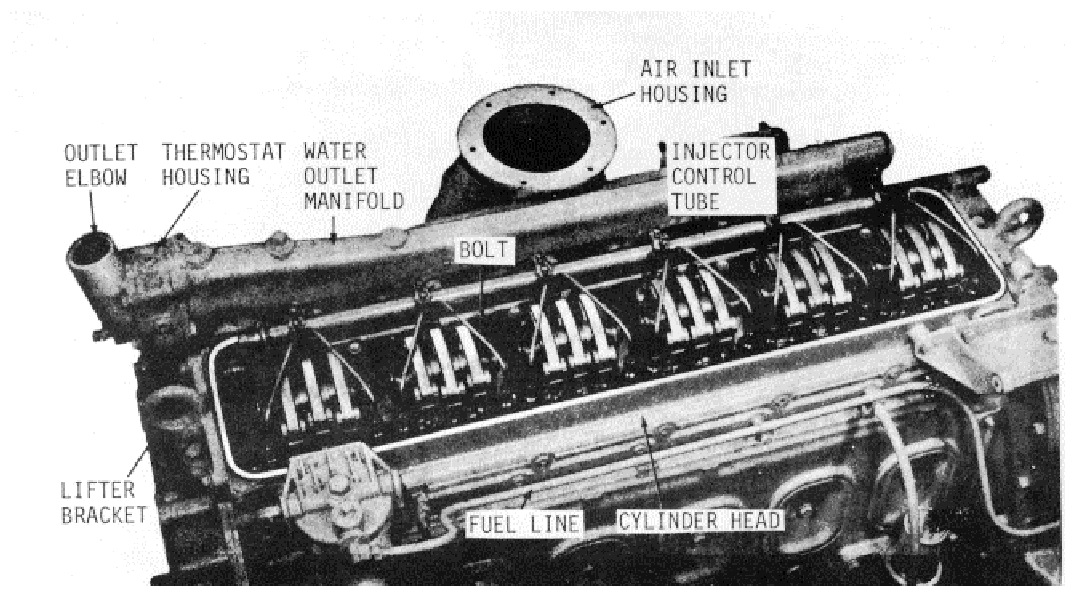



*Fig. 2*
*Typical Mounting Of Cylinder Head*

in the current four valve cylinder heads. These stress relief areas, which are shaped like a "dog bone" are cast in the fire deck of the cylinder head between the cylinders (Fig. 3). The current service cylinder heads which include the stress relief areas in the fire deck also include the non-magnetic turbo exhaust valve inserts identified by the letter "T" stamped on the face of the cylinder head.

Note: Production non-turbocharged cylinder heads include cast steel exhaust valve seat inserts which have magnetic qualities. An easy method for determining the type of exhaust valve seat insert in a cylinder head is with a magnet. The magnet will be attracted to the non-turbo insert (will stick). The magnet will not be attracted to the turbo insert, it will jump to the cylinder head.

5.1 Cylinder Head Maintenance

The engine operating temperature should be maintained between 160-185° F (71-85° C) and the cooling system should be inspected daily and kept full at all times. The cylinder head fire deck will overheat and crack in a short time if the collant does not cover the fire deck surface. When necessary, add water slowly to a hot engine to avoid rapid cooling which can result in distortion and cracking of the cylinder head (and cylinder block).

Abnormal operating conditions or neglect of certain maintenance items may cause cracks to develop in the cylinder head. If this type of failure occurs, a careful inspection should be made to find the cause and avoid a recurrence of the failure.

Unsuitable water in the cooling system may result in lime and scale formation and prevent proper cooling. The cylinder head should be inspected around the exhaust valve water jackets. This can be done by removing the injector tube. Where inspection discloses such deposits, use a reliable non-corrosive scale remover to remove the deposits from the cooling system of the engine, since a similar condition will exist in the cylinder block and other components of the engine. Refer to Operator's Manual for engine coolant recommendations.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and also result in loss of engine coolant. The tubes must be tight to be properly seated. Refer to SM6-5-34.0O.

Overtightened injector clamp bolts may also cause head cracks. Always use a torque wrench to tighten the bolts to the specified torque.

Other conditions which may eventually result in cylinder head cracks are:

(1) Excess fuel in the cylinders caused by leaking injectors.

(2) Slipping fan belts can cause overheating by reducing air flow through the radiator.


*Fig. 3*
*Stress Relief Areas*

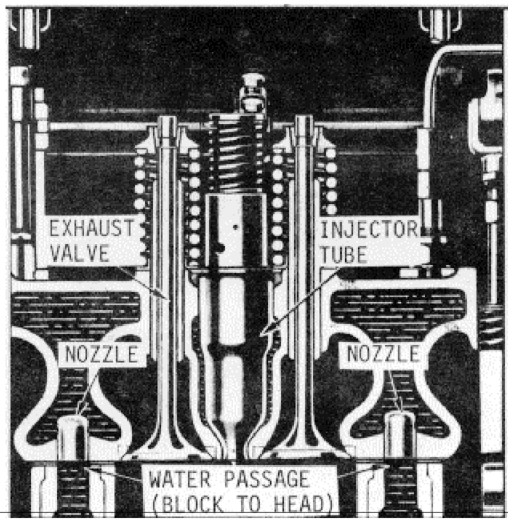



*Fig. 4*
*Coolant Passages Around Exhaust Valves And Fuel Injectors*

(3) Accumulation of dirt on the radiator core which will reduce the flow of air and slow the transfer of heat from the coolant to the air.
(4) Inoperative radiator cap which will result in loss of coolant.

5.2 Remove Cylinder Head

Certain service operations on the engine require removal of the cylinder head:
(1) Remove and install pistons.
(2) Remove and install cylinder liners.
(3) Remove and install exhaust valves.
(4) Remove and install exhaust valve guides.
(5) Recondition exhaust valves and valve seat inserts.
(6) Replace fuel injector tubes.
(7) Install new cylinder head gaskets and seals.
(8) Remove and install camshaft.

Due to the various optional and accessory equipment used, only the general steps for removal of the cylinder head are covered. If the engine is equipped with accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to ensure correct re-installation. Then refer to Fig. 2 and remove the cylinder head as follows:
(1) Drain the cooling system.
(2) Disconnect the exhaust piping at the exhaust manifold.
(3) Remove the air cleaners, or air silencer, and the air inlet housing.
(4) Remove the exhaust manifold.
(5) Disconnect the fuel lines at the cylinder head and remove the fuel filter (Fig. 2).
(6) Remove the thermostat housing assembly.
(7) Remove the water manifold.
(8) Clean and remove the valve rocker cover and the governor cover.
(9) Disconnect the fuel rod from the injector control tube lever and the governor. Remove the fuel rod.

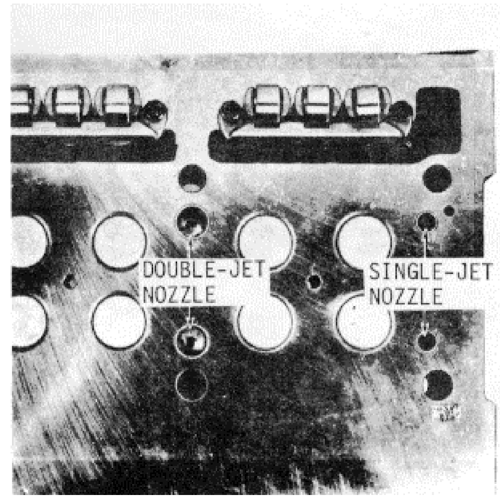



*Fig. 5*
*Water Nozzles In Cylinder Head*

(10) Remove the injector control tube (Fig. 6) and brackets as an assembly.
(11) If the cylinder head is to be disassembled for reconditioning of the exhaust valves and valve seat inserts or for a complete overhaul, remove the fuel pipes and injectors at this time. Refer to SM6-5-33.0 for removal of the injectors.
(12) Loosen (three or four turns) the two bolts directly below each lifter bracket which attach the balance weight cover and flywheel housing to the front and rear end plates. Otherwise, the threaded ends of the bolts may interfere with removal of the cylinder head.
(13) Remove the two bolts which secure the front lifter bracket to the balance weight cover and the two bolts attaching the rear lifter bracket to the flywheel housing.
(14) Check the torque on the cylinder head bolts and stud nuts (if used), before removing the head. Then remove the bolts and nuts and, using lifting hooks and a chain hoist, lift the cylinder head from the cylinder block. Checking the torque before removing the head bolts and examining the condition of the compression gaskets and seals after the head is removed may reveal the causes of any cylinder head problems.

**CAUTION**

When Placing The Cylinder Head Assembly On A Bench, Protect The Cam Followers And Injector Spray Tips, If The Injectors Were Not Removed, *By* Resting The Valve Side Of The Head On 2" Thick Wood Blocks.

(15) Place the cylinder head on its side and remove the engine lifter brackets and gaskets. Then attach the cylinder head holding plates J 3087-01 (Fig. 7) to raise the head above the work bench.

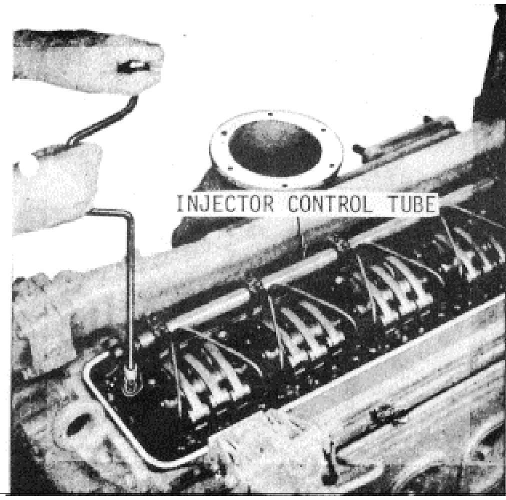



*Fig. 6*
*Removing Or Installing Injector Control Tube*

(16) Remove and discard the cylinder head compression gaskets, oil seals and water seals.
(17) After the cylinder head has been removed, drain the lubricating oil from the engine. Draining the oil at this time will remove any coolant that may have worked its way to the oil pan when the head was removed.

5.3 Disassemble Cylinder Head

If complete disassembly of the cylinder head is necessary, refer to SMs 6-5-6.0 and 6-5-7.0 for removal of the exhaust valve and injector operating mechanism.

5.4 Clean Cylinder Head

After the cylinder head has been disassembled and all of the plugs (except cup plugs) have been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tubes and water nozzles. Then clean the cylinder head in the same manner as outlined for cleaning the cylinder block (SM6-5-2.0).

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean all of the cylinder head components with fuel oil and dry them with compressed air.

5.5 Inspect Cylinder Head

(1) Pressure check the cylinder head as follows:
(a) Seal off the water holes in the head with steel plates and suitable rubber gaskets secured in place with bolts and washers as shown in Fig. 8. Drill and tap one of the cover plates for an air hose connection.

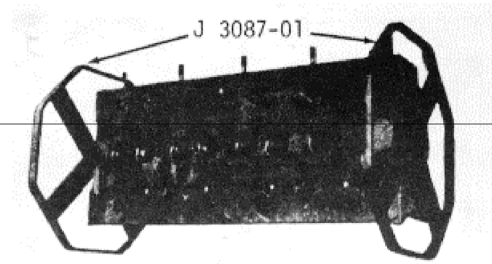



*Fig. 7*
*Cylinder Head Mounted On Holding Plates*

(b) Install scrap or dummy injectors to ensure proper seating of the injector tubes. Dummy injectors may be made from old injector nuts and bodies J-the injector spray tips are not necessary. Tighten the injector clamp bolts to 20-25 ft/lb. (27-34 N-m) torque.

(c) Apply 40 psi (276 kPa) air pressure to the water jacket. Then immerse the cylinder head in a tank of water, previously heated to 180-200° F (82-90° C), for about twenty minutes to thoroughly heat the head. Observe the water in the tank for bubbles which indicate a leak or crack. Check for leaks at the top and bottom of the injector tubes, oil gallery, exhaust ports, fuel manifolds and the top and bottom of the cylinder head.

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(d) Relieve the air pressure and remove the cylinder head from the water tank. Then remove the plates, gaskets and injectors and dry the head with compressed air.

| Engine | Maximum Longitudinal Warpage | Maximum Transverse Warpage |
|---|---|---|
| 6-71 | .010" | .004" |

Table 1

(e) If the pressure check revealed any cracks, install a new cylinder head.
(2) Check the bottom (fire deck) of the cylinder head for flatness.

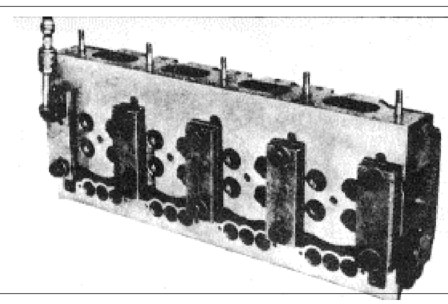


*Fig. 8*
*Cylinder Head Prepared For Pressure Testing*

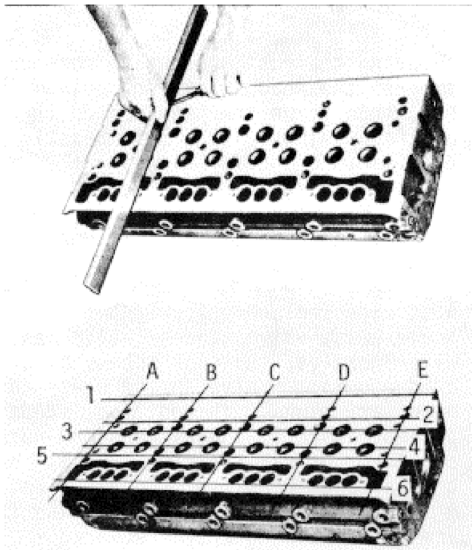



*Fig 9*
*Checking Bottom Face Of Cylinder Head*

(a) Use a heavy, accurate straight-edge and feeler gauges, tool J 3172, to check for transverse warpage at each end and between all cylinders. Also check for longitudinal warpage in six places as shown in Fig. 9. Refer to Table 1 for maximum allowable warpage.

(b) Use the measurements obtained and the limits given in Table 1 as a guide to determine the advisability of re-installing the head on the engine or of refacing it. The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

(c) If the head is to be refaced, remove the injector tubes prior to machining. Do not remove more than .020" (total)of metal from the fire deck of any cylinder head. The distance from the top deck to the bottom (fire deck) of the cylinder head must not be less than 3.536" (Fig. 10). Stamp the amount of stock removed on the face of the fire deck near the outer edge of the head, in an area not used as a sealing surface.

**CAUTION**

When A Cylinder Head Has Been Refaced, Critical Dimensions Such As The Protrusion Of Valve Seat inserts, Exhaust Valves, Injector Tubes And Injector Spray Tips Must Be Checked And Corrected. The Push Rods Must Also Be Adjusted To Prevent The Exhaust Valves From Striking The Pistons After The Cylinder Head Is Re-Installed In The Engine.

(3) Install new injector tubes (SM6-5-34.0) if the old tubes leaked or the cylinder head was refaced.

(4) Inspect the exhaust valve seat inserts and valve guides (refer to SM6-5-7.0).

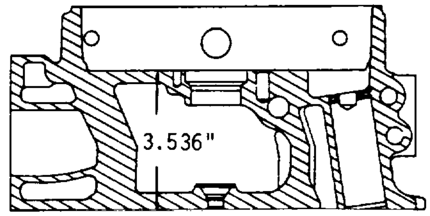



*Fig. 10*
*Minimum Distance Between Top And Bottom Faces Of Cylinder Head*

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(5) Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. Measure the bore diameter. The cam follower-to-cylinder head clearance must not exceed .006" with used parts (refer to SH6-5-70.0 for specifications). If the bores are excessively scored or worn, replace the cylinder head.

(6) Check the water hole nozzles to be sure they are not loose. If necessary, replace the nozzles as follows:

(a) Remove the old nozzles.

(b) Make sure the water inlet ports in the cylinder head are clean and free of scale. The water holes at each end of the head may be cleaned up with a 1/2" drill and the intermediate holes may be cleaned up with a 13/16" drill. Brake the edges of the holes slightly.

(c) Press the nozzles in place. Install the 1/2" diameter nozzles at the ends of the

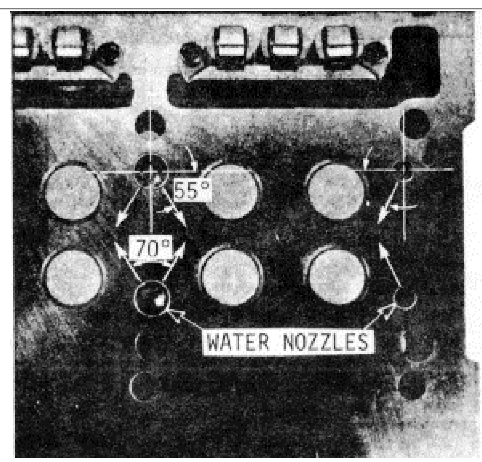



*Fig. 11*
*Correct Installation Of Water Nozzles In Cylinder Head*

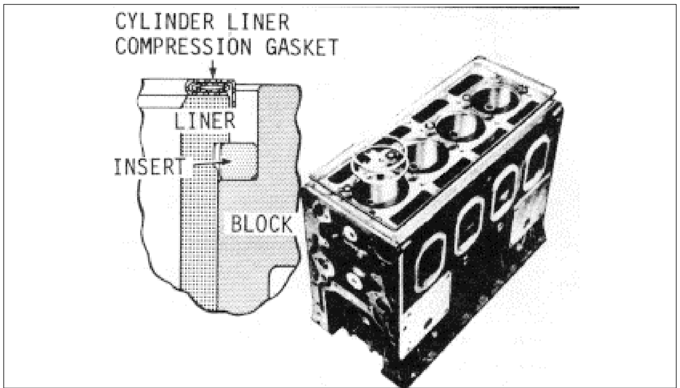



*Fig. 12*
*Cylinder Head Seals And Gaskets*

cylinder head. For the positioning of the nozzles in a four-valve cylinder head, refer to Fig. 11. Press the nozzles flush to .0312" recessed below the surface of the cylinder head.

(d) Check to make sure the nozzles fit tight. If necessary, use a wood plug or other suitable tool to expand the nozzles, or tin the outside diameter with solder to provide a tight fit. If solder is used, make sure the orifices in the nozzles are not closed with solder.

(7) Replace broken or damaged studs. Apply sealant to the threads of new studs and drive them to 10-25 ft/lb. (14-34 N.m) torque (water manifold cover studs) or to 25-40 ft/lb. (34-54 N-m) torque (exhaust manifold studs).

(8) Pilot sleeves have been added to the head mounting bolt holes at each end of the four-valve cylinder heads (on the camshaft side). Make sure the sleeves are flush or recessed below the fire deck of the cylinder head. Replace damaged sleeves. Pilot sleeves can be installed on early cylinder heads by reaming the end bolt holes (camshaft side of head) to .687" / .688" diameter by 750" deep and pressing the sleeves flush or slightly recessed below the fire deck. The sleeves, which act as a hollow dowel to provide a closer fit between the mounting bolts and the cylinder head, help to guide the head in place without disturbing the seals and gaskets.

(9) Inspect all other components removed from the cylinder head.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames. Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of all rust preventive compound, particularly inside the integral fuel manifolds, before installing the plugs. A simple method of removing the rust preventive compound is to immerse the head in solvent, oleum or fuel oil, then scrub the head and go through all of the openings with a soft bristle brush. A suitable brush for cleaning the various passages in the head can be made by attaching a 1/8" diameter brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

A service replacement cylinder head includes the exhaust valve guides, valve seat inserts, water nozzles, injector tubes, pilot sleeves, bridge guides, valve spring seats and the necessary plugs. In addition, studs, cover plates, gaskets, lockwashers and nuts are provided to seal the water outlet openings that are not required on certain engines. A length of flexible fuel hose and fittings are also included where required.

Injector clamp bolts or studs are not included and it is necessary to use new parts or transfer the old parts to the new head. Injector clamp bolts are interchangeable with the former studs and nuts; the special washer is used with either the bolt or stud.

5.6 Assemble Cylinder Head

After cleaning and inspection, assemble the cylinder head as follows:

(1) Install the necessary plugs and tighten them to the specified torque (SM6-5-71.0). Drive headless plugs flush to .0625" below the surface of the cylinder head. The 3/8" socket head oil gallery plug, at each end of the head, must not protrude more than .0625", and a .2187" diameter rod placed in the vertical oil feed hole must pass the inner face of the plug.

**CAUTION**

Apply A Small Amount Of "Dual Purpose" Sealer To The Threads Of The Plugs Only. Work The Sealant Into The Threads And Wipe The Excess With A Clean Lint-free Cloth So That Sealant Will Not Be Washed Into The Fuel And Oil Passages.

(2) After the following parts are cleaned and inspected, and replaced if necessary, reinstall them in the old cylinder head or transfer them to the new head.

(a) Exhaust valves, valve seat inserts and springs (SM6-5-7.O).

(b) Cam followers, guides, push rods, springs, retainers, rocker arms, shafts, brackets and other related parts (SM6-5-6.0)

(c) Place new washers on the fuel connectors. Then install the connectors and tighten them to 40-45 ft/lb. (54-61 N.m) torque.

(d) The fuel injectors, fuel pipes, injector control tube assembly and water manifold, if used, can be installed at this time or after the cylinder head is installed on the engine.

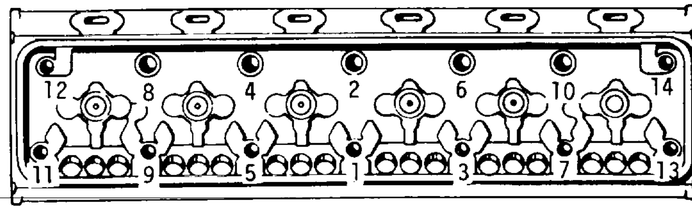



*Fig. 13*
*Cylinder Head Bolt Tightening Sequence*

(e) Attach the engine lifter brackets temporarily to the cylinder head, without gaskets, to permit lifting the head into position. The lifter brackets must not be permanently attached until the cylinder head attaching bolts have been installed and tightened to the specified torque.

5.7 Pre-Installation Inspection

Make the following inspections just prior to installing the cylinder head whether the head was removed to service only the head or to facilitate other repairs to the engine.

(1) Check the cylinder liner flange heights with relationship to the cylinder block (SM6-5- 22.0).

(2) lake sure the piston crowns are clean and free of foreign material.

(3) Make sure that each push rod is threaded into its clevis until the end of the push rod projects through the clevis. This is important since serious engine damage will be prevented when the crankshaft is rotated during engine tune-up.

(4) Check the cylinder block and cylinder head gasket surfaces, counterbores and seal groove to be sure they are clean and free of foreign material. Also check to ensure that there are no burrs or sharp edges in the counterbores.

(5) Inspect the cylinder head bolt holes in the block for accumulation of water, oil or any foreign material. Clean the bolt holes thoroughly and check for damaged threads.

(6) Check for extruded areas around the stud holes in the top of the cylinder block, if studs are used. Also check the studs for damaged threads.

(7) Check the four corner plugs or drive pins, used to plug the vertical oil galleries, to ensure that they are flush with or below the top surface of the cylinder block.

5.8 Install Cylinder Head

(1) Refer to Fig. 12 and install the water and oil seal rings and compression gaskets as follows:

(a) Place a new compression gasket on top of each cylinder liner.

(b) Place new seal rings in the counterbores of the water and oil holes in the cylinder block.

(c) Install a new oil seal in the groove at the perimeter of the cylinder block. The seal must lay flat in the groove and must not be twisted. Do not stretch the seal and do not use any adhesive or other material to secure it in the groove.

The current seal is identified by a yellow stripe. Install the seal with the stripe facing away from the cylinder bores.

Note: Never install used compression gaskets or seals.

(2) To install the cylinder head on the engine without disturbing the gaskets and seals, install guide studs J 9665 in two corner bolt holes in the cylinder block.

Note: Current four-valve cylinder heads have piloting sleeves installed in the corner bolt holes on the camshaft side of the head. The sleeves provide more accurate alignment of the cylinder head with the block bores. Do not install the guide studs in the bolt holes which line-up with piloting sleeves in the head.

(3) Insert the hooks of a chain, attached to a hoist, in the lifter brackets and lift the head into position above the cylinder block.

(4) Make a final visual check of the compression gaskets and seals to ensure that they are in place before the cylinder head is lowered. This is very important check. Gaskets and seals which are not seated properly will cause leaks and "blow-by" and result in poor engine performance and damage to the engine.

(5) Wipe the bottom of the cylinder head clean. Then lower the head until it is about 1/2" from the surface of the cylinder block.

(6) Apply a small amount of International Compound No. 2, or equivalent, to the threads and underside of the head of all cylinder head attaching bolts (to stud threads and head contact surface of stud nuts, if used). Then install a bolt through each piloting sleeve at the corners of the head and thread them finger tight into the cylinder block. continue to tighten these bolts (finger tight) as the head is lowered into position on the cylinder block.

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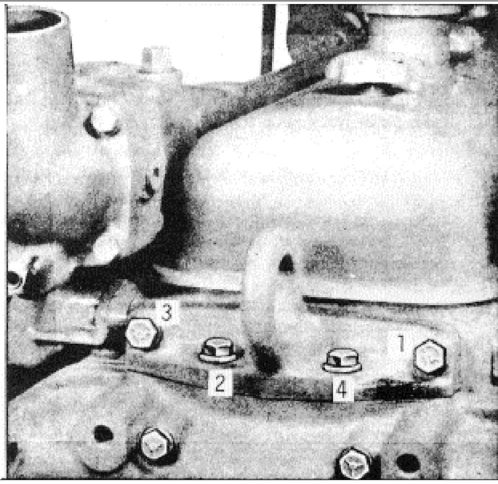


*Fig. 14*
*Lifter Bracket Bolt Tightening Sequence*

Note: Either one of two types of stud nuts are used. Both faces of one nut are square with the threads. The other type nut has a shoulder on one face. The shoulder side must contact the cylinder head. Important: Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

(7) After the head is in place, remove the guide studs and chain hoist and install the remaining bolts.

However, before tightening the bolts (or nuts), loosen the lifter bracket-to cylinder head attaching bolts, otherwise the head may be prevented from seating properly on the cylinder block. A similar condition could exist if the exhaust manifold is attached to the cylinder head. Clearance must be assured between the exhaust manifold and the bosses on the cylinder block. On some engine models, these bosses serve as a rest for the exhaust manifold after the cylinder head has been installed on the cylinder block.

(8) Tighten the bolts (or nuts) to 175-185 ft/lb. (238-251 N-m) with a torque wrench, one-half turn at a time, in the sequence shown in Fig. 13. Begin on the cam follower side of the head to take up tension in the push rod springs. Tighten the bolts to the high side of the torque specification, but do not exceed the limit or the bolts may stretch beyond their elastic limits. Attempting to tighten the bolts in one step may result in trouble and consequent loss of time in diagnosis and correction of difficulties, such as compression leaks, when the engine is put into operation.

Note: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage. the engine bearings.

(9) Tighten the two flywheel housing attaching bolts directly below the rear lifter bracket. Install a new gasket and secure the rear engine lifter bracket to the cylinder head and the flywheel housing. Tighten the bolts to 55-60 ft/lb. (75-81 N-m) torque.

(10) Affix a new gasket to the front lifter bracket and attach the bracket to the cylinder head and the balance weight cover. Tighten the bolts in the same sequence and to the same torque as on the rear lifter bracket bolts.

(11) If the fuel injectors were not previously installed, refer to SM6-5-33.0 and install them at this time.

(12) Adjust the exhaust valve bridges as outlined in SM6-5-7.0.

(13) Tighten the rocker arm bracket bolts to the specified torque SM6-5-71.0.

(14) Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 ft. lb. (16-20 N.m) torque.

**CAUTION**

Do Not Bend The Fuel Pipes And Do Not Exceed The Specified Torque. Excessive Tightening Will Twist Or Fracture The Flared Ends Of The Fuel Pipes And Result In Leaks. Lubricating Oil Diluted By Fuel Oil Can Cause Serious Damage To The Engine Bearings.

(15) Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight. When positioning the con- trol tube, be sure the ball- end of each injector rack control lever engages the slot in the corresponding injector control rack. With one end of the control tube return spring hooked around an injector rack control lever and the other end hooked around a control tube bracket, tighten the bracket bolts to 10-12 ft/lb. (14-16 N-m) torque.

(16) After tightening the bolts, revolve the injector control tube to be sure the return spring pulls the injector racks out (no-fuel position) after they have been moved all the way in (full-fuel position). Since the injector control tube is mounted in self-aligning bearings, tapping the tube lightly will remove any bind that may exist. The injector racks must return to the no-fuel position freely by aid of the return spring only. Do not bend the spring. If necessary, replace the spring.

(17) Attach the fuel rod to the differential lever in the governor housing. Secure the governor to the cylinder head with bolts and lockwashers.

(18) Connect the governor fuel rod to the injector control tube lever.

(19) Install the fuel filter and connect the fuel lines.
(20) Install the exhaust manifold.
(21) Install the water manifold.
(22) Install the temperature gauge thermocouple in the adaptor at the rear end of the water manifold
(23) Install the thermostat and secure the thermostat housing to the water manifold or heat exchanger with four bolts and lockwashers.
(24) Slide the hose into position on a radiator unit and secure it with two clamps.
(25) Install any other equipment or parts that were previously removed.
(26) Refer to Operator's Manual under Preparation For Starting Engine First Time and fill the cooling system and lubrication system.
(27) Before starting the engine, perform an engine tune-up as outlined in Operator's Manual.

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust valves and the center arm operates the fuel injector.

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Removal of the two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and the exhaust valve springs.

The rocker arms are operated by the camshaft through cam followers and short push rods extending through the cylinder head.

Each cam follower operates in a bore in the cylinder head. A guide for each set of three cam followers is attached to the bottom of the cylinder head to retain the cam-followers in place and to align the cam follower rollers with the camshaft lobes.

A coil spring, inside of each cam follower, maintains a pre-determined load on the cam follower to ensure contact of the cam roller on the camshaft lobe at all times.

6.1 Lubrication

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage on the camshaft side of the cylinder head, which connects with the main oil gallery in the cylinder block. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft to lubricate the rocker arms (Fig. 1).

Overflow oil from the rocker arms lubricates the exhaust valves, valve bridges and cam followers. The oil then drains from the top deck of the cylinder head through oil holes in the cam followers, into the camshaft pockets in the cylinder block and back tb the oil pan.

The cam follower rollers are lubricated with oil from the cam followers, oil picked up by the camshaft lobes and by oil emitted under pressure from milled slots in the camshaft intermediate bearings.

6.2 Service

Some service operations may be performed on the valve and injector operating mechanism without removing the cylinder head:

(1) Adjust valve clearance.
(2) Replace a valve spring.
(3) Replace or adjust an exhaust valve bridge or replace a valve bridge guide.
(4) Replace a rocker arm.
(5) Replace a rocker arm shaft or bracket.
(6) Replace a fuel injector.

It is also possible to replace a push rod, push rod spring, the spring seats or a cam follower without removing the cylinder head. However, these parts are more easily changed from the lower side when the cylinder head is off the engine. Both methods are covered in this section.

To replace the exhaust valves, valve guides and valve seat inserts, the cylinder head must be removed (refer to SM6-5-7.0).

6.3 Remove Rocker Arms And Shaft

(1) Clean and remove the valve rocker cover.
(2) Remove the fuel pipes from the injector and the fuel connectors.

Note: Immediately after removing the fuel. pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

(3) Turn the crankshaft, or crank the engine with the starting motor, to bring the injector and valve rocker arms in line horizontally. Important: Do not bar the crankshaft in a left-hand direction of rotation with a wrench or barring tool on the crankshaft bolt, or the bolt may be loosened.
(4) Remove the two bolts which secure the rocker arm shaft brackets to the cylinder head. Remove the brackets and shaft. Note: When removing the rocker arm shaft, fold the three rocker arms back just far enough so the shaft can be removed. Do not force the rocker arms all the way back with the shaft in place as this may impose a load that could bend the push rods.
(5) Loosen the locknuts at the upper ends of the push rods, next to the clevises, and unscrew the rocker arms from the push rods. Note: If the rocker arms and shafts from two or more cylinders are to be removed, tag them so they may be reinstalled in their original positions. 6

6.4 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

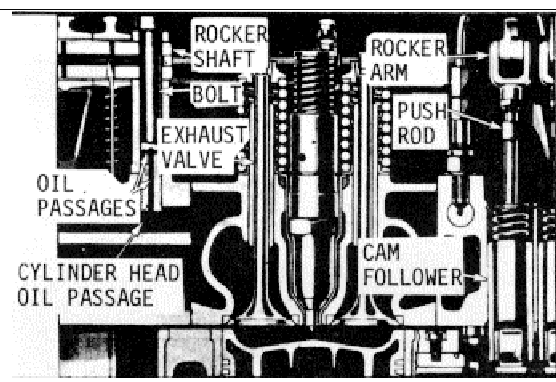


*Fig. 1*
*Lubrication Of Valve Operating mechanism*

Wash the rocker arms, shaft, brackets and bolts with clean fuel oil. Use a small wire to clean out the drilled oil passages in the rocker arms and rocker shaft bolts. Dry the parts with compressed air.

Inspect the rocker arm shaft and rocker arm bushings for wear. A maximum shaft to bushing clearance of .004" is allowable with used parts (refer to SM6-5-71.0). Service replacement bushings must be reamed to size after installation.

Inspect the rocker arms for galling or wear on the pallets (valve injector contact surfaces). If worn, the surface may be refaced up to a maximum of .010". However, proceed with caution when surface grinding to avoid overheating the rocker arm. Maintain the radius and finish as close to the original surface as possible. Also inspect the valve bridges for wear.

6.5 Remove Cam Follower And Push Rod (With Cylinder Head On Engine)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

To remove a push rod, spring, spring seats and cam follower from the top of the cylinder head, proceed as follows:

(1) Remove the rocker arm shaft and brackets as outlined under Remove Rocker Arms And Shaft.
(2) Loosen the locknut and unscrew the rocker arm from the push rod to be removed. Remove the locknut.
(3) Install remove J 3092-01, a flat washer and the locknut on the push rod, with the lower end of the tool resting on the upper spring seat.
(4) Thread the nut down to compress the spring.
(5) Remove the spring seat retainer from the groove in the cylinder head (Fig. 2).
(6) Unscrew The locknut to release the spring. Then remove the nut, flat washer and tool from the push rod.
(7) Pull the push rod, spring, spring seats and cam follower out of the cylinder head.

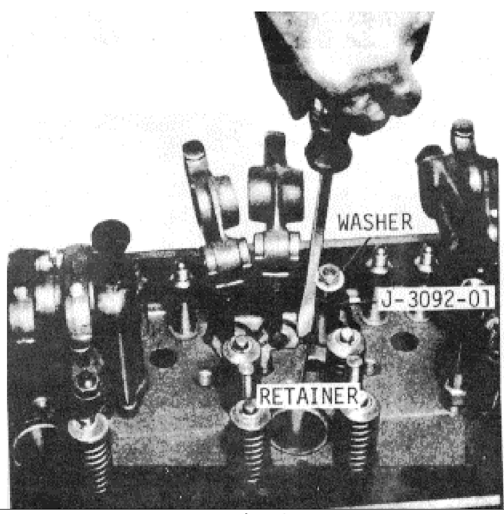


*Fig. 2*
*Removing Push Rod From Upper Side Of Cylinder Head*

6.6 Remove Cam Follower And Push Rod (Cylinder Head Removed)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

(1) Rest the cylinder head on its side (Fig. 3) and remove the cam follower guide.
(2) Pull the cam follower out of the cylinder head.
(3) Remove the fuel pipes from the injector and the fuel connectors.

Note: Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

(4) Loosen the push rod locknut and unscrew the push rod from the rocker arm clevis.
(5) Pull the push rod and spring assembly from the bottom of the cylinder head.
(6) Remove the push rod locknut, spring and spring seats from the push rod.

If the cylinder head is to be replaced, remove the spring retainers and install them in the new head.

6.7 Inspection

Proper inspection and service of the cam follower is very necessary to obtain continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, remove the cam followers and their related parts and inspect them for excessive wear. This change in injector timing or valve clearance can usually be detected by excessive noise at idle speed.

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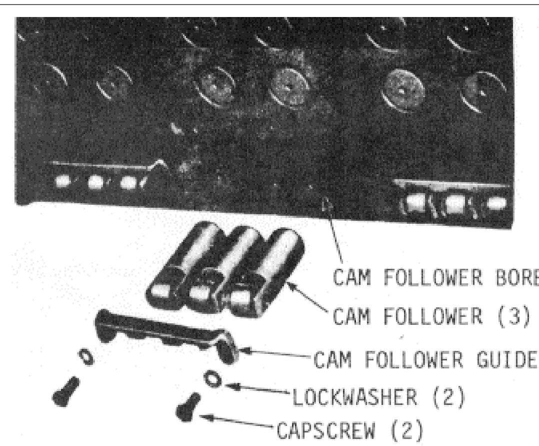


*Fig. 3*
*Cam Followers And Guide*

Wash the cam followers with lubricating oil or Cindol 1705 and wipe dry. Do not use fuel oil. Fuel oil working its way in between the cam roller bushing and pin may cause scoring on initial start-up of the engine since fuel oil does not provide adequate lubrication. The push rods, springs, and spring seats may be washed with clean fuel oil and dried with compressed air.

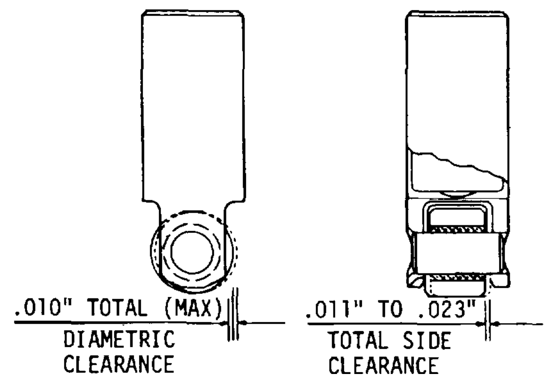


*Fig. 4*
*Cam Roller Clearances*

Examine the cam follower rollers for scoring, pitting or flat spots. The rollers must turn freely on their pins. Measure the total diametric clearance and side clearance. Install a new roller and pin if the clearances exceed those specified in Fig. 4. Cam followers stamped with the letter "S" on the pin, roller and follower body are equipped with an oversize pin and roller. The same clearances apply to either a standard or oversize cam follower assembly.

Examine the camshaft lobes for scoring, pitting or flat spots. Replace the camshaft if necessary.

Measure the cam follower bores in the cylinder head with a telescope gauge and micrometer and record the readings. Measure the diameter of the cam followers' with a micrometer. Record the readings and compare the readings of the followers and bores to determine the cam follower-to-bore clearances (refer to SM6-5-71.0 for specifications).

Inspect the push rods and spring seats for wear. The current push rods have milled wrench flats and a bright "turned" finish and the lower spring seats are serrated along the push rod contact surfaces (Fig. 5).

Note: When replacing a push rod or lower spring seat, do not use a plain spring seat (Flg. ) with push rod, Any other com1bination of spring seat and push rod may be used.

Examine the cam follower springs for wear or damage and check the spring load. Replace a spring when a load of less than 172 lbs. (765 N) will compress it to a length of 2.125". Use a spring tester J 22738-02 to check the spring load (Fig. 6).

6.8 Replace Cam Roller And Pin

To replace a cam roller and pin, proceed as fol- lows:

Note: Do not attempt to bore out the legs of a standard cam follower for an oversize pin.

(1) Clamp fixture J 5840-01 securely in a vise as shown in Fig. 7. Then place the cam follower in the groove in the top of the fixture, with the follower pin resting on top of the corresponding size plunger in the fixture.
(2) Drive the pin from the roller with a suitable drift. Exercise caution in removing the cam follower body and roller from the fixture as the roller pin is seated on a spring-loaded plunger in the fixture.
(3) Before installing the new roller and pin, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705 and wipe dry. Do not use fuel oil. After washing the parts, lubricate the roller and pin with Cindol 1705. 6
(4) Position the cam follower body in the groove of the fixture, with the small plunger extending through the roller pin hole in the lower leg of the follower body.
(5) Position the new cam roller in the cam follower body. When released, the plunger will extend into the roller bushing and align the roller with the cam follower body.
(6) Start the new pin in the cam follower body, then carefully tap it in until it is centered in the cam follower body.
(7) Remove the cam follower from the fixture and check the side clearance (Fig. 4). The clearance must be .011" to .023".

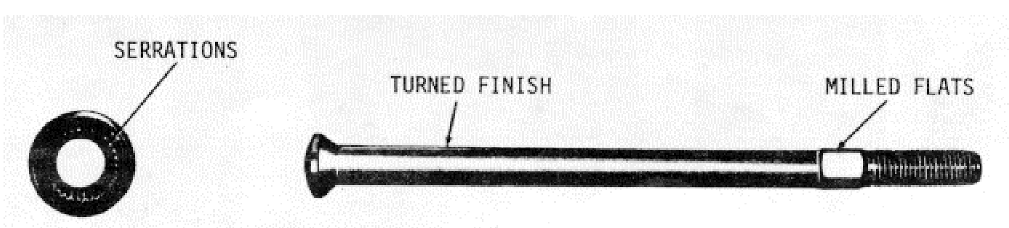


*Fig. 5*
*Push Rods And lower Spring Seats*

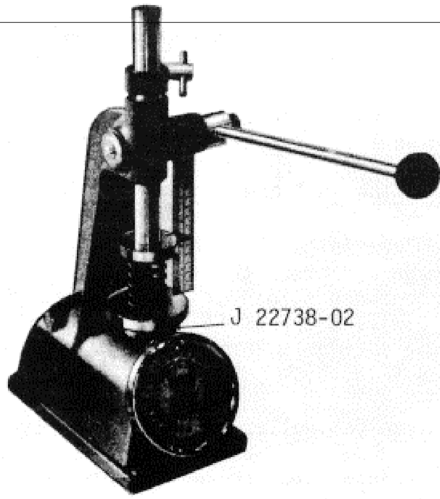


*Fig. 6*
*Testing Cam Follower Spring*

6.9 Install Cam Follower And Push Rod

If new cam follower assemblies are to be installed, remove the preservative by washing with Cindol 1705 and wipe dry. Do not use fuel oil.

Before cam followers are installed, immerse them in clean Cindol 1705 (heated to 100-125° F or 38-52° C' for at least one hour to ensure initial lubrication of the cam roller pins and bushings. Rotate the cam rollers during the soaking period to purge any air from the bushing roller area. The heated Cindol oil results in better penetration as it is less viscous than engine oil and flows more easily between the cam roller bushing and pin. After the cam follower are removed from the heated Cindol 1705, the cooling action of any air trapped in the bushing and pin area will tend to pull the lubricant into the cavity.

Note: <u>Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent the cam followers from the touching the bottom of the pail and avoid the possibility of contamination.</u>

Install used cam followers and push rods in their original locations. Refer to Fig. 8 and proceed as follows:

6.10 <u>Cylinder Head On Engine</u>:

(1) Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves (Fig. 9), slide the cam follower in position in the cylinder head.

(2) Assemble the serrated lower spring seat (Fig. 5) spring and upper spring seat on the push rod.

(3) Place a flat washer over the upper spring seat and start the locknut on the push rod. Place tool J 3092-01 on the push rod between the washer and the upper spring seat and place the push rod assembly in the cam follower. Then thread the locknut on the push rod until the spring is compressed sufficiently to permit the spring retainer to be installed. Install the retainer with the tangs facing the notch in the cylinder head.

(4) Remove the nut, flat washer and tool. Then reinstall the locknut and thread it as far as possible on the push rod.

6.11 Cylinder Head Removed From Engine

Refer to Fig. 8 and install the cam follower and push rod as follows:

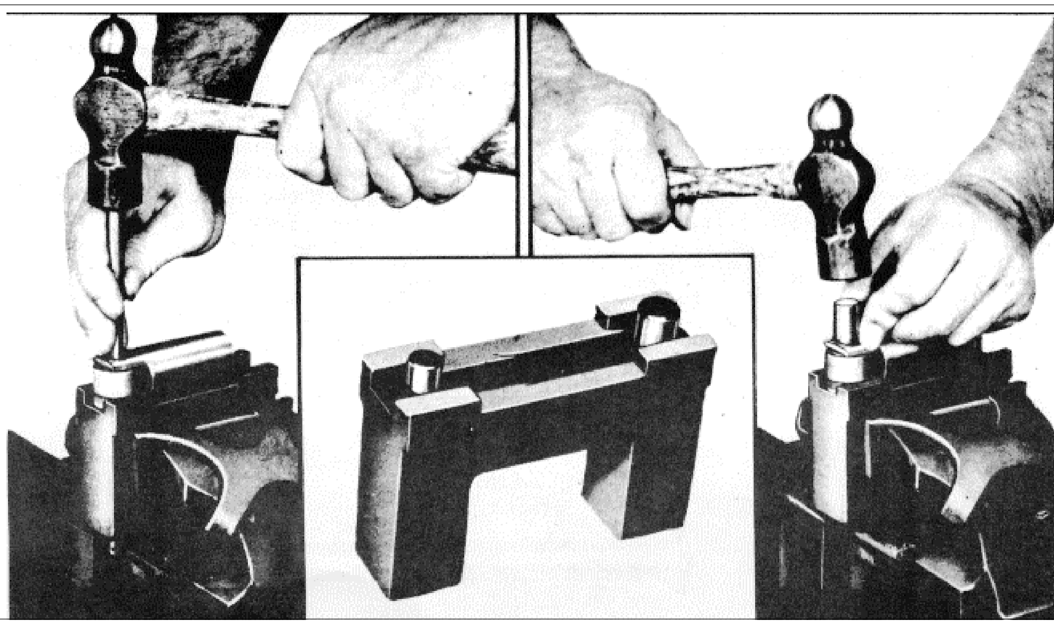

*Fig. 7*
*Removing Or Installing Cam Follower Roller*

(1) Assemble the serrated lower spring seat (Fig. 5), spring, upper spring seat and lock-nut on the push rod.

(2) With the spring retainer in place in the cylinder head, slide the push rod assembly in position from the bottom of the head.

(3) Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves (Fig. 9), slide the cam follower in position from the bottom of the head.

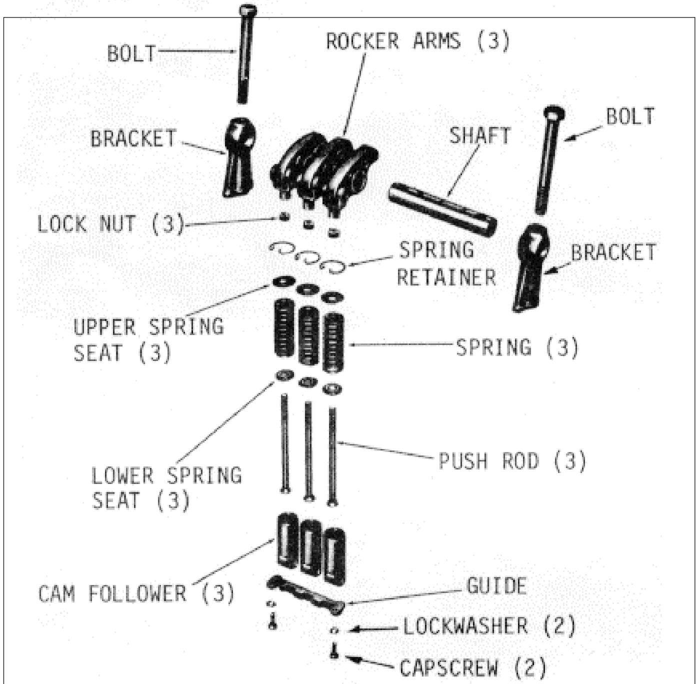


*Fig. 8*
*Valve And Injector Operating Mechanism And Relative Location Of Parts*

(4) Attach the follower guide to the cylinder head to hold the group of three cam followers in place. Tighten the guide bolts to 12-15 ft/lbs. (16-20 N.m) torque. Check to be sure there is at least .005" clearance between the cam follower legs and the cam follower guide (Fig. 10). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Fig. 11). Then retighten the bolts to the specified torque.

Note: It is important to use the correct bolts as prescribed in the parts books. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation.

6.12 Install Rocker Arms And Shaft

Note that the injector rocker arm (center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the shaft on the left and right-hand valve rocker arms is longer on one side. The extended boss of each valve rocker arm must face toward the injector rocker arm.

(1) Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. This will provide sufficient initial clearance between the exhaust valve and the piston when the crankshaft is turned during the valve clearance adjustment procedure.

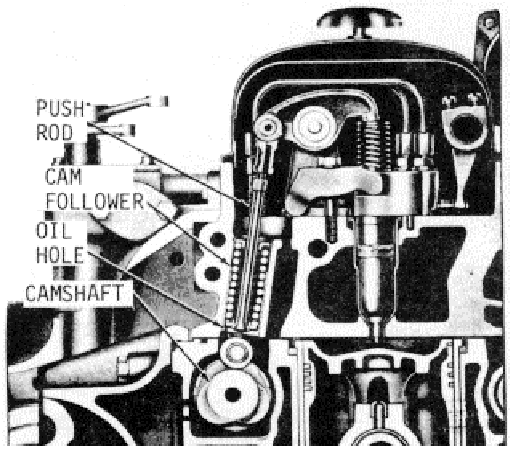


*Fig. 9*
*Installation Of Cam Followers*

(2) If removed, install the cylinder head on the engine (refer to SM6-5-5.0).

(3) Lubricate the valve bridge guides with sulphurized oil (E.P. type) and position the valve bridges in place on the guides. Refer to Exhaust Valve Bridge Adjustment in SM6-5-7.0 and adjust the valve bridges.

(4) If removed, install the fuel injectors.

(5) Apply clean engine oil to the rocker arm shaft and slide the shaft through the rocker arms. Then place a bracket over each end of the shaft, with the finished face of the bracket next to the rocker arm.

(6) Insert the rocker arm bracket bolts through the brackets and the shaft. Tighten the bolts to the specified torque (refer to SM6-5-71 .0).

(7) Align the fuel pipes and connect them to the injectors and fuel connectors. Tighten the fuel pipe nuts to 12-15 ft/lbs. (16-20 N.m) torque using socket J 8932-01.

6

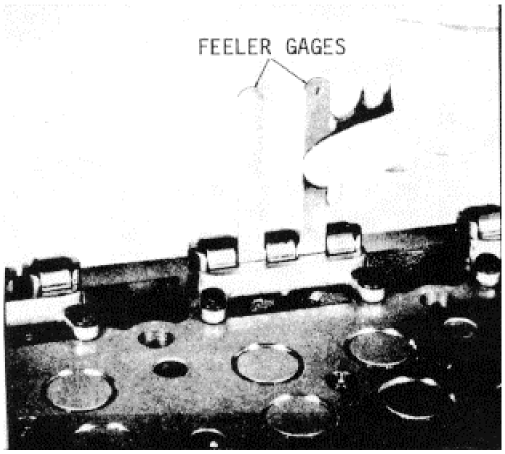


*Fig. 10*
*Checking Cam Follower To Guide Clearance*

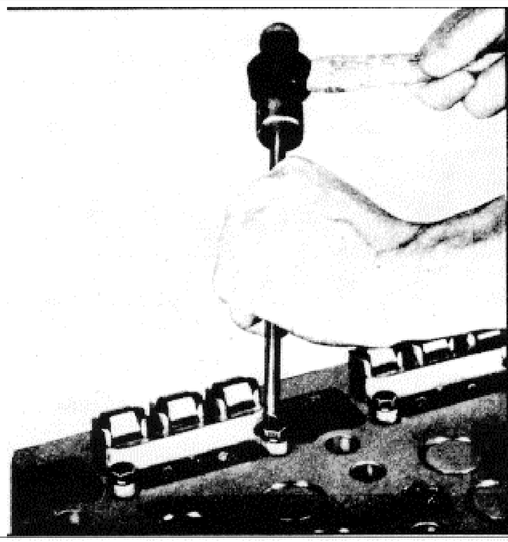

*Fig. 11*
*Adjusting Cam Follower Guide*

Note: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

(8) Fill the cooling system.
(9) Adjust the exhaust valve clearance and time the injectors (Refer to SM6-5-68.0).
(10) If necessary, perform an engine tune-up.

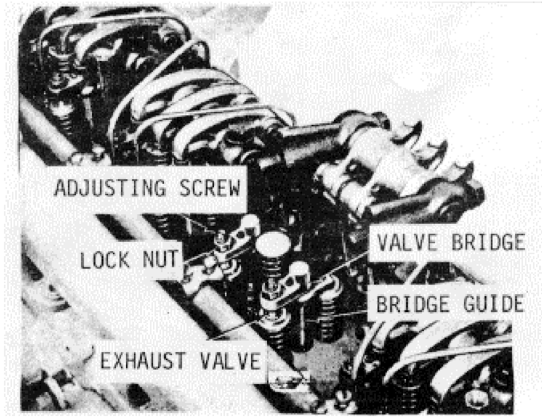


Fig.1
Location of Exhaust Valves

Four exhaust valves are provided for each cylinder (Fig.1).The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the exhaust valve bridge.

The exhaust valve rotator, used in conjunction with a special valve spring cap, is installed between the valve spring and the cylinder head (Fig.2).The valve rotator includes six spring-loaded steel balls in individual grooves. The grooves are tapered so that the balls aid rotation, in one direction only, on each downward stroke of the exhaust valve. When the valve closes, rotation in the opposite direction is prevented since the narrow ends of the grooves restrict movement of the steel balls.

The exhaust valve used with the valve rotator includes an integral deflector (Fig.2) which directs the exhaust gases away from the valve stem and valve guide. This reduces the possibilities of carbon formation at this point.

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head (Fig.3).This engine is equipped with exhaust valve guide oil seals.

Exhaust valve seat inserts (Fig.3), pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head.

The exhaust valves are ground to a 30 ° seating angle while the exhaust valve seat inserts are ground to a 31 ° seating angle. The exhaust valve springs are held in place by the valve spring caps and tapered two-piece valve locks.

Excess oil from the rocker arms lubricates the exhaust valve stems. The valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

7.1 Exhaust Valve Maintenance

Efficient combustion in the engine requires that the exhaust valves be maintained in good operating condition. Valve seats must be true and unpitted to assure leakproof seating, valve stems must work freely and smoothly within the valve guides and the correct valve clearance (refer to Operator's Manual) must be maintained.

Proper maintenance and operation of the engine is important to long valve life .Engine operating temperatures should be maintained between 160-185°F (71-850C).Low operating temperatures (usually due to extended periods of idling or light engine loads) result in incomplete combustion, formation of excessive carbon deposits and fuel lacquers on valves and related parts, and a greater tendency for lubrication oil to sludge.

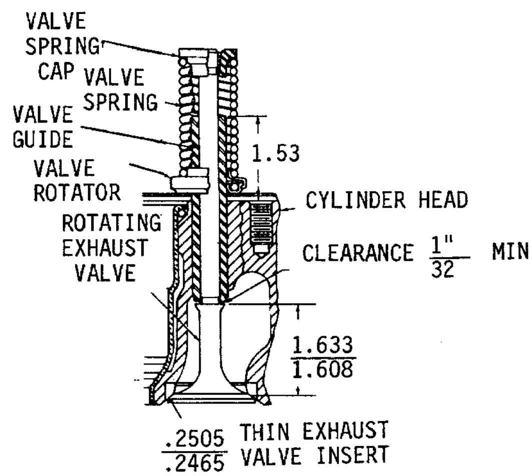


Fig.2
Rotating Valve Mechanism

Unsuitable fuels may also cause formation of deposits on the valves, especially when operating at low temperatures.

When carbon deposits, due to partially burned fuel, build up around the valve stems and extend to that portion of the stem which operates in the valve guide, sticking valves will result. Thus, the valves cannot seat properly and pitted and burned valves and valve seats and loss of compression will result.

Lubricating oil and oil filters should be changed periodically to avoid the accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of antifreeze (glycol) into the lubricating oil which forms a soft sticky carbon and gums the valve stems, and bent or worn valve guides. Sticking valves may eventually be struck by the piston and become bent or broken.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically. Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion.

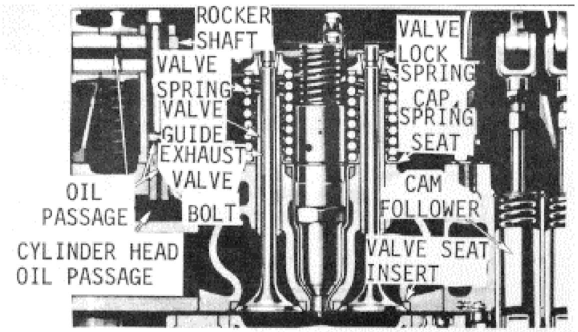


Fig.3
Assembly of Exhaust Valves and Guides

7.2 Remove Exhaust Valve Spring (Cylinder Head Installed)

An exhaust valve spring may be removed, without removing the cylinder head from the engine, as follows:

(1) Clean and remove the valve rocker cover.
(2) Crank the engine over to bring the valve and injector rocker arms in line horizontally.

Note: When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may loosen.

(3) Disconnect and remove the fuel pipes from the injector and the fuel connectors.

Note: Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

(4) Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and shaft.
(5) Remove the exhaust valve bridge. (6 Remove the cylinder block air box cover so that piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.
(7) Thread the valve spring compressor adaptor J 7455-7 into one of the rocker arm bracket bolt holes in the cylinder head (Fig.4). Then compress the valve spring and remove the two-piece tapered valve lock.
(8) Release the tool and remove the valve spring cap, valve spring and spring seat.

7.3 Remove Exhaust Valves and Valve Springs (Cylinder Head Removed)

With the cylinder head removed from the engine remove the exhaust valves and springs as follows:

(1) Support the cylinder head on 2" thick wood blocks to keep the cam followers clear of the bench.
(2) Remove the fuel pipes from the injectors and the fuel connectors.

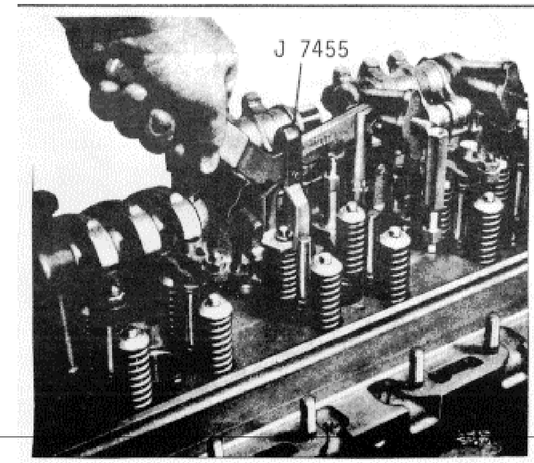


Fig.4
Removing Exhaust Valve Spring

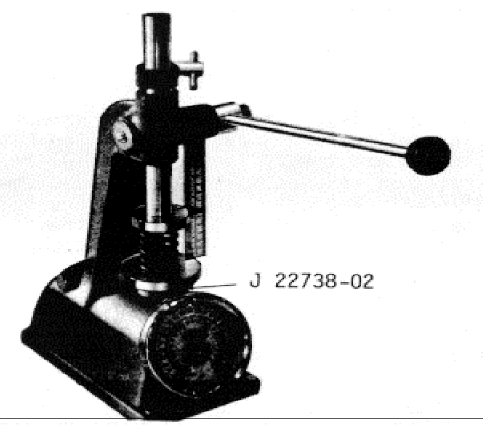


Fig.5
Testing Exhaust Valve Spring

Note: Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

(3) Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and the shaft.
(4) Remove the fuel injectors.
(5) Remove the exhaust valve bridges.
(6) Place a block of-wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in Steps 7 and 8 above.
(7) Turn the cylinder head over, using care to keep the valves from falling out of the head. If the valves are to be re-used, number each valve to facilitate reinstallation in the same location. Then withdraw the valves from the cylinder head.
(8) Remove the cam followers and push rod assemblies as outlined in SM6-5-6. 0 under Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).

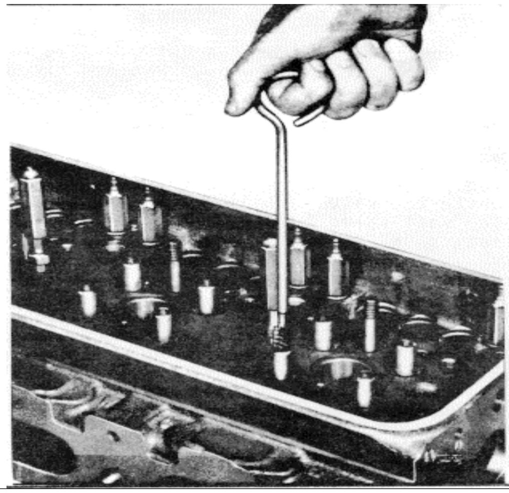

Fig. 6
Cleaning Valve Guide

7.4 Inspection

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Clean the springs with fuel oil, dry them with compressed air and inspect them. Replace a pitted or fractured spring.

Use spring tester J 22738-02 to check the spring load (Fig.5).The exhaust valve spring has an outside diameter of approximately. 953".Replace this spring when a load of less than 25 pounds (111 N) will compress it to 1. 80" (installed length).

Note: When an exhaust valve spring is replaced on a four-valve head, both springs under a valve bridge should be replaced at the same time to ensure balanced valve operation.

Inspect the valve spring seats and caps for wear. If worn, replace with new parts.

Examine the contact surfaces of the exhaust valve bridge guides, bridges and adjusting screws for wear or galling. Replace excessively worn parts.

Carbon on the face of a valve could indicate blow-by due to a faulty seat. Black carbon deposits extending from the valve seats to the valve guides may result from cold operation due to light loads or the use of too heavy a grade of fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the valve guides is evidence of high operating temperatures.

High operating temperatures are normally due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil.

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges, cracks or pitting. If necessary, reface the valves or install new valves. If the valve heads are warped, replace the valves.

If there is evidence of engine oil running down the exhaust valve stem into the exhaust chamber, creating a high oil consumption condition because of excessive idling and resultant low engine exhaust back pressure, replace the valve guide oil seals or, if not previously used, install valve guide oil seals.

Clean the inside diameter of the valve guides with brush J 5437 (Fig.6).This brush will remove all gum or carbon deposits from the valve guides, including the spiral grooves.

Inspect the valve guides for fractures, chipping, scoring or excessive wear. Measure the valve guide inside diameter with a pin gauge or inside micrometer and record the readings. After inspecting and cleaning the exhaust valves, measure the outside diameter of the valve stems with a micrometer and record the readings. Compare the readings to obtain the valve-to-guide clearance. If the clearance exceeds . 005", replace the valve guides.

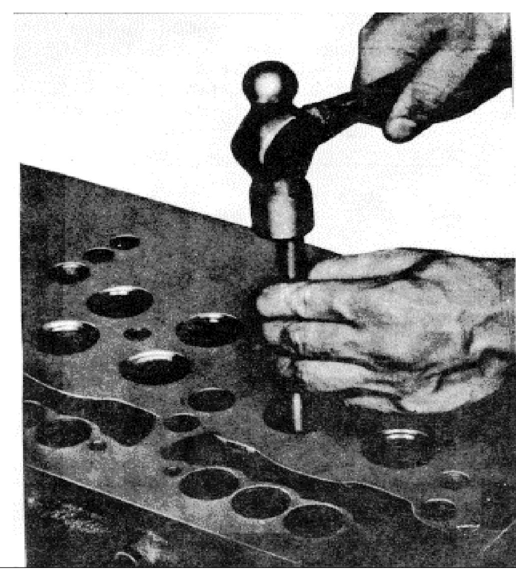

Fig.7
Removing Exhaust Valve Guide

Valve Guide Installer

| Tool No. | Cylinder Head | Valve Guide | Distance of Guide Above Top of Head |
|---|---|---|---|
| J21520 | 4-Valve | Machined | .69Q" |

Table 1

7.5 Replace Exhaust Valve Guide

Remove an exhaust valve guide as follows:
(1) Remove and discard the valve guide oil seal.
(2) Support the cylinder head, bottom side up, on 3" thick wood blocks.
(3) Drive the valve guide out of the cylinder head with valve guide remover J6569 as shown in Fig.7.

Place the cylinder head right side up on the bed of an arbor press and install the valve guide (Fig.8) as follows:
(a) Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to Table 1).Be sure to use the correct tool to avoid damage to the valve guide, and to locate the valve guide to the proper dimension.
(b) Position the valve guide squarely in the bore in the cylinder head and press the installing tool gently to start the guide in place (Fig.9).Then press the guide in until the tool contacts the cylinder head.

Note: Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

Service replacement valve guides are completely finish reamed during manufacture and, therefore, do not require reaming after installation.
c) Install a new valve guide oil seal (refer to Item 5 under Install Exhaust Valves and Springs).

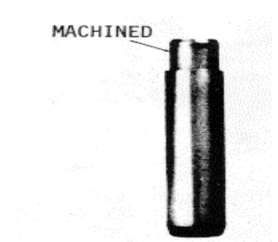

Fig.8
Valve Guides

7.6 Inspect Exhaust Valve Bridge and Guide

Inspect the valve bridge guide, valve bridge and adjusting screw for wear. Replace excessively worn parts.

The exhaust valve bridge guides are press-fit (Fig.10).

The press-fit valve bridge guide is hardened steel while the valve bridge is relatively soft steel. The soft valve bridge may be identified by the letter "S" forged on one side of the bridge.

Avoid a combination of a soft steel guide and soft steel bridge, otherwise premature wear of the bridge and guide will occur.

Two designs of the valve bridge are used. One has a drilled oil hole and the other has a forged oil hole in the side. The two bridges are interchangeable and can be mixed in an engine.

The valve bridge adjusting screw has a valve contact surface. The screw may be identified by the machined (undercut) surface at the lower end of the screw.

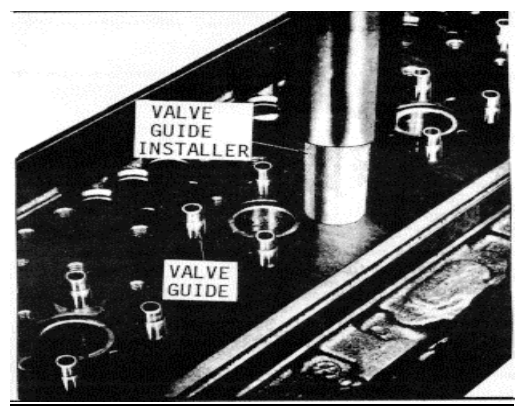

Fig.9
Installing Valve Guide

7.7 Remove Exhaust Valve Bridge Guide

Remove the valve bridge guide from cylinder head as follows:
(1) Remove the press-fit guide (Fig.11) with tool set J 7091-01 as follows:
(a) File or grind two diametrically opposite notches 1/16" deep in the side of the guide, approximately 1-1/4" to 1-1/2" from the upper end.
(b) Place spacer J 7091-3 over the guide. Then slide the guide remover J 7091-5 over the guide and align the set screws with the notches in the guide. Tighten the set screws to hold the tool securely.

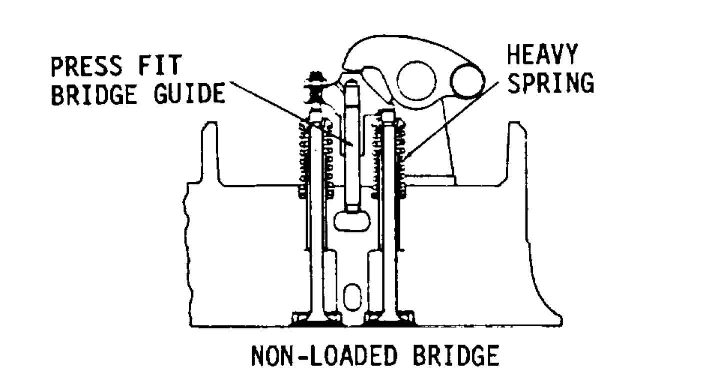


Fig. 10
Exhaust Valve Bridge and Guide

(c) Place spacer J 7091-4 over the guide remover. Thread the nut on the guide remover and turn it clockwise to withdraw the guide from the cylinder head.

To remove a broken valve bridge guide, drill a hole approximately 1/2" deep in the end of the guide with a No.3 (. 2130") drill. Then tap the guide with a 1/4"-28 bottoming tap. Thread remover J 7453 into the guide and attach slide hammer J 2619-01 to the remover tool. One or two sharp blows with the puller weight will remove the broken guide (Fig.12).

7.8 Install Exhaust Valve Bridge Guide

Install the press-fit bridge guide as follows:

(1) Start the guide (undercut end first) into the cylinder head.

(2) Place the installer J 7482 over the guide and drive it into place. The installer will properly position the guide to the correct height in the cylinder head (2. 040").

7.9 Inspect Exhaust Valve Seat Insert

A new exhaust valve insert is pre-ground and only needs to be checked for concentricity after installation. Do not grind a new insert unless the runout exceeds . 002".

Inspect the valve seat inserts for excessive wear pitting, cracking or an improper seat angle. The proper angle for the seating face of the valve is 30° and the angle for the insert is 31°.

7.10 Remove Exhaust Valve Seat Insert

The valve seat inserts are pressed into the cylinder head and must be removed as outlined in the following procedure to avoid damage to the cylinder head:

(1) Place the cylinder head on its side as shown in Fig.13.

(2) Place the collet of tool J 6567-02 inside of the valve seat insert so that the bottom of the collet is flush with the bottom of the insert.

(3) Hold the collet handle and turn the T handle to expand the collet cone until the insert is held securely by the tool.

(4) Insert the drive bar of the tool through the valve guide.

(5) Tap the drive bar once or twice to move the insert about 1/16" away from its seat in the cylinder head.

(6) Turn the T handle to loosen the collet cone and move the tool into the insert slightly so the narrow flange at the bottom of the collet is below the valve seat insert.

(7) Tighten the collet cone and continue to drive the insert out of the cylinder head.

Note: In place of the above procedure, a new cam operated insert remover J 23479-15 and collet J 23479-10 can be used to remove the exhaust valve seat insert from the cylinder head.

7.11 Install Exhaust Valve Seat Insert

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses, Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(1) Clean the valve seat insert counterbores in the cylinder head with trichloroethylene or other suitable solvent. Also wash the valve seat inserts with the same solvent. Dry the counterbores and the inserts with compressed air.

(2) Inspect the counterbores in the cylinder head for cleanliness, concentricity, flatness and cracks. The counterbores in a four-valve cylinder head have a diameter of 1.260" to 1.261" and a depth of .338" to .352".The counterbores must be concentric with the valve guides within .003" total indicator reading. Valve seat inserts which are . 010" oversize on the outside diameter are available, if required.

(3) Immerse the cylinder head for at least thirty minutes in water heated to 180-200F (82-93°C).


Fig. 11
Removing Press-Fit Exhaust Valve Bridge Guide

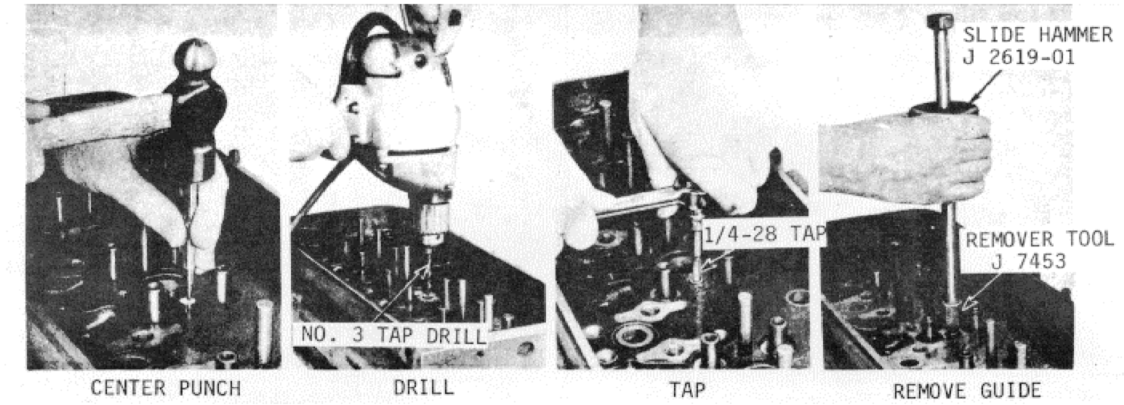


Fig.12
Removing Broken Exhaust Valve Bridge Guide

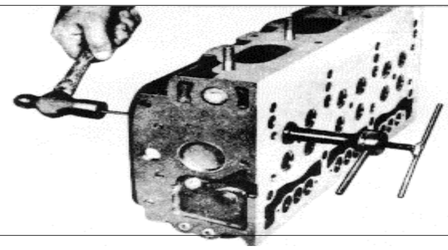

Fig.13
Removing Valve Seat Insert

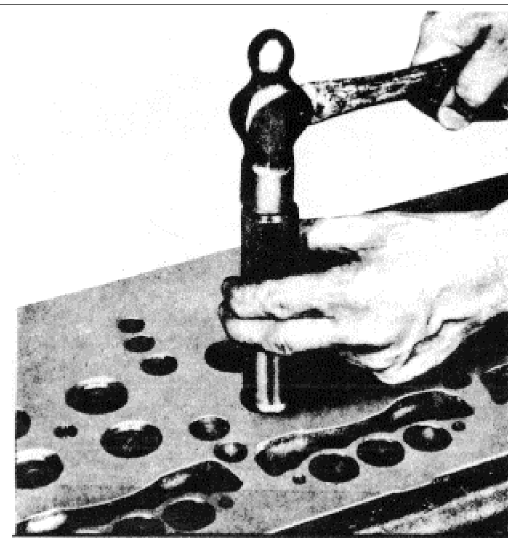

Fig.14
Installing Valve Seat Insert

(4) Rest the cylinder head, bottom side up, on a bench and place an insert in the counterbore valve seat side up. Install the insert in the cylinder head while the head is still hot and the insert is at room temperature, otherwise installation will be difficult and the parts may be damaged.

(5) Drive the insert in place with installer J 24357 as shown in Fig.14 until it seats solidly in the cylinder head.

(6) Check the valve seat inserts for concentricity in relation to the valve guides as outlined below.

7.12 Recondition Exhaust Valve and Valve Seat

An exhaust valve which is to be reused may be refaced, if necessary (Fig.15).To provide sufficient valve strength and spring tension, the edge of the valve at the valve head must not be less than . 031" in thickness and must still be within the specifications shown in Fig.18 after refacing.

Before either a new or used valve is installed, examine the valve seat insert in the cylinder head for proper valve seating. The proper angle for the seating face of the valve is 300 and for the valve seat insert it is 31°.

When a new valve seat insert is installed or an old insert is reconditioned, the work must be done with a grinding wheel (Fig.16).

The eccentric grinding method for reconditioning valve seat inserts is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits feeding the grinding wheel into the work .001" at a time.

Eccentric valve seat grinder set J 7040, which includes the grinder, dress stand and pilot, and dial gage, is used to grind the inserts. An adaptor set which includes the grinding wheels and pilot is used with the grinder.

Adaptor set J 6390-02, used for the four valve head, consists of the following:
(1) Pilot, tool J 7659-1.
(2) Grinding wheel (15°), tool J 6390-2.
(3) Grinding wheel (310), tool J 6390-3.
(4) Grinding wheel (600), tool J 6390-4.

Grind the inserts as follows:
(1) First apply the 31° grinding wheel on the valve seat insert.
(2) Use the 60° grinding wheel to open the throat of the insert.
(3) Grind the top surface of the insert with the 15° wheel to narrow the width of the seat to the dimensions shown in Fig.18.The 310 face of the insert may be adjusted relative to the center of the valve face with the 15°and 60°grinding wheels.

Note: Do not permit the grinding wheel to contact the cylinder head when grinding the insert. When an insert has been ground to the extent that the grinding wheel will contact the cylinder head, install a new insert

The maximum amount the exhaust valve should protrude beyond the cylinder head (when the valve is closed) and still maintain the proper piston-to-valve clearance is shown in Fig.18.Grinding will reduce the thickness of the valve seat insert and cause the valve to recede into the cylinder head. If, after several grinding operations, the valve recedes beyond the specified limits, replace the valve seat insert.

Note: Engines with 18.7:1 compression ratio must incorporate valve seat inserts that are no more than .251" thick to ensure adequate clearance between the pistons and the exhaust valves.

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with the dressing tool provided with the grinder set (Fig.19).

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(4) After grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165-2 in position as shown in Fig.17 and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. If the runout exceeds . 002", check for a bent valve guide before regrinding the insert.

After the valve seat insert has been ground, determine the position of the contact area between the valve and the valve seat insert as follows:

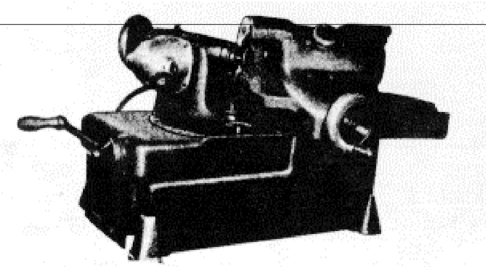

Fig.15
Refacing Exhaust Valve

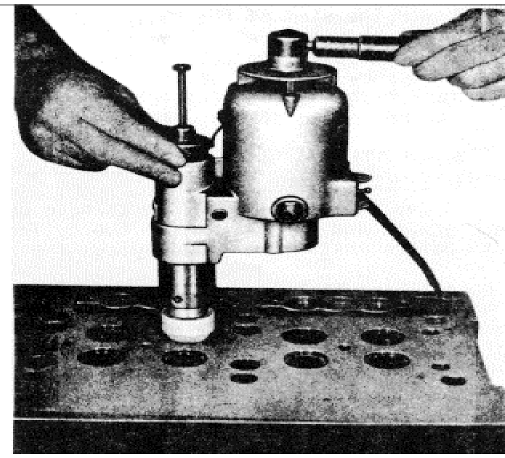

Fig.16
Reconditioning Valve Seat Insert

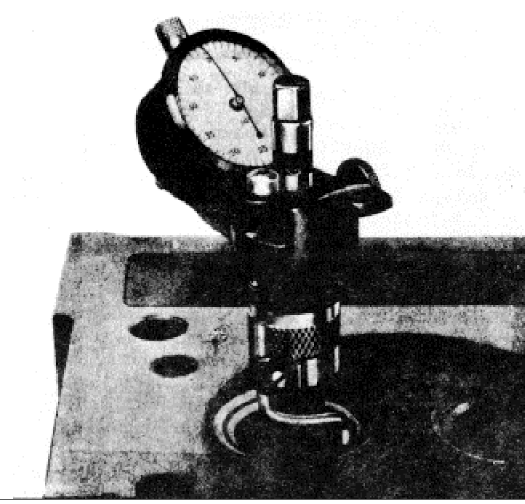

Fig.17
Determining Concentricity of Valve Seat Insert with Dial Indicator

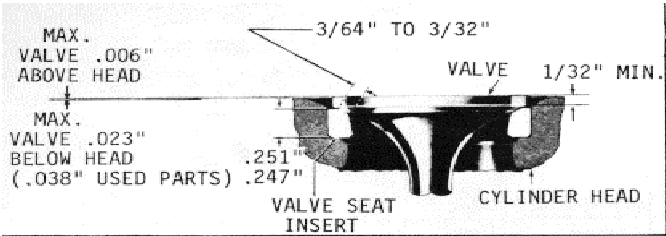


Fig. 18
Exhaust Valve, Insert and Cylinder Head

(1) Apply a light coat of Prussian blue, or a similar paste, to the valve seat insert.

(2) Lower the stem of the valve in the valve guide and "bounce" the valve on the seat. Do not rotate the valve. This procedure will show the area of contact on the valve face. The most desirable area of contact is at the center of the valve face.

Note: The use of valve lapping compounds is not recommended.
After the valve seat inserts have been ground and checked, clean the cylinder head before installing the valves.

7.13 Install Exhaust Valves and Springs

Springs with 8-3/4 coils and an outside diameter of approximately . 953" are used on the exhaust valves only. Valve spring caps and seats of a corresponding diameter must be used with the valve springs.

Install the exhaust valves as follows:

(1) Clean the valve guides.

(2) Lubricate the valve stems with sulphurized oil (E. P.type) and slide the valves all the way into the guides.

Important: If reconditioned valves are used install them in the same relative location from which they were removed.

(3) Hold the valves in place temporarily with a strip of masking tape. Then turn the cylinder head right side up on the work bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.

(4) Install the valve spring seats.

(5) Install the valve guide oil seals, if used, on the valve guides as follows:

(a) Place the plastic seal installation cap on the end of the valve stem. If the cap extends more than 1/16" below the groove on the valve stem, remove the cap and cut off the excess length.

(b) Lubricate the installation cap and start the seal carefully over the valve stem. Push the seal down slowly until it rests on top of the valve guide.

(c) Remove the installation cap.

(6) Install the valve springs and valve spring caps.

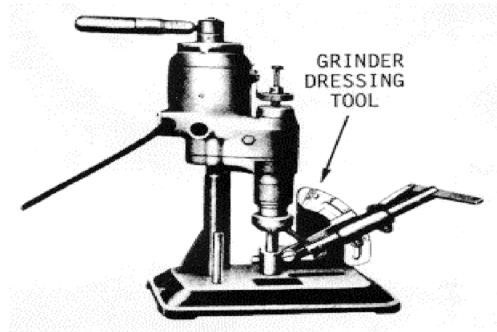


Fig. 19
Grinding Wheel Dressing Tool of Set J 8165-1

Note: The four-valve cylinder head valve spring caps have a ridge for identification purposes on the upper tapered surface (Fig.20)

(7) Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig.4).

(8) Apply pressure to the free end of the tool to compress the valve spring and install the two-piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring.

Note: If valve guide oil seals are used, compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

(9) Release the tool and install the valve locks on the remaining exhaust valves in the same manner.

(10) Check the position of the exhaust valves (Fig.18).Support the cylinder head at each end with wood blocks and remove the masking tape so that the exhaust valves are free. Then give the end of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.

(11) With the exhaust valves installed in the cylinder head, use spring checking gauge J 25076-01 and note the gauge reading the moment the exhaust valve starts to open (Fig.21).The minimum allowable pressure required to start to open the exhaust valve must not be less than 20 pounds (89 N) for a four-valve cylinder head (two-spring design).

(12) Install the injectors, rocker arms, shafts, brackets and any other parts previously removed from the cylinder head.

(13) Install the cylinder head. Refer to PreInstallation Inspection and Install Cylinder Head in SM6-5-5.0.

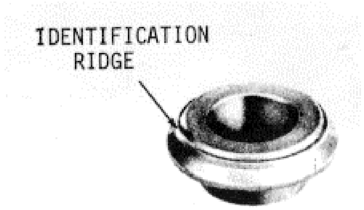


Fig. 20
Exhaust Valve Spring Cap

7.14 Exhaust Valve Bridge Adjustment

The exhaust valve bridge assembly is adjusted and the adjustment screw is locked securely after the cylinder head is installed on the engine. Until wear occurs, or the cylinder head is reconditioned, no further adjustment is required on the valve bridge. A complete valve bridge adjustment is performed as follows:

(1) Place the valve bridge in a vise or bridge holding fixture J 21772 and loosen the lock nut on the bridge adjusting screw.

Note: Loosening or tightening the locknut with the bridge in place may result in a bent bridge guide or bent rear valve stem.

(2) Install the valve bridge on the valve bridge guide.

(3) While firmly pressing straight down on the pallet surface of the valve bridge, turn the adjusting screw clockwise until it just touches the valve stem. Then turn the screw an additional 1/8 to 1/4 turn clockwise and tighten the locknut finger tight (Fig.22).

(4) Remove the valve bridge and place it in a vise. Use a screwdriver to hold the adjustment screw from turning and tighten the locknut to 20-25 ft-lbs (27-34 N.m) torque.

(5) Lubricate the valve bridge guide and the valve bridge with engine oil.

(6) Reinstall the valve bridge in its original position.

(7) Place a . 0015" feeler gauge (J 23185) under each end of the valve bridge or use a narrow strip cut from .0015" feeler stock to fit in the bridge locating groove over the inner exhaust valve. While pressing down on the pallet surface of the valve bridge, both feeler gauges must be tight. If both of the feeler gauges are not tight, readjust the adjusting screw as outlined in Steps 3 and 4.

(8) Remove the valve bridge and reinstall it in its original position.

(9) Adjust the remaining valve bridges in the same manner.

(10) Swing the rocker arm assembly into position, making sure the valve bridges are properly positioned on the rear valve stems. This precaution is necessary to prevent valve damage due to mislocated valve bridges. Tighten the rocker arm shaft bracket bolts to the torque specified in SM6-5-70.0.

After the cylinder head is installed and the valve bridges adjusted, proceed as follows:

(1) Refer to SM6-5-33. 0 under Install Injector and install the fuel pipes.

(2) Fill the cooling system.

Note: Remove the vent plug from the thermostat housing or open the vent valve when filling the cooling system.

(3) Adjust the exhaust valve clearance and time the injectors (refer to Operator's Manual).

(4) Start the engine and check for leaks in the fuel, cooling and lubrication systems.

(5) Perform a complete engine tune-up as outlined in SM6-5-68.0.

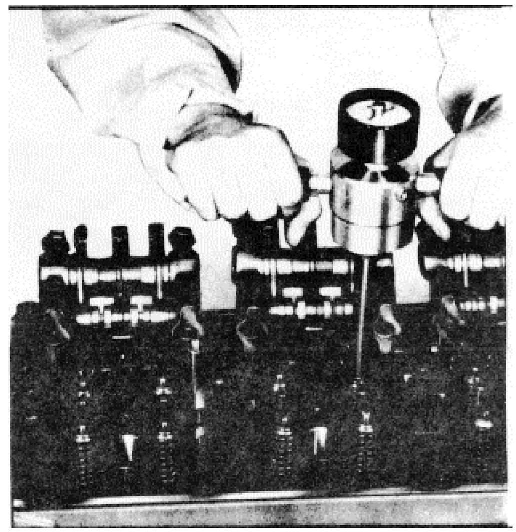

Fig.21
Checking Pressure Required to Open the Exhaust Valve in Cylinder Head

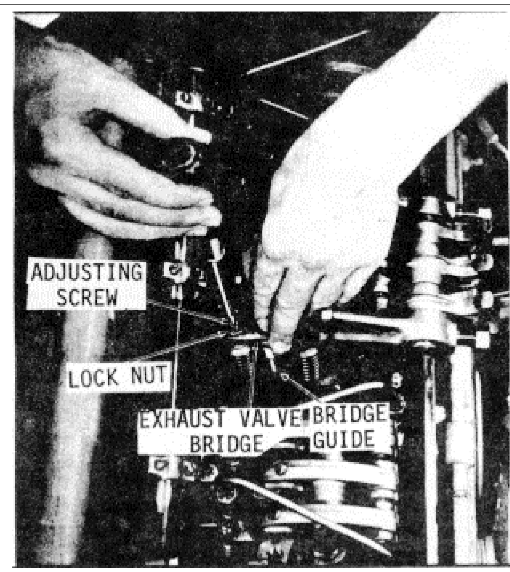


Fig.22
Valve Bridge Adjustment

The engine lifter brackets provide a means of lifting the engine assembly, the cylinder head or the flywheel housing.

Lifter brackets require no servicing other than removal during other service operations.

8.1 Install Engine Lifter Bracket

(1) Remove all traces of the old gasket material.

(2) Affix a new gasket to the front lifter bracket.

(3) Attach the lifter bracket and gasket to the cylinder head with two bolts and to the front balance weight cover with two bolts.

Note: The lifter bracket must not be permanently attached until all of the cylinder head stud nuts or retaining bolts have been tightened to their specified torque.

(4) Install the bolts finger tight, draw them down snug and then tighten to the specified torque. Draw the bolts down in the proper sequence (Fig.2) for each of these steps to draw the mating parts together evenly, thus providing a good seal. Tighten the bolts to 55-60 ft/lbs.(75-81 N. m) torque.

(5) Install the rear lifter bracket to the cylinder head and flywheel housing in a similar manner.

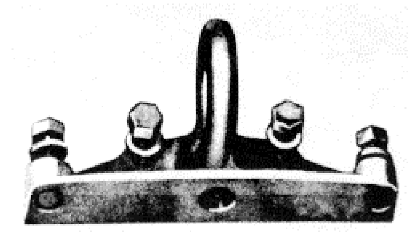

Fig. 1
Engine Lifter Bracket

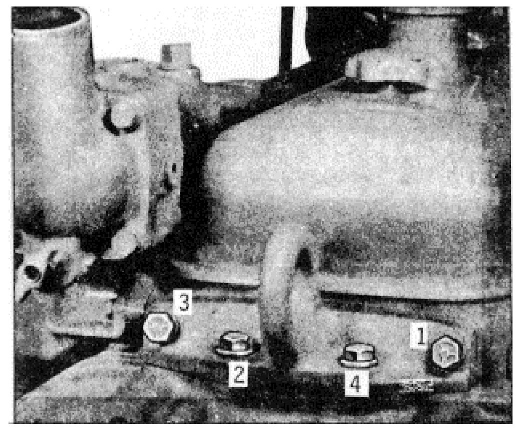


Fig. 2
Typical Installation Of Lifter Bracket And Bolt Tightening Sequence

The valve rocker cover assembly (Fig. 1) completely encloses the valve and injector rocker arm compartment at the top of the cylinder head. The top of the cylinder head is sealed against oil leakage by a gasket located in the groove of the lower rail of the current die cast rocker cover or in the flange edge of the former stamped metal rocker cover.

An option plate is inserted in a retainer attached to the cover on each single engine unit and to one of the covers on a multiple engine unit.

The current die cast rocker cover (Fig. 1) is held in place by 3/8" -16 twelve-point head shoulder bolts with a steel washer and silicone isolator. The bolts have a shoulder which bottoms out against the cylinder head or throttle delay bracket. The isolators and gasket use low compression-set materials which provide long sealing life and minimize engine noise levels. Tighten the bolts to 15-20 ft/lbs. (20-27 N.m) torque.

**Note**: The shorter rocker cover bolt, which threads into the throttle delay bracket, can crack the bracket if overtightened.

**Important**: The rocker cover bolt is especially designed for this purpose and must not be replaced by an ordinary bolt.

The valve rocker cover assembly includes a breather assembly.

9.1 Remove and Install Valve Rocker Cover

Clean the valve rocker cover before removing it from the engine to avoid dust or dirt from entering the valve mechanism. Then loosen the bolts and lift the cover straight up from the cylinder head. Use a new gasket when re-installing the cover.

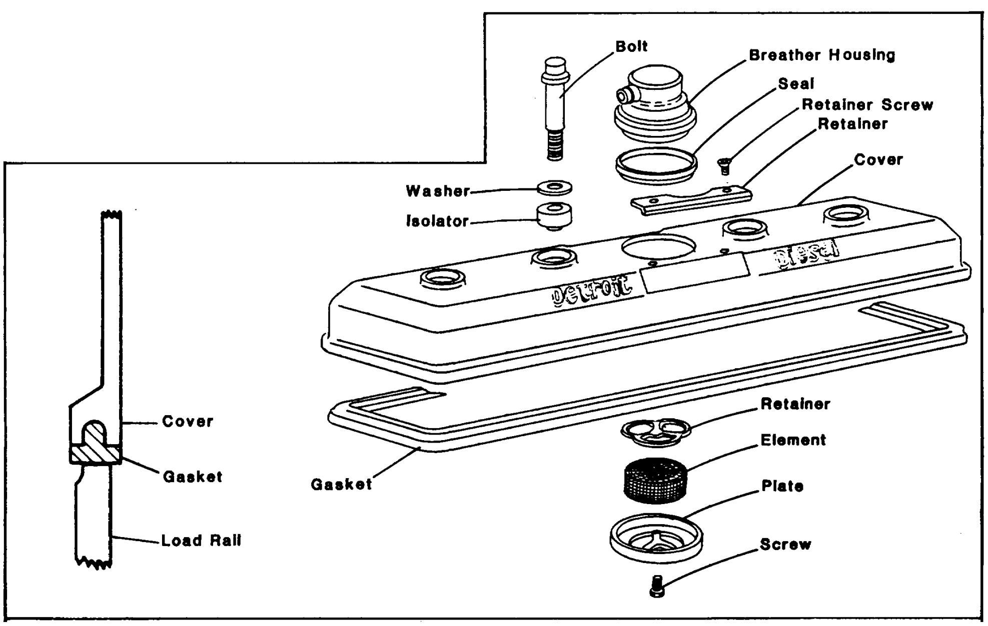


*Fig. 1. Typical Current Valve Rocker Cover Assembly*

The crankshaft (Fig. 1) is a one-piece steel forging, heat-treated to ensure strength and durability. All main and connecting rod bearing journal surfaces are induction hardened.

Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft.

The crankshaft end play is controlled by thrust washers located at the rear main bearing cap of the engine. Full pressure lubrication to all connecting od and main bearings is provided by drilled passages within the crankshaft and cylinder block.

Two dowels (Fig. 2) and six tapped holes are provided in the rear end of the crankshaft for locating and attaching the flywheel. One hole is unequally spaced so that the flywheel can be attached in only one position.

Each main bearing journal is 3-1/2" in diameter, and each connecting rod journal is 2-3/4" in diameter.

## 10.1 Remove Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

(1) Clean the exterior of the engine.
(2) Drain the cooling system.
(3) Drain the engine crankcase.
(4) Remove all engine to base attaching bolts. Then, with a chain hoist and sling attached to the lifter brackets or eye bolts at each end of the engine, remove the engine from its base.
(5) Remove all of the accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an over-haul stand.
(6) Mount the engine on an overhaul stand and fasten it securely to the mounting plate.

**CAUTION**

Be Absolutely Sure The Engine Is Securely Attached To The Stand Before Releasing The Lifting Sling. Severe Injury To Personnel And Destruction OF Engine Parts Will Result If The Engine Breaks Away From The Stand.

(7) Remove the oil pan.
(8) Remove the lubricating oil pump.
(9) Remove the flywheel and flywheel housing.
(10) Remove the crankshaft cap or pulley.
(11) Remove the vibration damper.
(12) Remove the front engine support.
(13) Remove the crankshaft front cover.
(14) Remove the vibration damper inner cone or oil seal spacer.
(15) Remove the cylinder head.
(16) Remove the connecting rod bearing caps.
(17) Remove the main bearing caps.
(18) Remove the thrust washers from each side of the rear main bearing.
(19) Remove the pistons, connecting rods and liners.
(20) Remove the crankshaft, including the timing gear and oil pump drive gear (Fig. 2).
(21) Refer to SM6-5-28.0 for removal of the crank- shaft timing gear and SM6-5-46.0 for the procedure covering removal of the oil pump drive gear.

## 10.2 Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

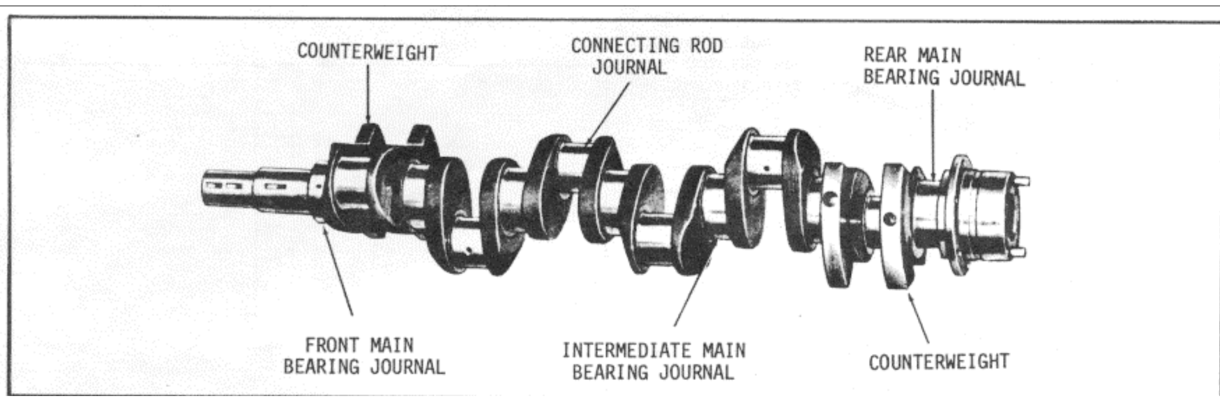


*Fig. 1. Typical Six Cylinder Crankshaft*

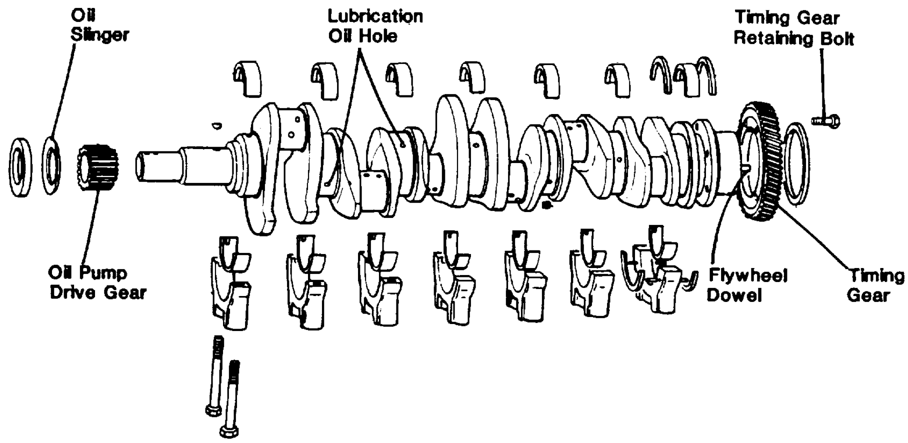


*Fig. 2. Crankshaft, Timing Gear and Oil Pump Drive Gear Assembly*

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then reinstall the plugs.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary. If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Fig. 3). Ridges exceeding .0002" must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0005", first use 120 grit emery cloth to clean up the ridge, 240 grit emery cloth for finishing and wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out-of-round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than .001", the crankshaft may have to be re-ground.

Carefully inspect the rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

Slight ridges on the crankshaft oil seal contact surface may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. If the crankshaft cannot be cleaned up satisfactorily, the oil seal may be repositioned in the flywheel housing as outlined in SM6-5-11.0.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Other-wise it will be necessary to regrind the thrust surfaces.

Check the oil pump drive gear and the crankshaft timing gear for worn or chipped teeth. Replace the gears, if necessary.

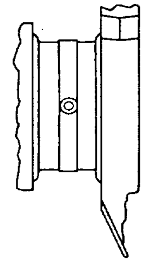

*Fig. 3. Typical Ridging of Crankshaft*

Check the crankshaft dowel extension. The dowels extend 1/2" from the crankshaft. When converting to or rebuilding engines for Torqmatic converter applications, check to make sure the dowels DO NOT extend more than 1/2", otherwise interference with the Torqmatic converter flywheel will result.

Inspect the crankshaft for cracks as outlined under Inspection for Cracks.

0.3 Crankshaft Measurements
Support the crankshaft on its front and rear journals on V-blocks or in a lathe and check the alignment at the adjacent intermediate main journals with a dial indicator.
When the runout on the adjacent journals is in opposite directions, the sum must not exceed .003" total indicator reading. When the runout on the adjacent journals of the six cylinder crankshaft is in the same direction, the difference must not exceed .003" total indicator reading. If the runout limit is greater than given in Table 1, the crankshaft must be re- placed.

Measure all of the main and connecting rod bearing journals (Fig. 6). Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum journal-to-bearing shell clearance (with new shells) exceeds .0044", the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002". Also, if the journal taper of a used crankshaft exceeds .0015" or the out-of round is greater than .001", the crankshaft must be reground.

Also measure the crankshaft thrust surfaces (Fig. 8).

10.4 Inspection for Cracks

Carefully check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 450 to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined above.

| CRANKSHAFT RUNOUT | | |
|---|---|---|
| **Engine** | **Journals** | **Max. Runout (Total indicator reading)** |
| 671 | At No. 2 and No. 6 | .002" |
| | At No. 3 and No. 5 | .004" |
| | At No. 4 | .006" |

*Table 1*

MAGNETIC PARTICLE METHOD: The part is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be demagnetized after the test.
FLUORESCENT MAGNETIC PARTICLE METHOD: This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under "black light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "black light".

FLUORESCENT PENETRANT METHOD: This is a method which may be used on non-magnetic materials such as stainless steel, aluminum and plastics. A highly fluorescent liquid penetrant is applied to the part. Then the excess penetrant is wiped off and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under "black light".

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of the indications is but a first step in the procedure. Interpretation of the indications is the most important step.

All Detroit Diesel crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock.

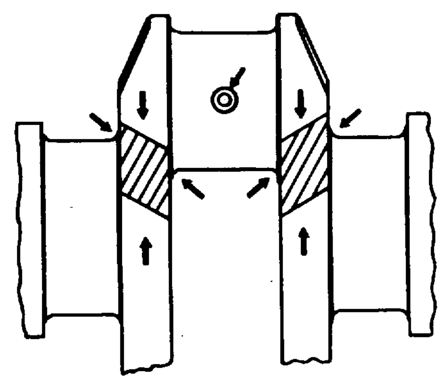

*Fig. 4. Critical Crankshaft Loading Zones*

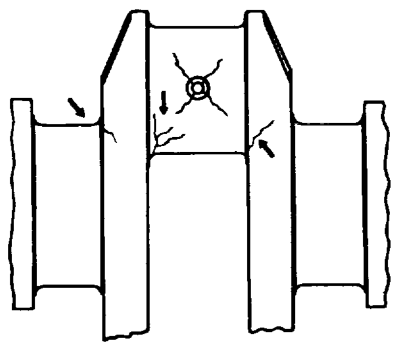

*Fig. 5 Crankshaft Fatigue Cracks*

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service a bending force and a twisting force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load (Fig. 4).

Bending Fatigue failures result from bending of the crankshaft which takes place once per revolution.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the journal fillet. If main bearings are replaced due to one or more

| Bearing Sizes | Conn. Rod Journal Dia. "A" | Main Bearing Journal Dia. "B" |
|---|---|---|
| Standard | 2.750" | 3.500" |
| .002" Undersize | 2.750" | 3.500" |
| .010" Undersize | 2.740" | 3.490" |
| .020" Undersize | 2.730" | 3.480" |
| .030" Undersize | 2.720" | 3.470" |

Table 2

badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional Fatigue failures result from torsional vibration which takes place at high frequency.

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 4.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are usual cases of this type of failure. Also, overspeeding of the engine or resetting the governor at a different speed than intended for the engine application may be contributory factors.

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 450 cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes as shown in Fig. 5. Replace the crankshaft when cracks of this nature are found.

10.5 Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002", .010", .020" and .030" undersize bearings are available.

Note: <u>The .002" undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.</u>

If the crankshaft is to be reground, proceed as follows:

(1) Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 2 and Fig. 6 and determine the size to which the journals are to be reground.
(2) If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.
(3) All journal fillets must have a .130" to .160" radius between the crank cheek and the journal and must not have any sharp grind marks (Fig. 7). The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.
(4) Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.

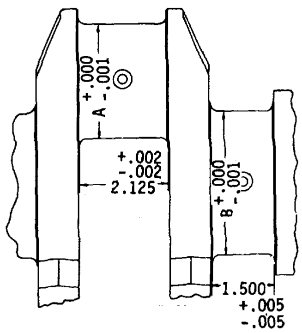


*Fig. 6. Dimensions of Crankshaft Journals*

(5) Polish the ground surfaces to an 8-12 R.M.S. finish. The reground journals will be subject to excessive wear unless polished smooth.

(6) If the thrust surfaces of the crankshaft (Fig. 8) are worn or grooved excessively, they must be taken to leave a .130" to .160" radius between each thrust surface and the bearing journal.

(7) Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32".

(8) After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

(9) Demagnetize the crankshaft.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(10) Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

10.6 Install Crankshaft

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

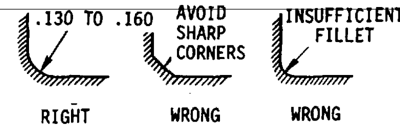


*Fig. 7. Crankshaft Journal Fillets*

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the plugs. Then install the crankshaft

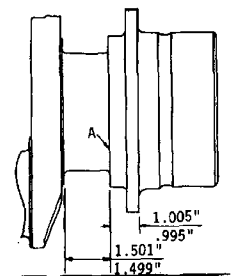


*Fig. 8. Standard Dimensions at Crankshaft Thrust Surfaces*

as follows:

(1) Assemble the crankshaft timing gear (SM6-5-28.0) and the oil pump drive gear (SM6-5-46.0) on the crankshaft.

(2) Refer to SM6-5-12.0 for main bearing details and install the upper grooved main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed.

**Note**: <u>When a new or reground crankshaft is installed, ALL new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.</u>

(3) Apply clean engine oil to all crankshaft journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to SM6-5-24.0 for the correct method of timing the gear train.

(4) Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. The grooved side of the thrust washers must face toward the crankshaft thrust surfaces.

**Note**: <u>If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 8 and Table 3.</u>

(5) Install the lower bearing shells (no oil

grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

(6) Install the bearing caps and lower bearing shells as outlined under Install Main Bearing Shells in SM6-5-12.0.

**Note**: If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

| Nominal Size | Thrust Washer Thickness | |
|---|---|---|
| | **Min.** | **Max.** |
| Standard | .1190" | .1220" |
| .005" Oversize | .1255" | .1270" |
| .010" Oversize | .1300" | .1320" |

*Table 3*

(7) Check the crankshaft end play by moving the crankshaft toward the gauge (Fig. 9) with a pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .004" to .014" with new parts or a maximum of .018" with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers.

(8) Install the cylinder liner, piston and connecting rod assemblies (SM6-5-22.0).

(9) Install the cylinder head (SM6-5-5.0).

(10) Install the flywheel housing (SM6-5-18.0), then install the flywheel (SM6-5-16.0).

(11) Install the crankshaft front cover and gasket.

**Note**: Install the oil seal spacer or inner cone after the crankshaft front cover is in place to avoid damage to the oil seal lip.

(12) Install the engine front support.

(13) Install the vibration damper inner cone or oil seal spacer.

(14) Install the vibration damper assembly.

(15 Install the crankshaft pulley.

(16) Install the lubricating oil pump assembly (SM6-5-46.0).

(17) Affix a new gasket to the oil pan flange and install the oil pan.

(18) Use a chain hoist and sling attached to the lifting bracket or eye bolts at each end of the engine and remove the engine from the overhaul stand.

(19) Install all of the accessories that were removed.

(20) After the engine has been completely reassembled, refer to the Lubricating Oil Specifications in Operator's Manual and re-fill the crankcase to the proper level on the dipstick.

(21) Close all of the drains and fill the cooling system.

(22) After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the run-in schedule (SM6-5-67.0).

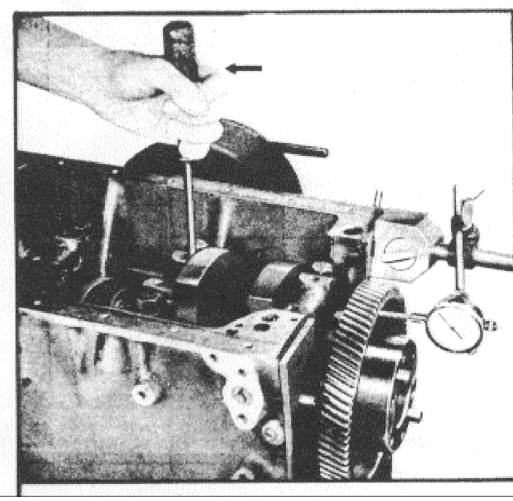

*Fig. 9. Checking Crankshaft End Play*

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring.

The front oil seal is pressed into the crankshaft front cover, and the lip of the seal bears against a removable spacer or vibration damper inner cone on the end of the crankshaft, next to the lubricating oil pump drive gear (Figs. 1 and 2).

A single-lip oil seal is used at the rear end of the crankshaft (Fig. 3). The rear oil seal is pressed into the flywheel housing (Fig. 4).

The gear itself acts as an oil slinger and throws the surplus oil back into a cavity adjacent to the gear (the oil in the cavity flows back into the oil pan).

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout or grooved sealing surfaces on the crankshaft or oil seal spacers. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected

11.1 Remove Crankshaft Oil Seals

Remove the crankshaft front cover (SM6-5-13.0) and the flywheel housing (SM6-5-18.0) and remove the oil seals as follows:

(1) Support the forward face of the front cover or the rear face of the flywheel housing on wood blocks.
(2) Drive the oil seal out and clean the seal bore in the front cover or flywheel housing. Discard the oil seal.

When necessary, an oil seal may be removed without removing the front cover or flywheel housing (except a front cover that is used with trunnion mounts this cover must be removed). This may be done by drilling diametrically opposite holes n the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars.

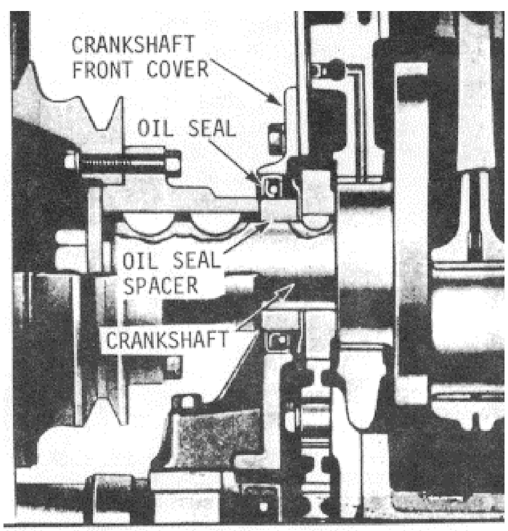


*Fig. 1. Crankshaft Front Oil Seal*

11.2 Inspection

Inspect the rear end of the crankshaft for wear caused by the rubbing action of the oil seal, dirt build-up or fretting by the action of the flywheel. The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed. Slight ridges may be removed from the crankshaft as outlined under Inspection in SM6-5-10.0.

The maximum runout of the oil seal bore in the flywheel housing is .008". The bore may be checked with a dial indicator mounted on the end of the crankshaft in a manner similar to the procedure for checking the flywheel housing concentricity as outlined in SM6-5-18.0. This check must be made with the flywheel housing in place on the engine and the oil seal removed.

If the crankshaft rear oil seal surface is grooved excessively, an oil seal spacer (Fig. 5) may be installed between the counterbore in the flywheel housing and the oil seal. The spacer changes the relative position of the seal and establishes a new contact surface.

When the oil seal spacer can no longer be used, an oil seal sleeve (Fig. 5) may be installed on the crankshaft to provide a replaceable wear surface at the point of contact with the rear oil seal. The oil seal sleeve can be used in conjunction with the seal spacer. However, an oversize oil seal must be used with the sleeve.

Install an oil seal sleeve as follows:

(1) Stone the high spots from the oil seal contact surface of the crankshaft.
(2) Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.

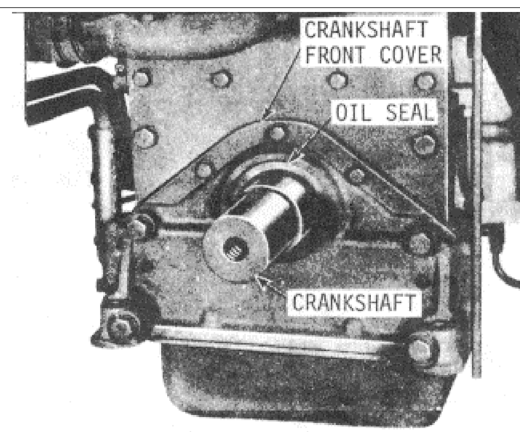


*Fig. 2. Crankshaft Front Oil Seal Mounting*

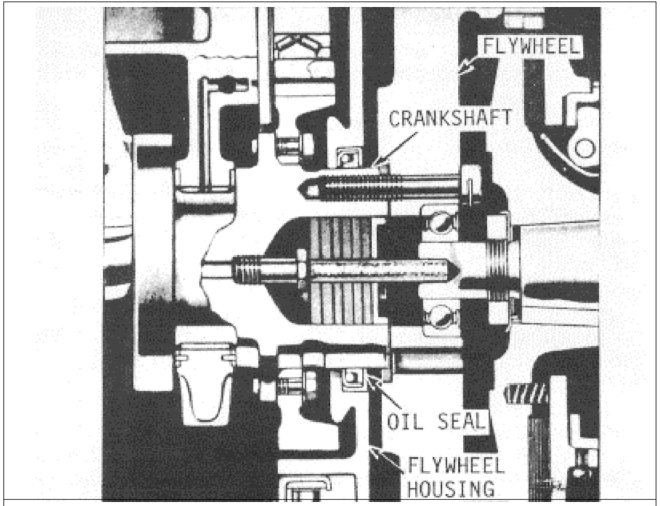


*Fig. 3. Crankshaft Rear Oil Seal - Single Lip*

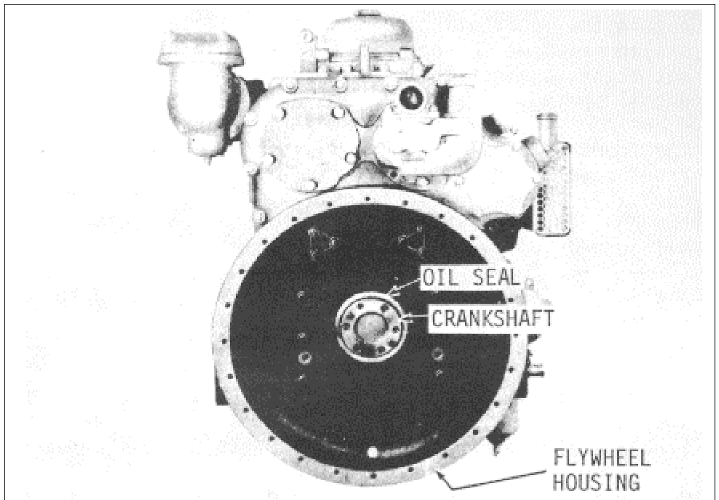


*Fig. 4. Crankshaft Rear Oil Seal Mounting*

(3) Drive the sleeve squarely on the shaft with oil seal sleeve installer J 4194.
(4) Wipe off any excess sealant.
(5) Coat the outside diameter of the sleeve with engine oil.

To remove a worn sleeve, peen the outside diameter until the sleeve stretches sufficiently so it can be slipped off the end of the crankshaft.

Prior to the use of the crankshaft rear oil seal, early engines incorporated an oil deflector which was pressed into the crankshaft bore of the flywheel housing. However, all replacement flywheel housings are counterbored for the installation of an oil seal.

11.3 Oil Seals

Current oil seals are made of an oil resistant synthetic rubber which is pre-lubricated with a special lubricant. Do not remove this lubricant. Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surface of the casing. Do not remove this coating.
The rear oil seal may have either an open or closed back. Both types are serviced.

11.4 Install Crankshaft Front Oil Seal

(1) If the oil seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing.
(2) Coat the lip of the new oil seal lightly with grease or vegetable shortening. Then position the seal in the front cover with the lip of the seal pointed toward the inner face of the cover.

Note: The vibration damper inner cone or oil seal spacer must be removed before installing the oil seal.

(3) Drive the seal into the front cover with installer J 9783, which seats the oil seal in the bore. The installer prevents damage to the seal by exerting force only on the outer edge of the seal casing.
(4) Remove any excess sealant from the cover and seal.
(5) Install the crankshaft front cover as outlined in SM6-5-13.0.
(6) Install the vibration damper inner cone or oil seal spacer after the front cover and seal assembly is in place.

11.5 Install Crankshaft Rear Oil Seal

(1) Support the inner face of the flywheel housing on a flat surface.
(2) Install the rear oil seal spacer, if used. Install the spacer against the shoulder in the flywheel housing oil seal bore.
(3) If the new seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing. Then position the seal with the lip pointed toward the inner face (or shoulder in the counterbore) of the housing.
(4) Coat the lip of the oil seal lightly with engine oil. Do not scratch or nick the sealing edge of the oil seal.
(5) Drive the seal into the housing with installer J 9727 and handle J 3154-1 (Fig. 6) until it is seated against the seal spacer (if used) or on the shoulder in the housing bore. The installer prevents damage to the seal by exerting force only on the outer edge of the seal casing.

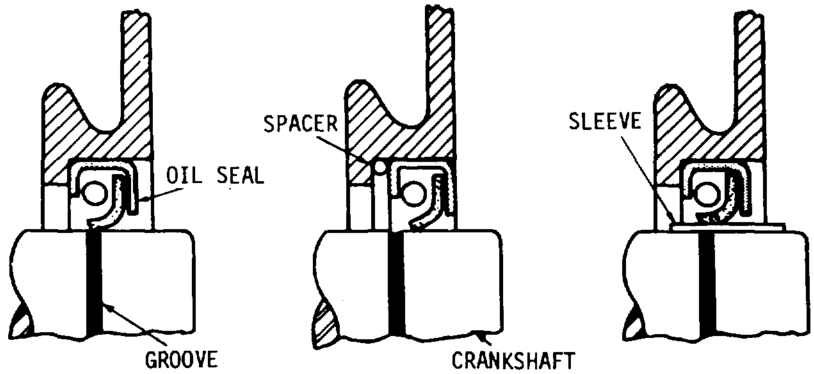


*Fig. 5. Use of Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft*

If it is necessary to install the oil seal with the flywheel housing on the engine, place oil seal expander J 22425 (standard size seal) or expander J 4195-01 with handle J 8092 (oversize seal) against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the tool and on the crankshaft. Remove the seal expander and drive the seal in place with installer J 9727 and handle J 3154-1.

(6) Remove any excess sealant from the flywheel housing and the seal.

(7) Install the flywheel housing as outlined in SM6-5-18.0.

**Note**: If the oil seal is of the type which incorporates a brass retainer in the inner diameter of the seal, be sure the retainer is in place on the seal before installing the flywheel housing on the engine. If the retainer is left out, oil leakage will result.

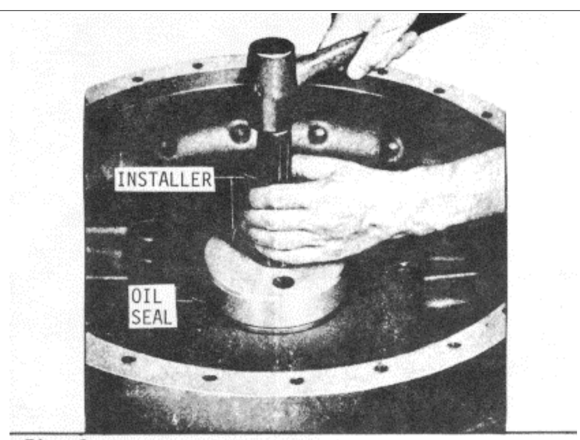


*Fig. 6. Installing Oil Seal in Flywheel Housing*

The crankshaft main bearing shells (Fig. 1) are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

An oil hole in the groove of each upper bearing shell, midway between the parting lines, registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings.

The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells most not be interchanged.

Thrust washers (Fig. 1), on each side of the rear main bearing, absorb the crankshaft thrust. The lower halves of the two-piece washers are doweled to the bearing cap; the upper halves are not doweled.

Main bearing trouble is ordinarily indicated *by* low or no oil pressure. All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time, as outlined below and examine the bearing shells.

12.1 Remove Main Bearing Shells (Crankshaft in Place)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position.

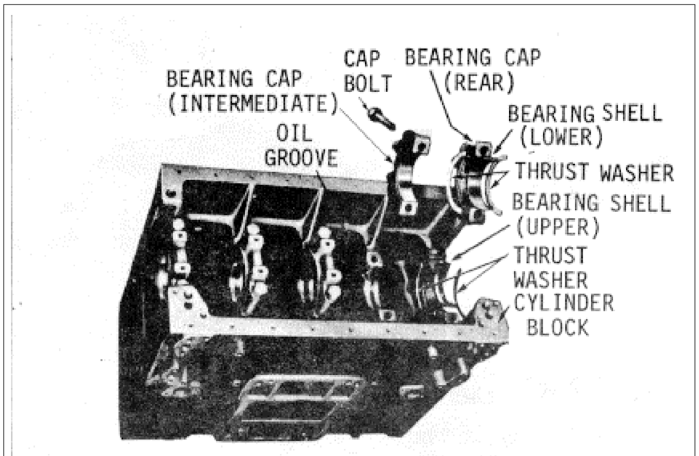


*Fig. 1. Typical Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers*

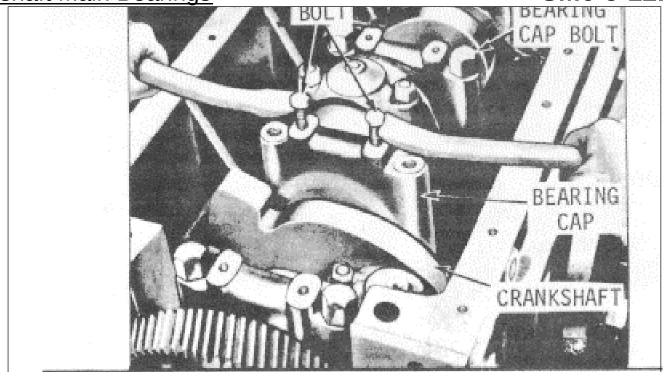


*Fig. 2. Removing Main Bearing Cap*

All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bearing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove the main bearing shells as follows:

(1) Drain and remove the oil pan to expose the main bearing caps.

(2) Remove the oil pump and the oil inlet and outlet pipe assemblies.

**Note**: <u>If shims are used between the oil pump and the main bearing caps, save the shims so that they may be reinstalled in exactly the same location.</u>

(3) Remove one main bearing cap at a time (Fig. 2) and inspect the bearing shells as outlined under Inspection. Reinstall each bearing shell and bearing cap before removing another bearing cap:

(a) To remove all except the rear main bearing shell, insert a 1/4" x 1" bolt with a 1/2" diameter and 1/16" thick head (made from a standard bolt) into the

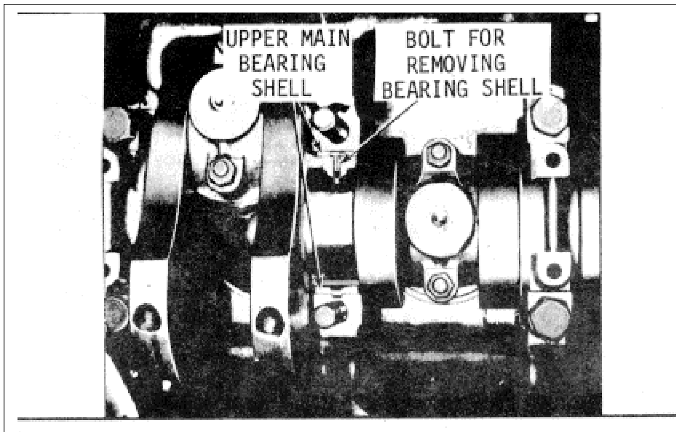


*Fig. 3. Removing Upper Main Bearing Shell (Except Rear Main)*

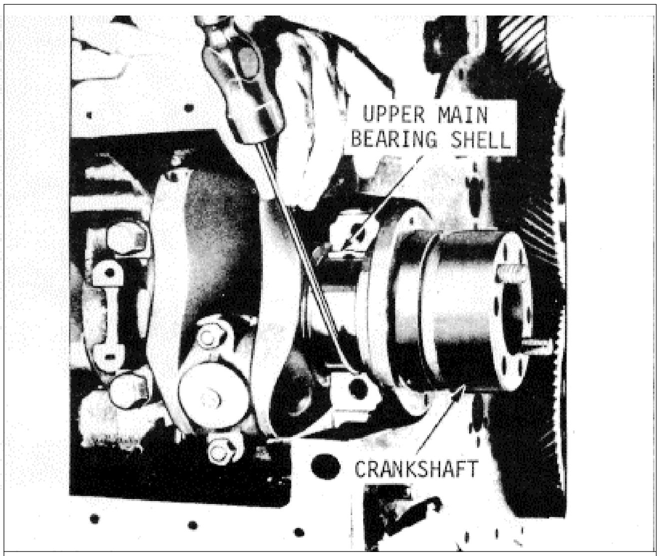


*Fig. 4. Removing Upper Rear Main Bearing Shell*

crankshaft journal oil hole. Then revolve the shaft to the right (clockwise) and roll the bearing shell out of position as shown in Fig. 3. The head of the bolt must not extend beyond the outside diameter of the bearing shell.

(b) Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out as shown in Fig. 4.

(c) The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

12.2 Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

Check the oil filter elements and replace them if necessary. Also, check the oil by-pass valve to make sure it is operating freely.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt or signs of overheating (Fig. 5). The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells. However, bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are not detrimental to this type of bearing. They should not be replaced for these minor surface imperfections since function of the bearings is in no way impaired and they will give many additional hours of trouble-free operation.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells at point "C", 90° from the parting line, as shown in Figs. 6 and 7. Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn stand-

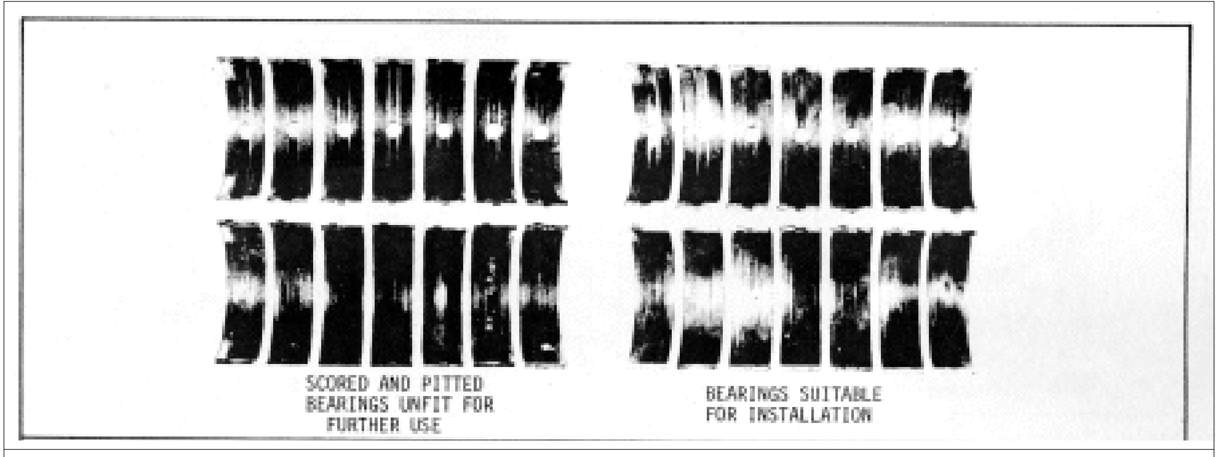


*Fig. 5. Comparison of Main Bearing Shells*

| **Bearing Size** | **Bearing Thickness** | **Minimum Worn Thickness** |
|---|---|---|
| Standard | .1548"/.1533" | .1530" |
| .002" Undersize | .1558"/.1563" | .1540" |
| .010" Undersize | .1598"/.1603" | .1580" |
| .020" Undersize | .1648"/.1653" | .1630" |
| .030" Undersize | .1698"/.1703" | .1680" |

*Table 1*

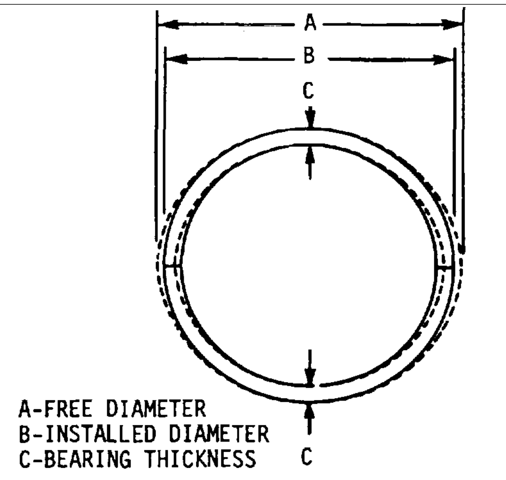


*Fig. 6. Main Bearing Measurements*

ard main bearing shell is .1530" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of .1548" to .1553". Refer to Table 1.

In addition to the thickness measurement, check the clearance between the main bearings and the crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to Shop Notes in SM6-5-31.0). With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque on the bearing cap bolts. When installed, the bearing shells are .001" larger in diameter at the part- ing line than $90^\circ$ from the parting line.

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This crush assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds .0060", all of the bearing shells must be discarded and replaced. This clearance is .0014" to .0044" with new parts.

Before installing new replacement bearings it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to SM6-5-10.0 under Crankshaft Inspection for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .010", .020", and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to Crankshaft Grinding in SM6-5-10.0. Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

**Note**: Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Inspect the crankshaft thrust washers. If the washers are scored or worn excessively or the crankshaft end play is excessive, they must be replaced. Improper clutch adjustment can con- tribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to Install Crankshaft in SM6-5-10.0. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is

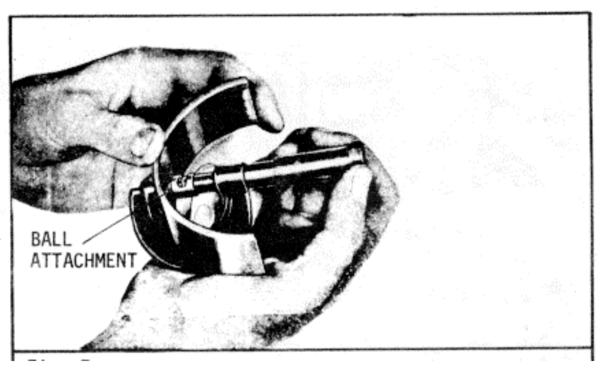


*Fig. 7. Measuring Thickness of Bearing Shell*

.1190" to .1220" thick. Thrust washers are available in .005" and .010" oversize.

12.3 Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then apply clean engine oil to each crankshaft journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

The upper and lower main bearing shells are not alike; the upper bearing shell is grooved and drilled for lubrication - the lower bearing shell is not. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

(1) When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.

(2) Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.

(3) Assemble the crankshaft thrust washers (Fig. 8) before installing the rear main bearing cap. Clean both halves of each thrust washer carefully and remove any burrs from the washer seats - the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then assemble the lower halves over the dowel pins in the bearing cap.

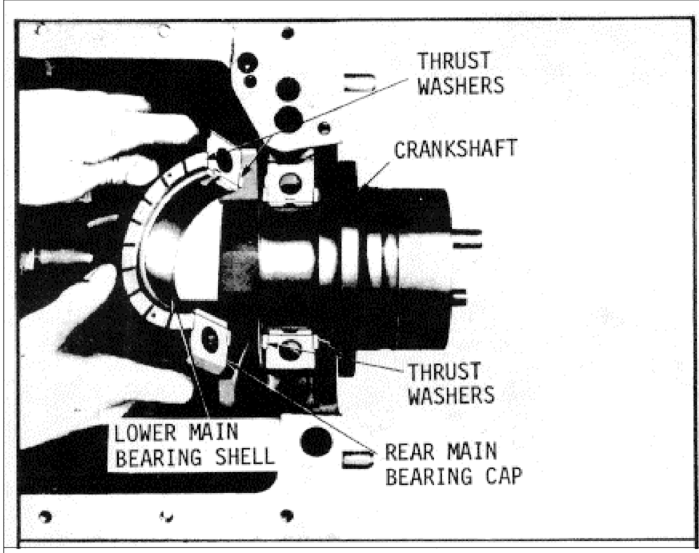


*Fig. 8. Crankshaft Thrust Washers in Place*

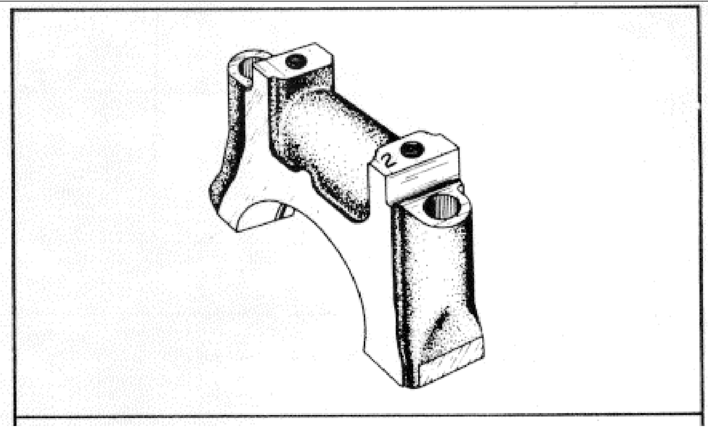


*Fig. 9. Main Bearing Cap Marking*

Note: <u>The main bearing caps are bored in position and stamped 1, 2, 3, etc. (Fig. 9). They must be installed in their original positions with the marked side of each cap toward the blower side of the cylinder block.</u>

(4) With the lower main bearing shells installed in the bearing caps, apply a small quantity of International Compound No. 2, or equivalent, to the bolt or stud and nut threads and the bolt head (or nut) contact area. Install the bearing caps and draw the bolts (or nuts) up snug. Then rap the caps sharply with a soft hammer to seat them properly and tighten all bolts to 44-55 ft-lbs (61-75 Nm) torque. Turn all bolts (except the rear main bearing bolts) an additional 110°-130° of bolt head rotation starting with the center bearing cap bolts and working alternately towards both ends of the block.

**Note**: <u>An accurate way to determine bolt head rotation is to paint or permanently scribe the sockets used with two marks 120° apart (Fig. 10). After torquing bolts to 45-55 ft-lbs (61-75 Nm) put a pencil line opposite the first mark on the socket. Then rotate the bolt until the next socket mark lines up with the pencil line.</u>

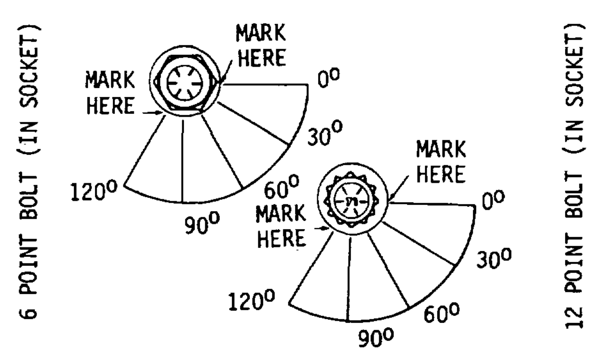


*Fig. 10. Main Bearing Cap Bolt Turn Torque Method*

Strike both ends of the crankshaft two or three sharp blows with a soft hammer to insure proper positioning of the rear main bearing cap in the block saddle. Turn the rear main bearing cap bolts an additional 110-130° of bolt head rotation. If studs and nuts are used, tighten all nuts (except the rear main bearing nuts) to 155-185 ft-lbs (211-251 Nm) torque starting with the center bearing cap nuts and working alternately towards both ends of the block. Tighten the rear main bearing nuts to 40-50 ft-lbs (54-68 Nm) torque. Strike both ends of the crankshaft two or three sharp blows with a soft hammer to insure proper positioning of the rear main bearing cap in the block saddle. Retorque all bearing nuts to 155-185 ft-lbs (211-251 NT).

**Note**: <u>If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts or nuts drawn to the specified torque</u>.

(5) Check the crankshaft end play as outlined under Install Crankshaft in SM6-5-10.0.

(6) Install the lubricating oil pump and the oil inlet and outlet pipe assemblies.

Note: <u>If shims were used between the pump and the bearing caps, install them in their original positions. Then check the oil pump gear clearance (SM6-5-46.0).</u>

(7) Install the oil pan, using a new gasket.

(8) Fill the crankcase to the proper level on the dipstick with heavy-duty lubricating oil of the recommended grade and viscosity (refer to Lubricating Oil Specifications in Operator's Manual).

(9) After installing new bearing shells, operate the engine on a run-in schedule as outlined in SM6-5-67.0.

The crankshaft front cover is mounted against the cylinder block end plate at the lower front end of the engine (Fig. 1). The engine is supported at the front end by engine supports attached to the front cover.

It will be necessary to remove the crankshaft front cover to remove and install the crankshaft or when the engine is overhauled.

13.1 Remove Crankshaft Front Cover

(1) Drain the oil and remove the oil pan.
(2) Remove the vibration damper (SM6-5-14.0), crankshaft pulley (SM6-5-15.0) and any other accessories that may be mounted on the front of the crankshaft.
(3) Remove the vibration damper inner cone or oil seal spacer.
(4) Remove the cover attaching bolts and washers (Fig. 1).
(5) Strike the rear face of the ears on the cover with a soft hammer to free the cover from the dowels. Pull the cover straight off the end of the crankshaft.
(6) Remove the cover gasket.
(7) Remove and inspect the oil slinger.
(8) Replace the oil seal (SM6-5-11.0).

13.2 Install Crankshaft Front Cover

(1) Install the oil slinger in place next to the oil pump drive gear, with the dished outer diameter of the slinger facing away from the gear.
(2) Shellac a new gasket to the bolting flange of the crankshaft front cover.
(3) Coat the lip of the oil seal lightly with cup grease.
(4) Attach the cover to the cylinder block front end plate with bolts and lockwashers. Use plain washers in addition to lockwashers on aluminum covers.

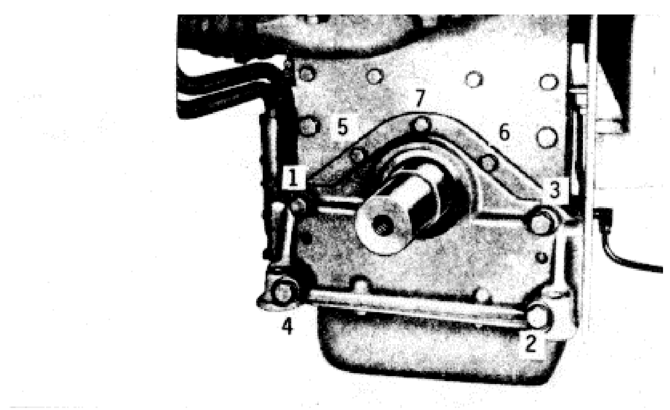


*Fig. 1. Crankshaft Front Cover Mounting (Vibration Damper Removed)*

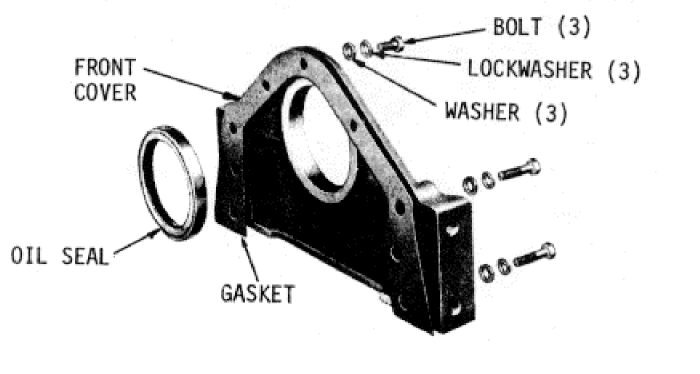


*Fig. 2. Crankshaft Front Cover Details and Relative Location of Parts*

(5) Tighten the cover attaching bolts *by* following the tightening sequence indicated in Fig. 3. Follow this sequence as the bolts are drawn up and then tightened to their proper torque to effect a good seal between the mating parts. Tighten the 3/8"-24 bolts to 25-30 ft-lbs (34-41 Nm) and the 1/2"-13 bolts to 80-90 ft-lbs (108-122 Nm) torque.
(6) Apply a light coating of engine oil to the vibration damper inner cone or the oil seal 6 spacer and slide it into place on the crankshaft.
(7) Install the oil pan, using a new gasket. Refer to Lubricating Oil Specifications in Operator's Manual and refill the crankcase with oil to the proper level on the dipstick.

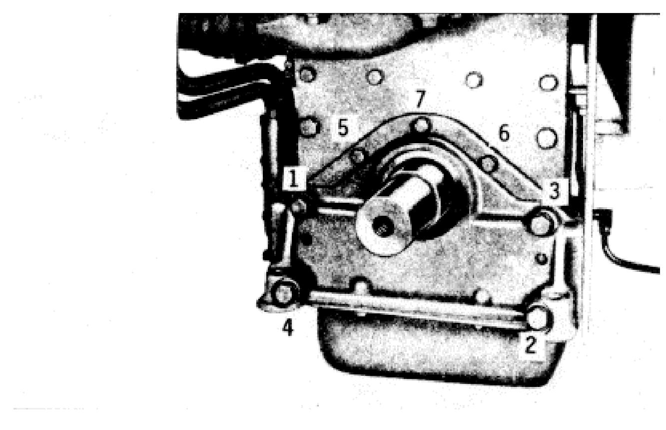


*Fig. 3. Crankshaft Front Cover Bolt Tightening Sequence*

**Service Manual** SM6-5-14.0 Crankshaft Vibration Damper

A vibration damper reduces the crankshaft stresses to a safe value.

The double (rubber) damper (Fig. 1) is made up of a light damper, a heavy damper, a hub, an inner cone and an outer cone. The light and heavy dampers in the assembly are in turn made up of rubber blocks bonded to an inertia mass in the form of a metal ring on one side and a stamped metal disc on the opposite side.

The two metal parts are, therefore, entirely separated and free to move freely within certain prescribed limits by virtue of the rubber blocks. The light and heavy dampers are bolted and doweled together and to the driving hub. The hub in turn is secured in place at the front end of the crankshaft between an inner and outer cone as shown in Fig. 1. The two cones provide-an adequate rigid mounting when the pulley, is drawn up tight against the outer cone by the bolt in the end of the crankshaft.

The bolts are lubrite coated to prevent possible damage (galling) to the bolt threads and to increase the clamp load to the front end stack up (crankshaft pulley, vibration damper, etc). Also the washer (retainer) is now case hardened.

The vibration damper must be removed whenever the crankshaft, crankshaft front cover or crankshaft front oil seal is removed or replaced.

14.1 Remove Vibration Damper From Crankshaft

(1) Remove the crankshaft pulley retaining bolt and washer.
(2) Remove the crankshaft pulley.

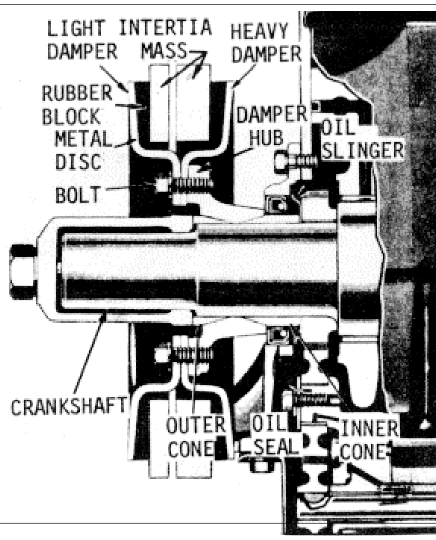


*Fig. 1*
*Crankshaft Cap and Double Vibration Damper Assembly and Mounting*

SM6-5-14.0

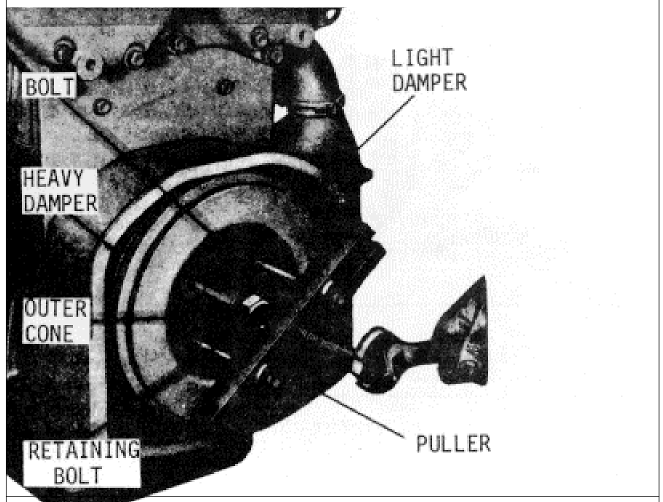


*Fig. 2*
*Loosening Vibration Damper Outer Cone*

(3) Remove two damper-to-hub bolts and lock washers diametrically opposite to each other(Fig. 2). Two puller holes are provided in -the bolt circle of the viscous damper.
(4) Reinstall the pulley crankshaft bolt and install a puller as shown in Fig. 2 to loosen the outer cone wedged between the crankshaft and the damper hub. After loosening the cone, it may be "fished" from the inner diameter of the damper hub with two thin shank screwdrivers.
(5) Slide the vibration dampers and damper hub as an assembly off the end of the crankshaft by hand.
(6) Slide the inner cone from the crankshaft.

14.2 Inspect Vibration Damper

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air**,** Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

After removal, clean the vibration damper in fuel oil and dry it with compressed air.

Note: Do not allow fuel oil to remain on a rubber type vibration damper too long, but dry it immediately after cleaning, otherwise, damage due to the action of the fuel oil on the rubber may result.

Inspect the rubber type damper to see *that* the rubber is firmly bonded to the metal parts at each side. If the damper has been exposed to fuel oil, lubricating oil or excessive heat, the rubber may have become loosened from the metal. In this event, the damper must be discarded and replaced with a new one. Also check to see that the metal discs are not bent.

**Service Manual** SM6-5-14.0 Crankshaft Vibration Damper

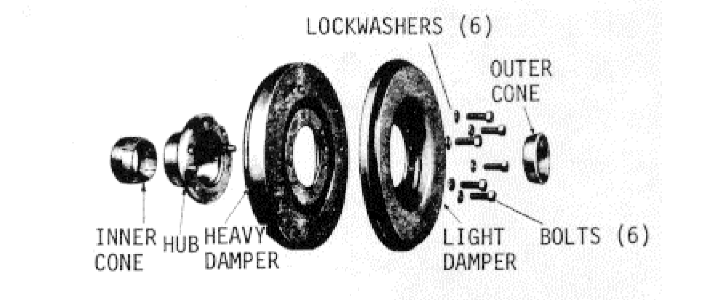


*Fig. 3*
*Double Vibration Damper (Rubber-Type) Details and Relative Location of Parts*

If damage to the vibration damper is extensive, inspect the crankshaft as outlined in SM6-5-10.0. A loose or defective vibration damper, after extended operation, may result in a cracked crank-shaft.

Inspect the damper spacer cones, hub, sleeve and the end of the crankshaft for galling or burrs. Slight scratches or burrs may be removed with emery cloth. If seriously damaged, the parts should be replaced and the end of the crankshaft refinished. Check the outside diameter of the inner cone for wear at the crankshaft front oil seal contact surface. If worn, replace the oil seal and cone (SM6-5-11.0).

14.3 Install Vibration Damper on Crankshaft

Refer to the illustrations for relative location of the parts and assemble as follows:

(1) Coat the lip of the oil seal in the front cover (trunnion) lightly with cup grease or vegetable shortening and lubricate the sleeve and spacer if used, with engine oil.

(2) With the Woodruff keys in place, slide the inner cone, with the tapered end pointing to the front of the crankshaft, next to the oil slinger or against the spacer.

Note: <u>When the vibrating damper and crank-shaft pulley are bolted together and mounted on the front end of the crankshaft (Fig.4), extra precaution should be taken to be certain that the inner cone does not prematurely clamp to the crankshaft</u>.

(3) If the light and heavy dampers were removed from the hub, assemble the two dampers over the dowels and against the hub with the flat faces of the dampers facing each other as shown in Fig. 1. Secure the dampers to the hub with bolts and lockwashers.

(4) Slide the damper and hub as an assembly --long end of the hub facing the crankshaft --into position.

(5) Install the crankshaft pulley and vibration damper assembly with the damper assembly side of the pulley facing the crankshaft front cover.

(6) Slide the outer cone over the crankshaft and into the crankshaft pulley.

(7) Install the crankshaft pulley.

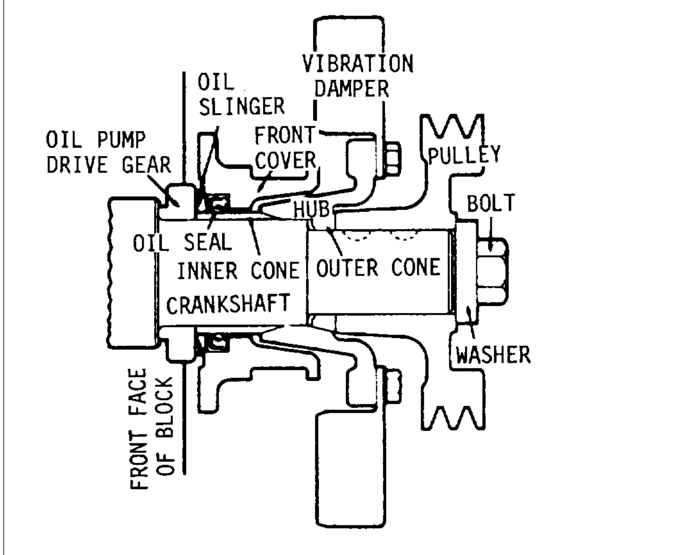


*Fig. 4*
*Vibration Damper and Crankshaft Pulley Assembly Mounting*

(8) Thread the crankshaft pulley retaining bolt with washer into the crankshaft and tighten it as follows:
(a) Tighten to 180 ft-lbs (244 Nm) torque.
(b) Strike the end of the bolt a sharp blow with a 2 to 3 lb. lead hammer.
(c) Tighten to 300 ft-lbs (407 Nm) torque and strike the bolt again.
(d) Tighten to 290-310 ft-lbs (393-421 Nm) torque.
Note: <u>Do not strike the bolt after final torque has been applied.</u>

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operation should ALWAYS be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

Note: <u>The damper assembly must be securely fastened to the crankshaft. When the bolt is drawn up to the specified torque, the cones will hold the damper rigidly in place.</u>

The crankshaft pulley is keyed to the crankshaft and secured with a special washer and bolt.

The crankshaft bolts are lubrite coated to prevent possible damage (galling) to the bolt threads and to increase the clamp load to the front end stack up (crankshaft pulley, vibration damper, etc). Also the washer (retainer is now case hardened.

15.1 Remove Crankshaft Pulley
The difference in the design of pulleys dictates the use of various puller tools as outlined below:

(1) Remove the bolt and washer.
(2) If a rigid type pulley without any tapped holes is being removed, use a two-jaw puller.
(3) If tapped holes are provided in the pulley hub, install the pulley bolt in the end of the crankshaft and use puller J 24420.

15.2 Install Crankshaft Pulley

Refer to Fig. 2 and install the crankshaft pulley as follows:

(1) Place the Woodruff keys in the key slots in the front end of the crankshaft, if they were removed.
(2) Slide the pulley over the end of the crank-shaft.
(3) Place the washer on the bolt and thread the bolt into the end of the crankshaft, drawing the pulley tight against the oil seal spacer.

The pulley must be drawn tight against the outer cone.

(4) Tighten the crankshaft pulley retaining bolt as follows:
(a) Tighten the bolt to 180 ft-lbs (244 Nm) torque.

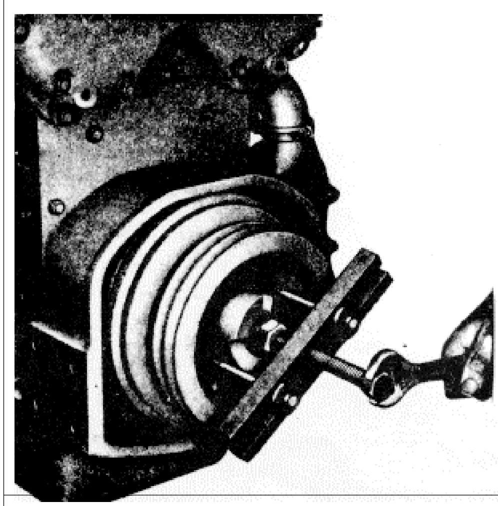

*Fig. 1*
*Removing Pulley from Crankshaft*

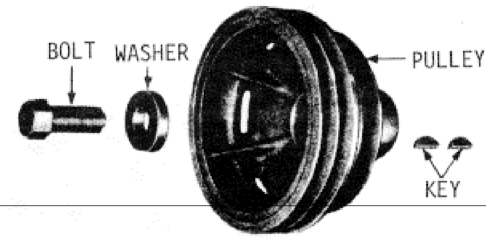


*Fig. 2*
*Crankshaft Pulley Details*

(b) Strike the end of the bolt a sharp blow with a 2 or 3 lb. lead hammer.
(c) Tighten the bolt to 300 ft-lbs (407 Nm) torque and strike the bolt again.
(d) Tighten the bolt to 290-310 ft-lbs (393-421 Nm) torque.

Note: Do not strike the bolt after final torque has been applied.

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. However, the barring operating should ALWAYS be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened during the barring operation. Otherwise serious engine damage may result if the vibration damper or pulley is not securely fastened to the crank-shaft.

**Service Manual** SM6-5-16.0 Flywheel **SM6-5-16.0**

The flywheel (Fig. 1) is attached to the rear end of the crankshaft with six self-locking bolts. Two dowels in the end of the crankshaft aid flywheel alignment and provide support when the flywheel bolts are removed. A scuff plate is used between the fly-wheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the fly-wheel.

A split tube type retainer (Fig. 2) is driven in the end of the crankshaft to prevent the pilot bearing from entering the crankshaft cavity.

The flywheel is machined to provide true alignment with the clutch and the center bore provides for installation of the clutch pilot bearing. The clutch is bolted to the flywheel. An oil seal ring, which provides an oil tight connection between the crankshaft and the flywheel, is fitted into a groove on the flywheel.
The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing.

16.1 Remove Flywheel (Torque Converter Removed)

(1) Remove the six flywheel attaching bolts and scuff plate.

**CAUTION**

If The Crankshaft Is Not Provided With Dowels, Install One Flywheel Bolt After Removing The Scuff Plate To Hold The Flywheel In Place Until The Lifting Tool Is Attached.

Note: <u>If the flywheel is equipped with a splined drive flange, it must be removed first.</u>

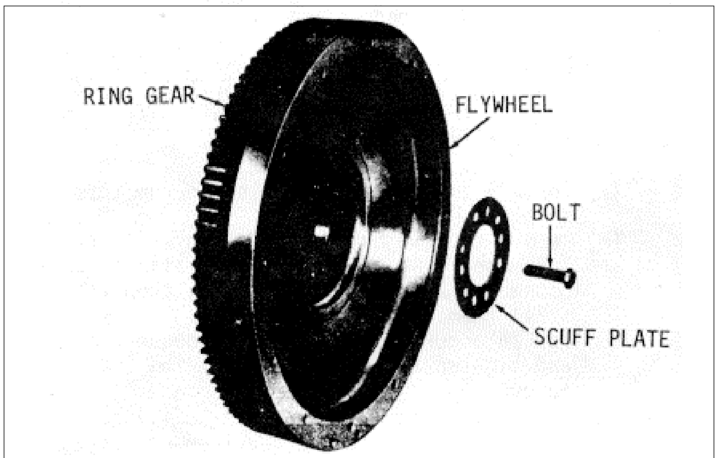


*Fig. 1*
*Typical Flywheel Assembly*

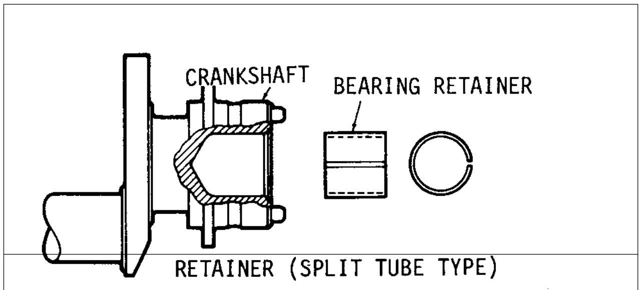


*Fig. 2*
*Pilot Bearing Retainers*

(2) Attach flywheel lifting tool J 6361-01 to the flywheel with two 7/16"-14 bolts of suitable length or use tool J 25026. Remove the remaining flywheel attaching bolt.
(3) Attach a chain hoist to the lifting tool to support the flywheel as shown in Fig. 3.
(4) Move the upper end of the lifting tool in and out to loosen the flywheel, then with-draw the flywheel from the crankshaft and the flywheel housing.
(5) Remove the clutch pilot bearing, as outlined in SM6-5-17.0.

16.2 Inspection

Check the clutch contact face of the flywheel for scoring, overheating or cracks. If scored, the flywheel may be refaced. However, do not
remove more than .020" of metal from the flywheel. Maintain all of the radii when refacing the flywheel.

Replace the ring gear if the gear teeth are excessively worn or damaged. Check the butt end of the crankshaft and flywheel contact surface. If necessary lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

Check the dowel extension on the crankshaft. Dowels must not extend more than 1/2" (13mm) from the crankshaft.

Make sure that the crankshaft and flywheel contact surfaces and the bolt threads in the crank-shaft end are clean and dry, to insure proper metal-to-metal contact and maximum friction, before starting the assembly procedure.

16.3 Remove Ring Gear

Note whether the ring gear teeth are chamfered. The replacement gear must be installed so that the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that is to be removed. Then remove the ring gear as follows:

(1) Support the flywheel, crankshaft side down, on a solid flat surface or hardwood block which is slightly smaller than the inside diameter of the ring gear.
(2) Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.

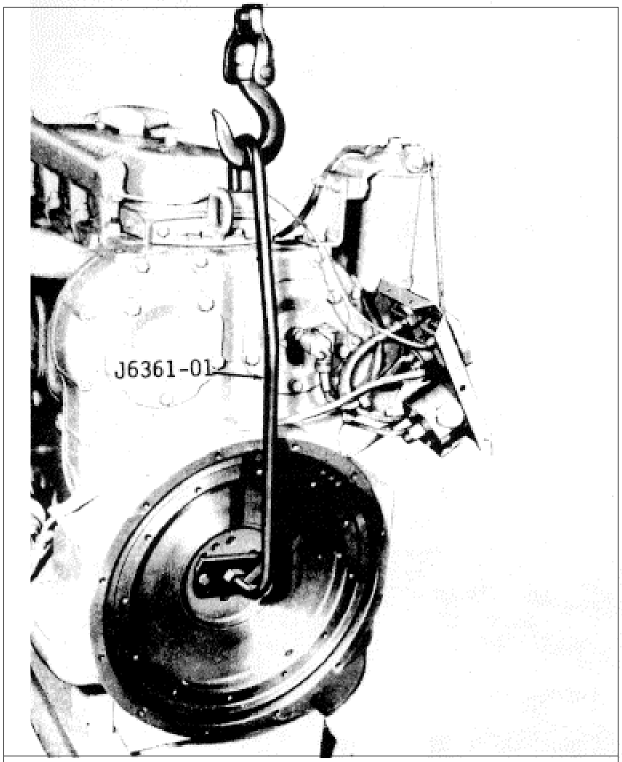


*Fig. 3*
*Removing Flywheel*

16.4 Install Ring Gear

(1) Support the flywheel, ring gear side up, on a solid flat surface.

(2) Rest the ring gear on a flat metal surface and heat the gear uniformly with an acetylen torch, keeping the torch moving around the gear to avoid hot spots.

**CAUTION**

Do Not, Under Any Circumstances, Heat The Gear Over 400°F (204 C); Excessive Heat May Destroy The Original Heat Treatment.

Note: Heat indicating "crayons", which are placed on the ring gear and melt at a predetermined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

(3) Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.

(4) Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it and apply additional heat, noting the above caution.

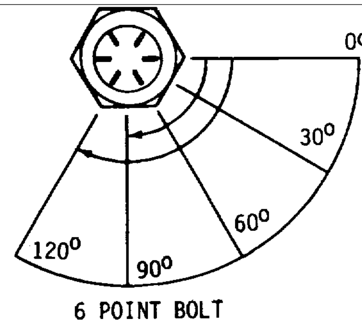


*Fig. 4*
*Torque - Turn Limits 16.5 Install Flywheel*

(1) Attach the flywheel lifting tool and, usinga chain hoist, position the flywheel in the flywheel housing (use guide studs). Align the flywheel bolt holes with the crankshaft bolt holes.

(2) Install the clutch pilot bearing.

(3) Install the washer type pilot bearing retainer. Install a split tube type retainer, drive the retainer in flush with the end of the crankshaft with a soft hammer.

**CAUTION**

Do Not Mar The Bearing Contact Surface Of The Retainer.

(4) Install two bolts through the scuff plate (or drive flange) 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide studs.

(5) Remove the flywheel lifting tool.

(6) Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. -The bolt threads must be completely filled with International Compound No. 2 and any excess wiped off.

Note: International Compound No. 2 must never be used between two surfaces where maximum friction is desired as between the crankshaft and the flywheel.

(7) Install the remaining bolts and run them in snug.

(8) Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.

(9) Use an accurately calibrated torque wrench and tighten the bolts to 50 ft-lbs (68 mn) torque.

(10) Turn the bolts an additional 90°-120° (Fig. 4) to obtain the required clamping.

Note: Since the torque-turn method provides ,more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

Important: When the clutch pilot bearing is installed, index the flywheel bolts so that the corners of the bolt heads do not overlap the pilot bearing bore in the flywheel. T us, one of the flats of each bolt head will be in line with the bearing bore. Always rotate bolts in the increased clamp direction to prevent underclamping.

(11) Mount a dial indicator on the flywheel housing and check the run out of the flywheel at the clutch contact face. The maximum allowable run out is .001" total indicator reading per inch of radius (or .001mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

## **Service Manual** SM6-5-17.0 Clutch Pilot Bearing



The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft.

The clutch pilot bearing is held in place *by* a scuff plate, or bearing retainer, secured in place by the flywheel attaching bolts.

17.1 Lubrication

A single-shielded ball type clutch pilot bearing should be packed with an all purpose grease such as Shell Alvania No. 2, or equivalent, if not previously packed by the manufacturer. A double-sealed ball type clutch pilot bearing is prepacked with grease and requires no further lubrication.

17.2 Remove Clutch Pilot Bearing (Torque Converter Removed)

With the flywheel attached to the engine, remove the ball type clutch pilot bearing as follows:

(1) Remove the six bolts and lock wires attaching the flywheel to the crankshaft. Remove the bearing retainer and reinstall two of the bolts to hold the flywheel in place.

(2) With the clutch pilot bearing remover adaptor J 23907-2 attached to slide hammer J 23907-1, insert the fingers of the adaptor through the pilot bearing and tighten the thumbscrew to expand the fingers against the inner race of the bearing.

(3) Tap the slide hammer against the shoulder on the shaft and pull the bearing out of the flywheel.

With the flywheel removed from the engine, the clutch pilot bearing may be removed as follows:

(1) Place the flywheel on wood supports to provide clearance for the bearing.

(2) Use bearing remover J 23907-2, as outlined above, or tool J 3154-04 with suitable adaptor plates, to tap the bearing from the flywheel.

17.3 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames. Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wipe the prepacked double-sealed bearing clean on the outside and inspect it. Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Clean the other types of bearing thoroughly with clean fuel oil and dry them with compressed air.

Check the bearing for free rolling by holding the inner race and revolving the outer race slowly by hand. Rough spots in the bearing are sufficient cause for rejecting it.

17.4 Install Clutch Pilot Bearing

Install a ball type bearing as follows:

(1) Lubricate the outside diameter of the bearing with clean engine oil.

(2) Start the bearing in the bore of the flywheel, with the numbered side of the bearing facing away from the engine, and drive the bearing in place with bearing installer J 3154-04 and suitable adaptor plates.

(3) If a straight-roller type bearing or an unshielded ball bearing is used, pack the crankshaft cavity with Shell Alvania No. 2 grease, or equivalent, flush with the rear face of the crankshaft. Make sure there are no air pockets in the grease.

(4) Install the flywheel on the crankshaft (refer to SM6-5-16.0).

**Service Manual** 5M6-5-18.0 Flywheel Housing

The flywheel housing (Fig. 1) is a one-piece casting, mounted against the rear cylinder block end plate, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motor and the torque converter.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without re- moving the housing (SM6-5-11.0).

18.1 Remove Flywheel Housing

(1) Mount the engine on an overhaul stand as outlined in SM6-5-2.0.

(2) Remove the starting motor, oil pan, flywheel and any accessories attached to the flywheel housing.

(3) Remove the two bolts securing the engine lifter bracket to the cylinder head. This will leave the lifter bracket attached to the flywheel housing for convenience in handling.

(4) Remove the twelve attaching bolts inside of the flywheel housing bell which attach the housing to the idler gear hub, spacer and cylinder block. Remove the twelve remaining bolts around the upper portion of the housing and the two bolts which go through the rear end plate from the front and thread into the housing (Fig. 1).

Note: When removing the flywheel housing bolts, note the location of the various bolts and washers so they may be reinstalled in their proper location.

(5) To guide the flywheel housing until it clears the end of the crankshaft, thread four pilot studs J 1927-01 into the cylinder block (Fig. 2).

(6) With the flywheel housing supported by a chain hoist attached to the lifter bracket, strike the front face of the housing alternately on each side with a soft hammer to work it off the dowels and away from the cylinder block rear end plate.

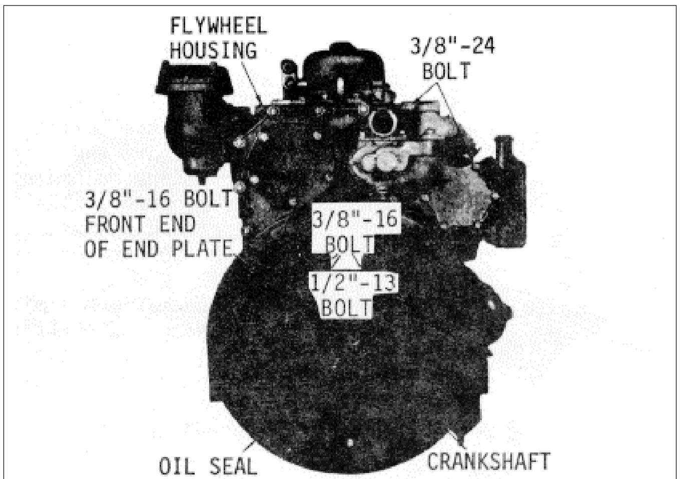


*Fig. 1*
*Typical Flywheel Housing Mounting*

SM6-5-18.0

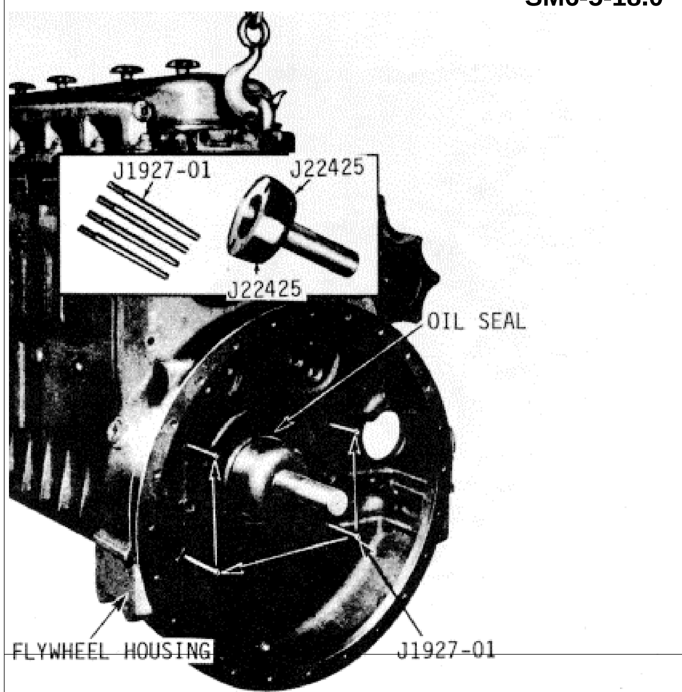


*Fig. 2*
*Removing or Installing Flywheel Housing*

18.2 Inspection

Clean the flywheel housing and inspect it for cracks or any other damage.

It is very important that all old gasket material be thoroughly removed from the flywheel housing and the end plate, otherwise runout of the pilot and the face of the housing may be affected when the housing is installed on the engine.

Remove and discard the crankshaft rear oil seal. Install a new oil seal as outlined in SM6-5-11.0.

18.3 Install Flywheel Housing

(1) Lubricate the gear train teeth with clean engine oil.

(2) Affix a new housing-to-end plate gasket to the flywheel housing.

(3) Coat the lip of the oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double-lip seal). Do not scratch or nick the sealing edge of the oil seal.

(4) Thread four pilot studs J 1927-01 into the cylinder block to guide the housing in place (Fig. 2). Use oil seal expander J 22425 on the end of the crankshaft to pilot the oil seal on the crankshaft.

(5) With the housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket. Remove the oil seal expander.

(6) Refer to Fig. 1 and install the six 3/8"-16 bolts with flat washers in the tapped holes of the idler gear hub and idler gear hole spacer, finger tight. Remove the pilot studs.

**Service Manual** SM6-5-18.0 Flywheel Housing

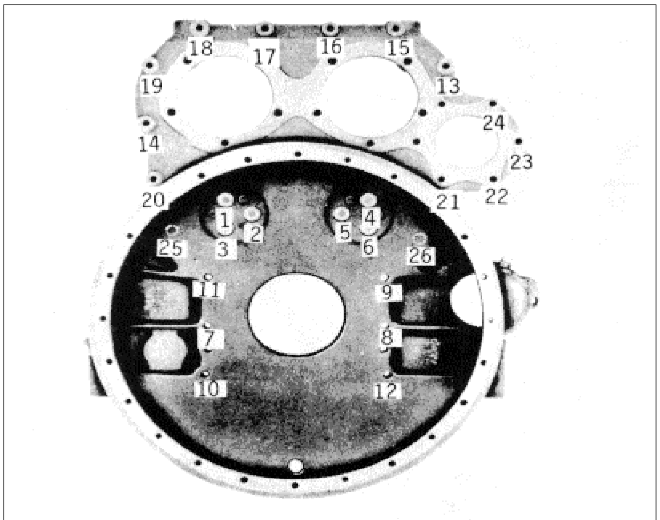

*Fig. 3*
*Flywheel Housing Bolt Tightening Sequence (Operation 1)*

(7) Install the six 1/2"-13 housing to block bolts with lockwashers, finger tight.

(8) Install the remaining flywheel housing attaching bolts and washers, finger tight.

(9) Refer to Fig. 3 for the bolt tightening sequence. Start at number 1 and, using the proper sequence, bring all bolts to within 10-15 ft-lbs (14-20 Nm) of their specified torque, drawing the mating parts together evenly.
Note: When tightening the idler gear hub bolts, turn the crankshaft to prevent any bind or brinelling of the idler gear bearing. The crankshaft must be rotated for the fly-wheel housing bell tightening also.

(10) Refer to Fig. 4 for the final bolt tightening sequence and, starting at number 1, tighten all of the bolts to the specified torque. Tighten the 3/8"-16 idler gear hub and hole spacer self-locking bolts to 40-45 ft-lbs (54-61 Nm) torque. Tighten all other 3/8"- 16 and 3/8"-24 bolts to 25-30 ft-lbs (34-41 Nm) torque, and the 1/2"-13 bolts to 90-100 ft-lbs (122-136 Nm) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts and flywheel housing bell.

For drilled head idler gear hub and spacer bolts, tighten them to 25-40 ft-lbs (34-54 Nm) torque. Line-up the lock wire holes in the bolt heads and install the lock wire, locking each group of three bolts together. The wide range in the torque specifications permits alignment of the bolt heads.

(11) Install the flywheel (SM6-5-15.0)

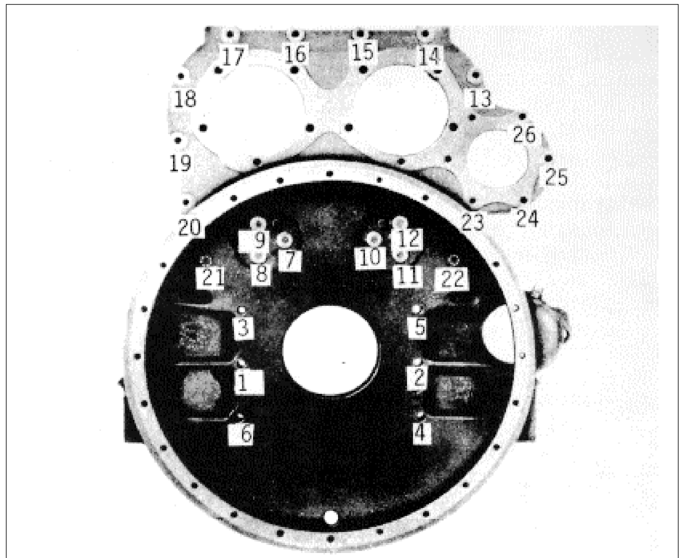

*Fig. 4*
*Flywheel Housing Bolt Tightening Sequence (Operation 2)*

(12) Check the flywheel housing concentricity and bolting flange face with tool set J 9737-01 as follows:

(a) Refer to Fig. 5 and thread the base post J 9737-3 tightly into one of the tapped holes in the flywheel. Then assemble the dial indicators on the base post.

(b) Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.

Note: If the flywheel extends beyond the housing bell, the bore and face must be checked separately. Use the special adaptor in the tool set to check the housing bore.

(c) Pry the crankshaft toward one end of the block to ensure the end play is in one direction only.

(d) Adjust each dial indicator to read zero at the twelve o'clock position. Then rotate the crankshaft one full revolution, taking readings at 45° intervals (8 readings each for the bore and the bolting flange face).: Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed .013" for either the bore or the face.

(e) If the runout exceeds the maximum limits, remove the flywheel housing and check for dirt or foreign material, such as old gasket material, between the end plate, flywheel housing and the new gasket and between the end plate and the cylinder block).

**Service Manual** SM6-5-18.0 Flywheel Housing

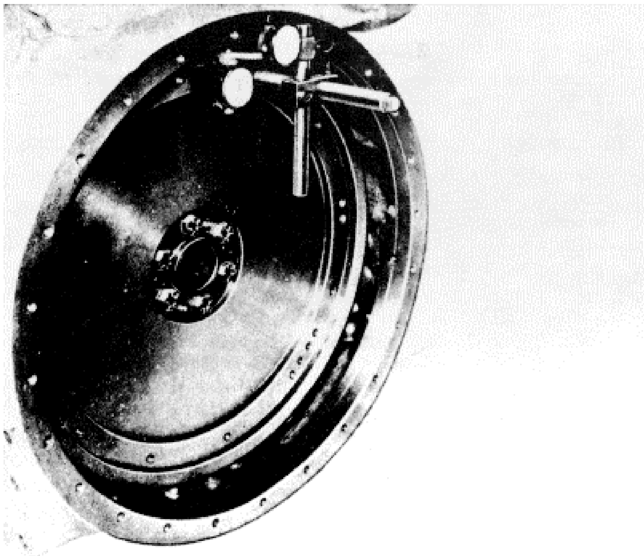

*Fig. 5*
*Checking Flywheel Housing Concentricity*

(f) Reinstall the flywheel housing and the flywheel and tighten the attaching bolts in the proper sequence and to the specified torque. Then recheck the runout. If necessary, replace the flywheel housing.

(13) Remove the bolts holding the lifter bracket to the flywheel housing. Affix a new gasket to the bracket, then alternately tighten the bracket-to-flywheel housing and bracket-to-cylinder head bolts, thus drawing the bracket into the corner formed by the cylinder head and housing (SM6-5-8.0).

(14) Install the oil pan (SM6-5-51.0).

(15) Remove the engine from the overhaul stand

6

**Service Manual** SM6-5-19.0 Piston and Piston Rings1 9.0 (Trunk-Type Piston) **SM6-5-9.0**

The trunk-type malleable Iron piston (Fig. 1) is plated with a protective coating of tin which permits close fitting, reduces scuffing and prolongs piston life. The top of the piston forms the combustion chamber bowl and is designed to compress the air into close proximity to the fuel spray. -

Each piston is internally braced with fin-shaped ribs and circular struts, scientifically designed to draw heat rapidly from the piston crown and transfer it to the lubricating oil spray to ensure better control of piston ring temperature.

The piston is cooled by a spray of lubricating oil directed at the underside of the piston head from a nozzle in the top of the connecting rod, by fresh air from the blower to the top of the piston and indirectly by the water jacket around the cylinder.

Each piston is balanced to close limits by machining a balancing rib, provided on the inside at the bottom of the piston skirt.

Two bushings, with helical grooved oil passages, are pressed into the piston to provide a bearing for the hardened, floating piston pin. After the piston pin has been installed, the hole in the piston at each end of the pin is sealed with a steel retainer. Thus lubricating oil returning from the sprayed underside of the piston head and working through the grooves in the piston pin bushings is prevented from reaching the cylinder walls.

Each piston is fitted with compression rings and oil control rings (Figs. 1 and 2). Equally spaced drilled holes just below each oil control ring groove permit excess oil, scraped from the cylinder walls, to return to the crankcase.

19.1 Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

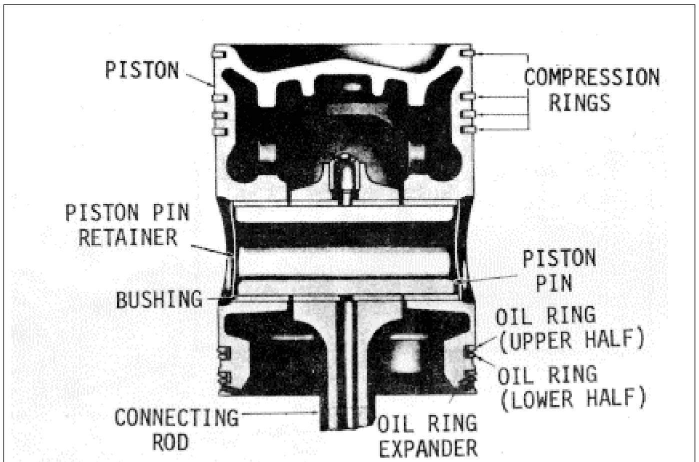


*Fig. 1*
*Typical Piston Assembly*


*Fig. 2*
*Comparison of Piston Ring Arrangements*

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Operator's Manual for the procedure for checking compression pressure. 6

19.2 Remove Piston and Connecting Rod

(1) Drain the cooling system.
(2) Drain the oil and remove the oil pan.
(3) Remove the oil pump and inlet and outlet pipes, if necessary (SM6-5-46.0).
(4) Remove the cylinder head (SM6-5-5.0).
(5) Remove the carbon deposits from the upper inner surface of the cylinder liner.
(6) Remove the bearing cap and the lower bearing shell from the connecting rod. Then push the piston and rod assembly out through the top of the cylinder block. The piston can not be removed from the bottom of the cylinder block.
(7) Reassemble the bearing cap and lower bearing shell to the connecting rod.

19.3 Disassemble Piston and Connecting Rod

Note the condition of the piston and rings. Then remove the rings and connecting rod from the piston as follows:

(1) Secure the connecting rod in a vise equipped with soft Jaws and remove the piston rings with tool J 8128 as shown in Fig. 3.
(2) Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushings.
(3) Withdraw the piston pin from the piston, then remove the connecting rod.
(4) Drive the remaining piston pin retainer out from the inside with a brass rod or other suitable tool.

**Service Manual** SM6-5-19.0 Piston and Piston Rings (Trunk-Type Piston)


*Fig. 3*
*Removing or Installing Piston Rings 19.4 Cleaning*

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Clean the piston components with fuel oil and dry them with compressed air. If fuel oil does not remove the carbon deposits, use a chemical solvent (Fig. 4) that will not harm the piston pin bushings or the tin-plate on the piston.

The upper part of the piston, including the compression ring lands and grooves, is not tinplated and may be wire-brushed to remove any hard carbon. However, use care to avoid damage to the tin-plating on the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston and the oil drain holes in the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

19.5 Inspection

If the tin-plate on the piston and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored pistons, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston for score marks, cracks, damaged ring groove lands or indications of overheating. A piston with light score marks which can be cleaned up may be reused (Fig. 5). Any piston that has been severely scored or overheated must be replaced. Indications of over- heating or burned spots on the piston may be the result of an obstruction in the connecting rod oil passage. Replace the piston if cracks are found across the internal struts.
Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston (refer to SM6-5-71.0 for specifications). Inspection of the connecting rod and piston pin are covered in SM6-5-20.0.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

Inspect and measure the piston pin bushings. The piston pin-to-bushing clearance with new parts is .0025" to .0034". A maximum clearance of .010" is allowable with worn parts. The piston pin bushings in the connecting rod are covered in SM6-5-20.0.

When replacing worn parts (pistons, rings, etc.), refer to the parts catalog or microfiche to select the current parts for the particular engine being serviced.

19.6 Remove Bushings From Piston

Remove the piston pin bushings with tool set J 1513-02 as follows:

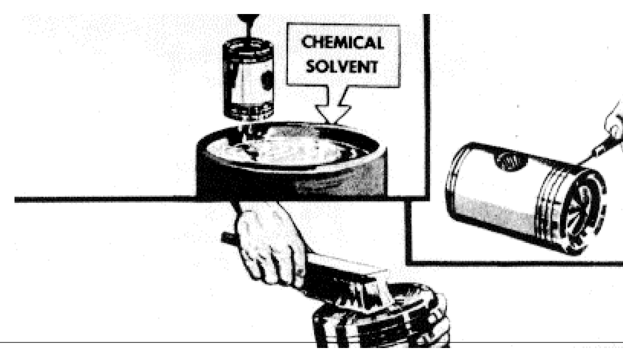


*Fig. 4*
*Cleaning Piston*


*Fig.5*
*Comparison of Used Pistons*

(1) Place the piston in the holding fixture J 1513-1 so that the bushing bores are in alignment with the hole in the fixture base.
(2) Drive each bushing from the piston with bushing remover J 1513-3 and handle J 1513-2 (Fig.6).

19.7 Install Bushings in Piston

(1) Place the spacer J 1513-4 in the hole in the fixture J 1513-1.
(2) Place the piston on the fixture so that the spacer protrudes into the bushing bore.
(3) Insert the installer J 1513-6 in a bushing, then position the bushing and installer over the lower bushing bore.

Note: Locate the joint in the bushing toward the bottom of the piston (Fig.7).

(4) Insert the handle J 1513-2 in the bushing installer and drive the bushing in until it bottoms on the spacer.
(5) Install the second bushing in the same manner.
(6) The bushings must withstand an end load of 1800 pounds (8. 007 kN) without moving after installation.
(7) Ream the bushings to size using tool set J 3071-01, as follows:
  (a) Clamp the reaming fixture J 5273 in a vise (Fig.8).Then insert the guide bushing J 3071-7 in the fixture and secure it with the set screw.
  (b) Place the piston in the fixture and insert the pilot end of the reamer J 3071-6 through the clamping bar, bushings and into the guide bushing.
  (c) With the piston, fixture and reamer in alignment, tighten the wing nuts securely.
  (d) Ream the bushings (Fig.8).Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.
  (e) Withdraw the reamer and remove the piston from the fixture. Blow out the chips and measure the inside diameter of the bushings. The diameter must be 1.5025" to 1.5030".

19.8 Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70°F or 21°C).The taper and out-of-round must not exceed . 0005".Refer to SM6-5-71.0 for piston diameter specifications.

A new (long port) cylinder liner has an inside diameter of 4.2495" to 4.2511".A maximum clearance of .012" is allowable with use parts.

With the cylinder liner installed in the cylinder block, hold the piston upside down in the liner and check the clearance in four places 900 apart (Fig.9).

Use feeler gauge set J 5438-01 to check the clearance. The spring scale, attached to the proper feeler gauge, is used to measure the force in pounds required to withdraw the feeler gauge.

Select a feeler gauge with a thickness that will require a pull of six pounds (26. 7 N) to remove. The clearance will be . 001" greater than the thickness of the feeler gauge used, i.e., a .004" feeler gauge will indicate a clearance of .005" when it is withdrawn with a pull of six pounds (26.7 N).The feeler gauge must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

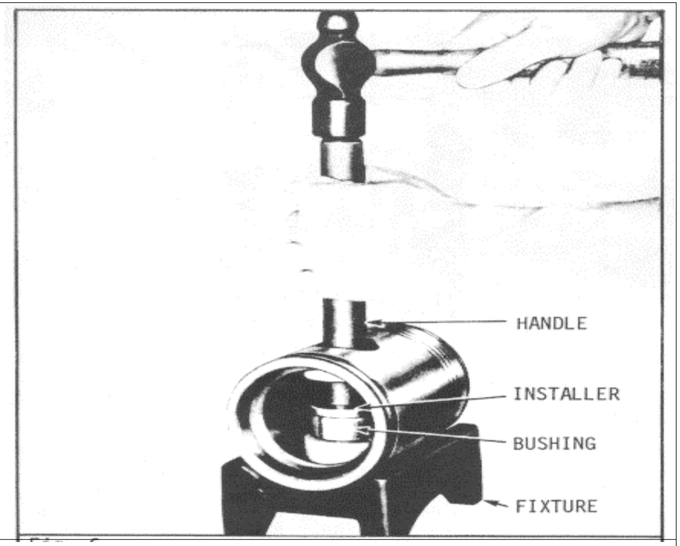


*Fig.6*
*Removing or Installing Piston Pin Bushings in Piston*

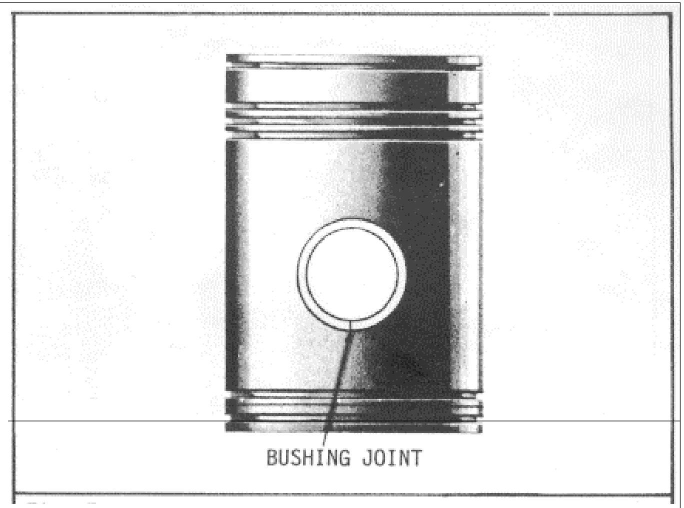


*Fig. 7*
*Location of Joint in Piston Pin Bushings for Piston*

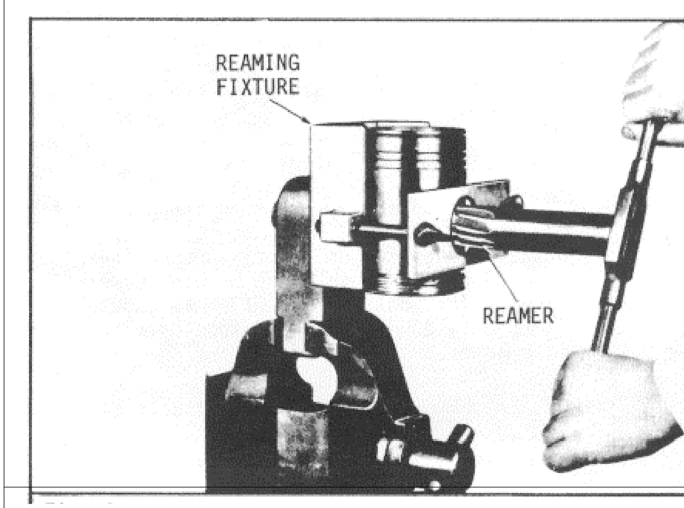


*Fig. 8*
*Reaming Bushings in Piston*

19.9 Fitting Piston Rings

The fire rings can be identified by the black oxide or copper color on the top and bottom. The prestressed fire ring is further identified by a small indentation on the top side of the ring near the gap.

A prestressed compression ring, also identified by the indentation mark, is also used in the ring groove immediately below the fire ring.

A two-piece oil control ring is used in both oil ring grooves in the pistons for non turbocharged (naturally aspirated) engines.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder lines is installed. Refer to the parts catalog or microfiche to select the current piston rings for a particular engine.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston to push the ring down to be sure it is parallel with the top of the liner. Then measure the ring gap with a feeler gauge as shown in Fig.10.Refer to SM6-5-71. 0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filling or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately . 015".

Check the ring side clearance as shown in Fig. 11.Ring side clearances are specified in SM6-5-71.0.

19.10 Install Piston Rings

Before installing the piston rings, assemble the piston and rod as outlined under Assemble Connecting Rod to Piston in SM6-5-20. 0.Then refer to Figs.1 and 12 and install the piston rings. Note: Lubricate the piston rings and piston with engine oil before installing the rings.

**Service Manual**

## SM6-5-19.0 Piston and Piston Rings (Trunk-Type Piston)

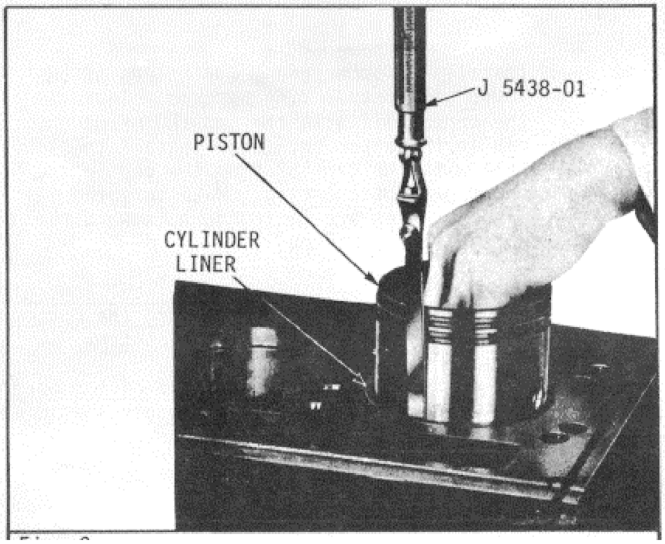


*Fig. 9*
*Measuring Piston-to-Liner Clearance*

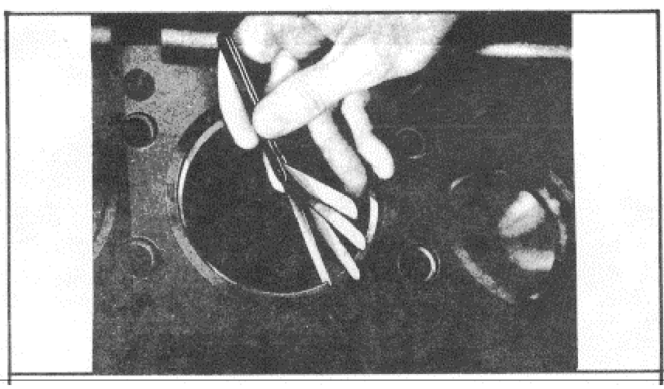

*Fig.10*
*Measuring Piston Ring Gap*

### Compression Rings

(1) Starting with the bottom ring, install the compression rings with tool J 8128 as shown in Fig.3.To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston.

Note: When installing the fire ring (top groove) and the top compression ring (second groove), be sure the oval marks are toward the top of the piston.

(2) Stagger the ring gaps around the piston.

### Oil Control Rings

The upper and lower oil control rings used on pistons for non-turbocharged engines consist of two halves (upper and lower).Peripheral abutment type oil ring expanders (Fig.13) are used on 71N engines. Install the oil control rings as follows:

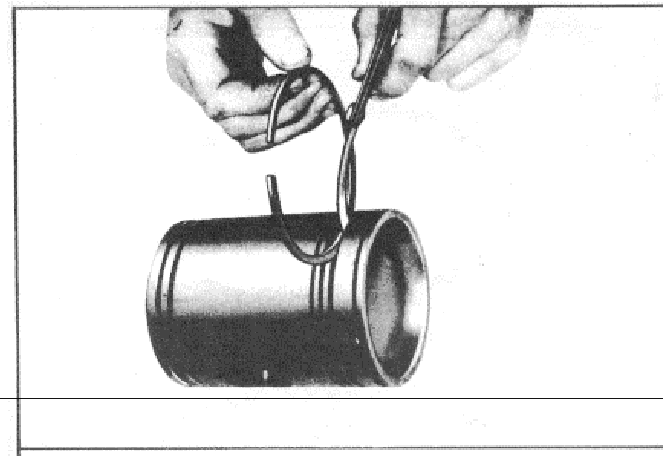

*Fig.11*
*Measuring Piston Ring Side Clearance*

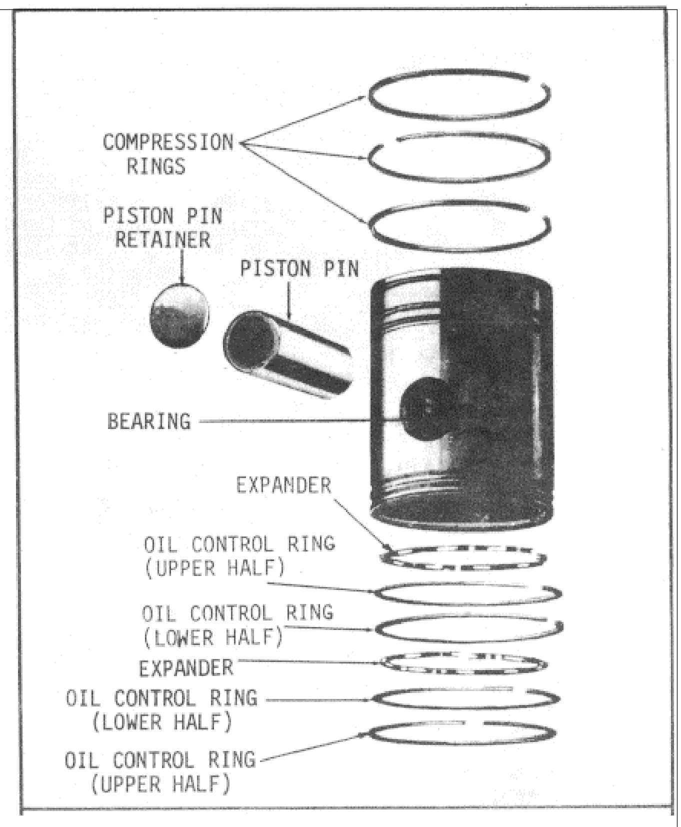


*Fig.12*
*Typical Piston, Piston Rings, Pin and Relative Location of Parts*

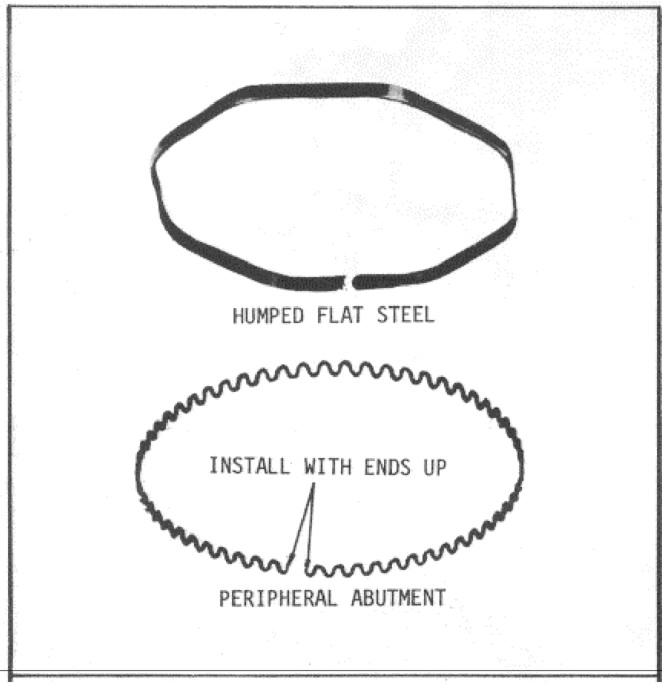


*Fig. 13*
*Oil Control Ring Expanders*

(1) Install the ring expanders in the oil control ring grooves in the piston.

Note: When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

Important: When peripheral abutment type ring expanders (Fig.13) are used, install them with the legs of the free ends toward the top of the piston. With the free ends pointing up, a noticeable resistance will be encountered during installation of the piston if the ends of the expander are overlapped and corrective action can be taken before ring breakage occurs.

(2) To install the ring, position it over the upper ring groove, using tool J 8128, with the gap 1800 from the gap in the expander and the scraper edge facing down. Press the ring against the gap side of the expander to prevent the ends of the expander from overlapping, then align the ring with the groove and release the tension on the tool, permitting the ring to slip in position.

Install the upper and lower halves of the lower oil control ring by hand. Install the upper half with the gap 180° from the gap in the expander. Then install the lower half with the gap 450 from the gap in the upper half of the ring. Make sure the scraper edges are facing down (toward the bottom of the piston).

Note: The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

Note: The face of the top half of the upper oil control ring used on 71N engines is chrome plated, Each connecting rod (Figs.1 and 2) is forged to an "I" section with a closed hub at the upper end and a bearing cap at the lower end. The connecting rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with a nozzle to spray cooling oil to the underside of the piston head. An orifice is pressed into a counterbore at the lower end of the oil passage to meter the 'flow of oil.

A helically-grooved bushing is pressed into each side of the connecting rod at the upper end. The cavity between the inner ends of these bushings registers with the drilled oil passage in the connecting rod and forms a duct around the piston pin. Oil entering this cavity lubricates the piston pin bushings and is then forced out the spray nozzle to cool the piston. The piston pin floats in the bushings of both the piston and the connecting rod.

A service connecting rod includes the bearing cap, bolts, nuts, spray nozzle, orifice and the piston pin bushings pressed in place and bored to size.

The replaceable connecting rod bearing shells are covered in SM6-5-21.0.

20.1 Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined in SM6-5-19.0.

20.2 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

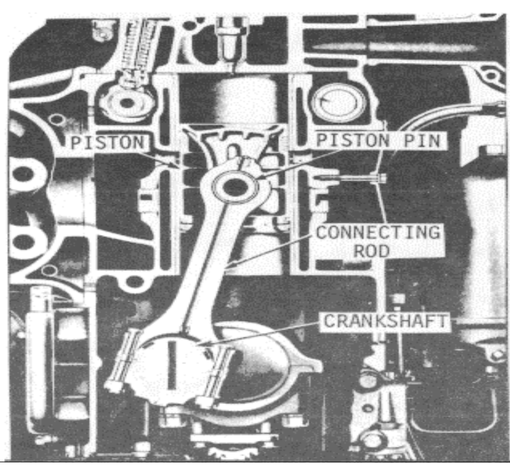


*Fig. 1*
*Connecting Rod Mounting*

Clean the connecting rod and piston pin with a suitable solvent and dry them with compressed air. Blow compressed air through the drilled oil passage in the connecting rod to be sure the orifice, oil passage and spray holes are not clogged.

Visually check the connecting rod for twist or bending. Check for cracks (Fig.3) by the magnetic particle method outlined in SM6-5-10.0 under Crankshaft Inspection.

Remove any nicks or burrs from the connecting rod bolt holes with reamer J 28460 (Fig.4). The reamer includes a 60° angle to clean-up the chamfer at the bolt hole to ensure proper seating of the underside of the bolt head.

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to SM6-5-22. 0).

Important: Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure the orifice, oil passage and spray holes are not clogged. Also make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting6 bearing shell "crush".

Check the connecting rod bushings for indications - of scoring, overheating or other damage. Bushings that have overheated may become loose and creep together, thus blocking off the supply of lubricating oil to the piston pin, bushings and spray nozzle.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear.

Since it is subjected to downward loading only, free movement of the piston pin is desired to secure perfect alignment and uniform wear. Therefore, the piston pin is assembled with a full floating fit in the connecting rod and piston bushings, with relatively large clearances. Worn piston pin clearances up to .010"are satisfactory.

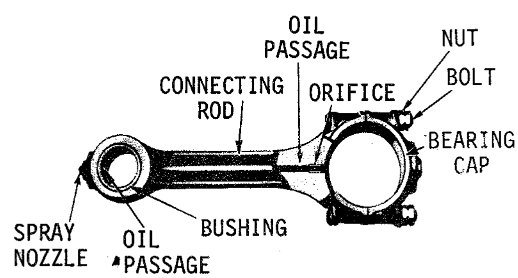


*Fig. 2*
*Connecting Rod Assembly*

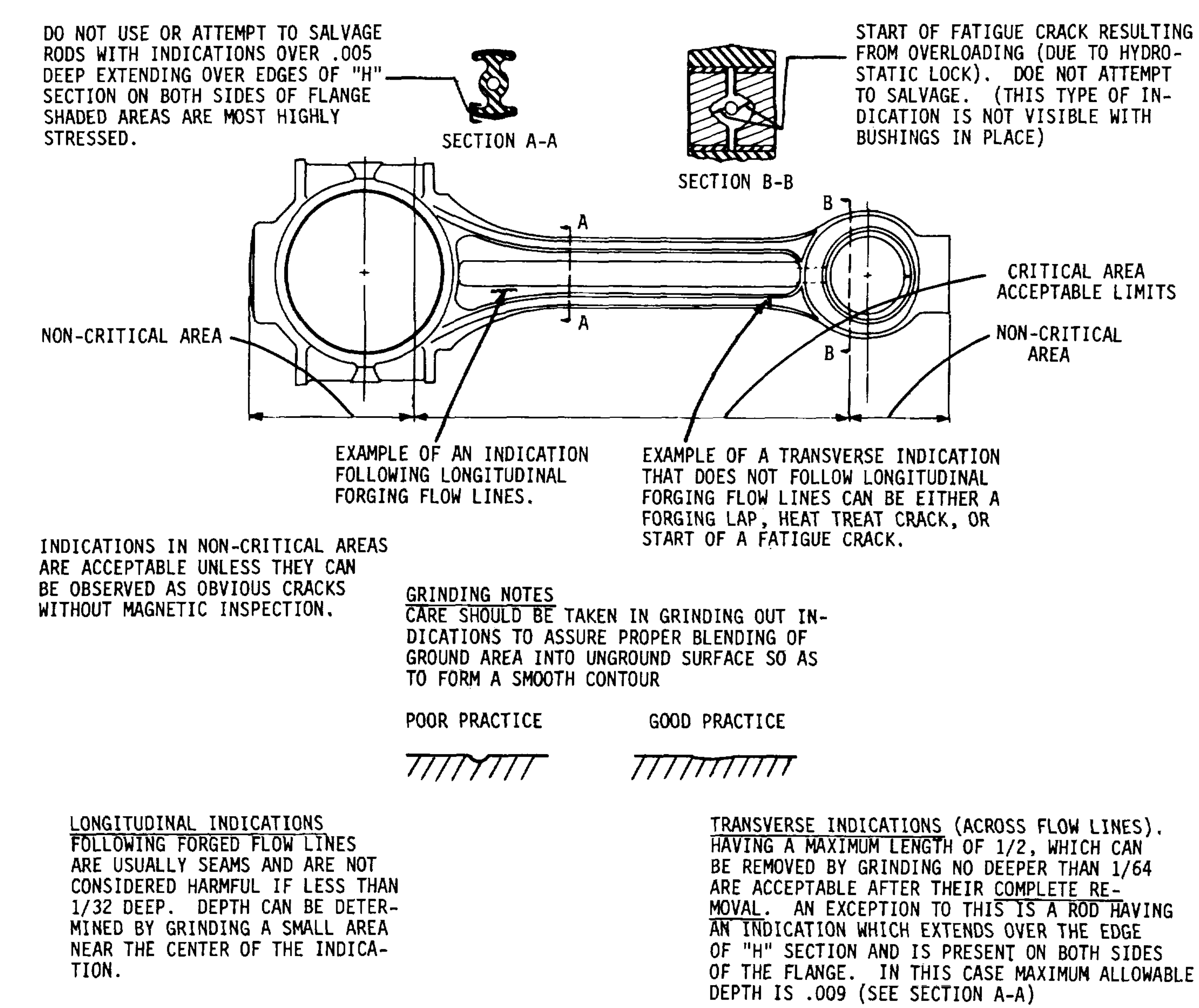


*Fig.3*
*Magnetic Particle Inspection Limits For Connecting Roc*

20.3 Remove Bushings

If it is necessary to replace the connecting rod bushings, remove them as follows:

(1) Clamp the upper end of the connecting rod in holder J 7632 (Fig.5) so that the bore in the bushings is aligned with the hole in the base of the holder.

(2) Place the bushing remover J 1513-3 in the connecting rod bushing, insert handle J 1513-2 in the remover and drive the bushings from the rod.

20.4 Replace Spray Nozzle and Orifice

The connecting rod bushings must be removed before the spray nozzle or orifice can be replaced. Replace the spray nozzle as follows:

(1) Remove the connecting rod bushings.

(2) Insert spray nozzle remover J 8995 through the upper end of the connecting rod and insert the pin, in the curved side of the tool,

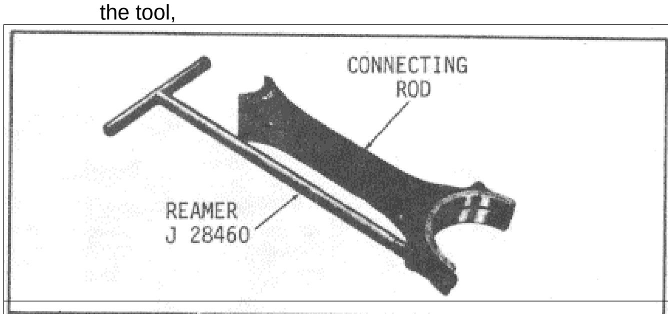


*Fig. 4*
*Connecting Rod Bolt Hole Reamer*

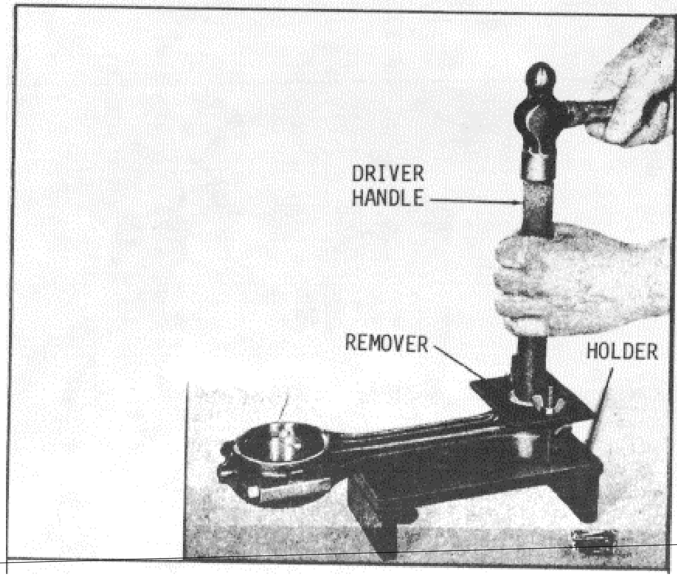


*Fig. 5*
*Removing or Installing Bushings*

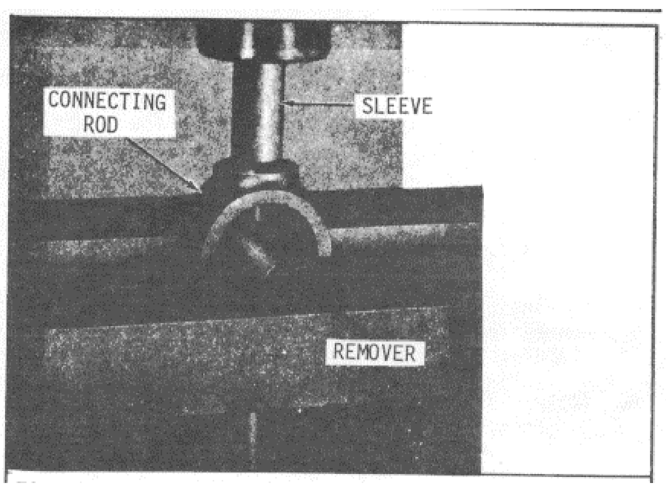


*Fig. 6*
*Removing Spray Nozzle*

in the opening in the bottom of the spray nozzle.

(3) Support the connecting rod and tool in an arbor press as shown in Fig.6.

(4) Place a short sleeve directly over the spray nozzle. Then press the nozzle out of the connecting rod.

(5) Remove the tool.

The steel bushing-type orifice in the lower end of the drilled passage can be replaced, if necessary, at this time.
With the spray nozzle removed, insert a rod in the oil passage and drive the orifice from the lower end of the connecting rod. Install the current steel bushing-type orifice .3125" in from the lower surface of the rod. When installing a service spring pin type orifice, drive it in .200" from the lower surface of the rod.

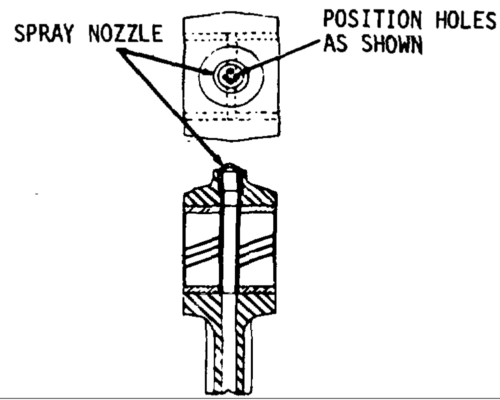


*Fig. 7*
*Position of Spray Nozzle Holes*

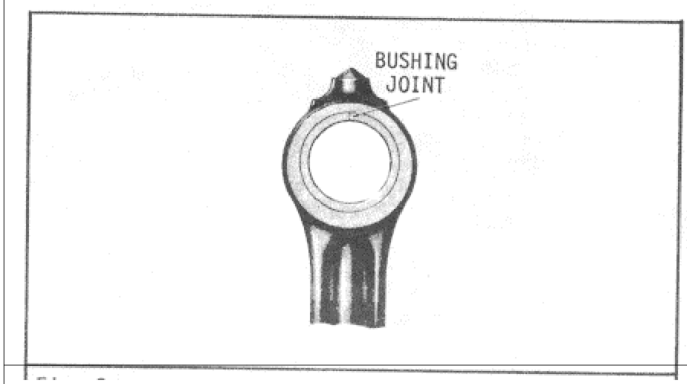


*Fig. 8*
*Location of Bushing Joint*

Install a new spray nozzle in the connecting rod
as follows:

(1) Start the new spray nozzle, with the holes positioned as shown in Fig.7, straight into the counterbore in the connecting rod.

(2) Support the connecting rod in the arbor press, place a short 3/8" I. D. sleeve on top of the nozzle and press the nozzle into the connecting rod until it bottoms in the counterbore.

(3) Install new bushings in the connecting rod.

20.5 Install Bushings

A .812" long bushing is serviced for the connecting rod assembly.

Install connecting rod bushings as follows:

(1) Clamp the upper end of the connecting rod assembly in holder J 7632 so that the bore for the bushings aligns with the hole in the base of the tool (Fig.5).

(2) Start a new bushing straight into the bore of the connecting rod, with the bushing joint at the top of the rod (Fig.8).

(3) Insert installer J 1513-6 in the bushing, then insert handle J 1513-2 in the installer and drive the bushing in until the flange of the installer bottoms on the connecting rod.

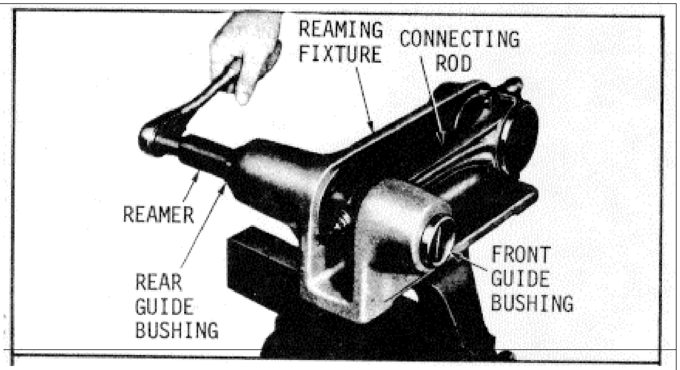


*Fig. 9*
*Reaming Bushings*

(4) Turn the connecting rod over in the holder and install the second bushing in the same manner.

(5) The bushings must withstand an end load of 2000 pounds (8. 896 kN) without moving after installation.

(6) Ream the bushings to size, using tool set J 1686-03, as follows:

(a) Clamp reaming fixture J 1686-9 in a bench vise.

(b) Place the crankshaft end of the connecting rod on the arbor of the fixture (Fig.9) and tighten the connecting rod cap nuts to 60-70 ft-lbs (81-95 Nm) torque.

(c) Slide the front guide bushing J 1686-11 (with the pin end facing out) in the fixture.

(d) Align the upper end of the connecting rod with the hole in the reaming fixture.

(e) Install the rear guide bushing J 1686-5 on reamer J 1686-20, then slide the reamer and bushing into the fixture.

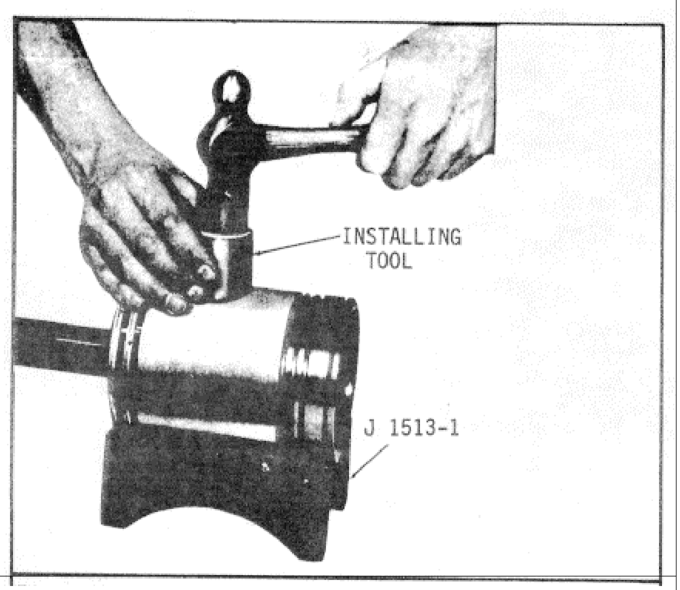


*Fig. 10*
*Installing Piston Pin Retainer*

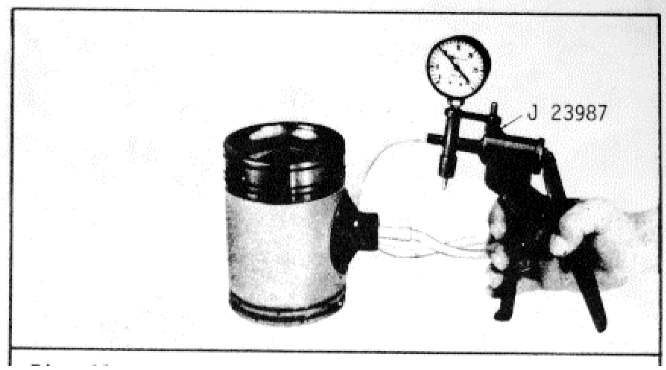


*Fig.11*
*Checking Piston Pin Retainer for Proper Sealing*

(f) Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

(g) Remove the reamer and the connecting rod from the fixture, blow out the chips and measure the inside diameter of the bushings. The inside diameter of the bushings must be 1.5025" to 1.5030".This will provide a piston pin-to-bushing clearance of .0025" to .0034" with a new piston pin. A new piston pin has a diameter of 1. 4996" to 1. 5000".

20.6 Assemble Connecting Rod to Piston

Apply clean engine oil to the piston pin and bushings. Refer to Fig.2 and assemble the connecting rod to the piston as follows:

(1) Place the piston in the holding fixture (Fig.10).

(2) Place a new piston pin retainer in position. Then place the crowned end of installer J 24107-01 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston.

Note: <u>Do not drive the-retainer in too far or the piston bushing may be moved inward and result in reduced piston pin end clearance.</u>

(3) Place the upper end of the connecting rod between the piston pin bosses and in line with the piston pin holes. Then slide the piston pin in place If the piston pin-to-bushing clearances are within the specified limits, the pin will slip into place without use of force.

(4) Install the second piston pin retainer as outlined in Steps 1 and 2.

(5) After the piston pin retainers have been installed, check for piston pin end clearance by cocking the connecting rod and shifting the pin in its bushings.

(6) One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushings, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987 (Fig.11).Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gauge. A drop in the gauge reading indicates air leakage at the retainer.

(7) Install the piston rings on the piston as outlined in SM6-5-20.0.

(8) Install the piston and connecting rod assembly in the engine as outlined in SM6-5-22.0.

The connecting rod bearing shells (Fig.1) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell is grooved midway between the bearing edges, part way up from each parting line, with an oil hole *through the shell at the termination of each groove. The lower bearing shell has a continuous oil groove, extending from one parting line to the other, in line with that of the upper bearing shell. These grooves maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings and spray nozzle through the oil passage in the connecting rod.

21.1 Remove Bearing Shells

The connecting rod bearing caps are numbered 1, 2, 3, etc., with matching numbers stamped on the connecting rod. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

Remove the connecting rod bearing as follows:

(1) Drain the oil and remove the oil pan.

(2) Remove the lubricating oil pump and the pump inlet and outlet pipes.

Note: <u>If shims are used between the oil pump body and the main bearing caps, save the shims so they may be reinstalled when installing the oil pump.</u>

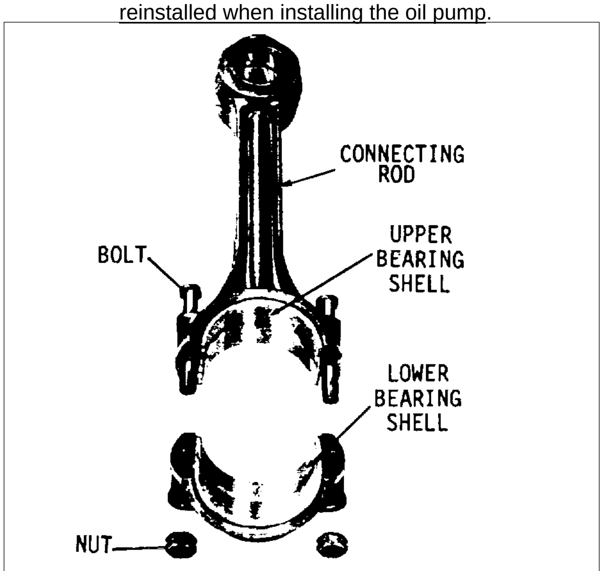


*Fig. 1*
*Connecting Rod and Bearing Shells*

| Bearing Size | *New Bearing Thickness | Minimum Worn Thickness |
|---|---|---|
| Standard | .1 548"/.1553" | .1530" |
| .002" Undersize | .1558"/.1563" | .1540" |
| .010" Undersize | .1598"/.1603" | .1580" |
| .020" Undersize | .1648"/.1653" | .1630" |
| .030" Undersize | .1698"/.1703" | .1680" |

*Thickness 900 from parting line of bearing.

*Table 1*

(3) Remove one connecting rod bearing cap. Push the piston and rod assembly up into the cylinder liner far enough to permit removal of the upper bearing shell. Do not pound on the edge of the bearing shell with a sharp tool.

(4) Inspect the upper and lower bearing shells as outlined under Inspection.

(5) Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

21.2 Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, chipping, cracking, loss of babbitt or signs of over-heating. If any of these defects are present, the bearings must be discarded. However, bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are NOT detrimental to this type of bearing. The bearings should not be replaced for these minor surface imperfections. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been shifting in their supports. If such spots are present, discard the bearing shells. Also inspect the connecting rod bearing bore for burrs, foreign particles, etc.

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under Inspection in SM6-5-12.0. The minimum thickness of a worn standard connecting rod bearing shell should not be less than . 1530" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1548" to 1553".Refer to Table i.

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to Shop Notes in SM6-5-31. 0).The maximum connecting rod bearing-to-journal clearance with used parts is .006".

Before installing the bearings, inspect the crankshaft journals (refer to Inspection in SM6-5-10.0).

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .010", . 020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to Crankshaft Grinding in SM6-5-10. 0. Bearings which are . 002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

**CAUTION**

Bearing Shells Are NOT Reworkable From One Undersize To Another Under Any Circumstances.

21.3 Install Connecting Rod Bearing Shells

With the crankshaft and the piston and connecting rod assembly in place, install the connecting rod bearings as follows:

(1) Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then wipe the journal clean and lubricate it with clean engine oil.
(2) Install the upper bearing shell -- the one with the short groove and oil hole at each parting line -- in the connecting rod. Be sure the tang on the bearing shell fits in the groove in the connecting rod.
(3) Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.
(4) Note the numbers stamped on the connecting rod and the bearing cap and install the lower bearing shell -- the one with the continuous oil groove -- in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.
(5) Install the bearing and cap and tighten the connecting rod bolt nuts to 60-70 ft-lbs (81-95 Nm) torque (lubrite nut) or 65-75 ft-lbs (88-102 Nm) torque (castellated nut).
(6) Install the lubricating oil pump and the oil inlet and outlet pipes.

Note: <u>If shims were used between the oil pup body and the main bearing caps, install the shims in exactly the same location from which they were removed</u>.

(7) Install the oil pan, using a new gasket.
(8) Refer to the Lubricating Oil Specifications in Operator's Manual and fill the crankcase to the proper level on the dipstick. If new bearings were installed, operate the engine on the run-in schedule as outlined in SM6-5-67.0.

The replaceable type cylinder liner (Fig.1) is accurately machined and heat treated to provide a long wearing scuff-resistant surface. The flange at the top fits into a counterbore in the cylinder block and rests on a replaceable cast iron insert which permits accurate alignment of the cylinder liner.

A long-oval port cylinder liner (Fig.2) is used with pistons equipped with three compression rings and afire ring (top ring groove).

Note: Do not use the short-oval port liners in an engine requiring long-oval port liners.

The liner is cooled by means of a water jacket in the cylinder block and by the scavenging air introduced into the cylinder through the air inlet ports around the liner (Figs.1 and 2).The air inlet ports are machined at an angle to create a uniform swirling motion to the air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

The wear on a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaners must be serviced regularly according to the surroundings in which the engine is operating.

22.1 Remove Cylinder Liner

It is very important that the proper method is followed when removing a cylinder liner. Do not

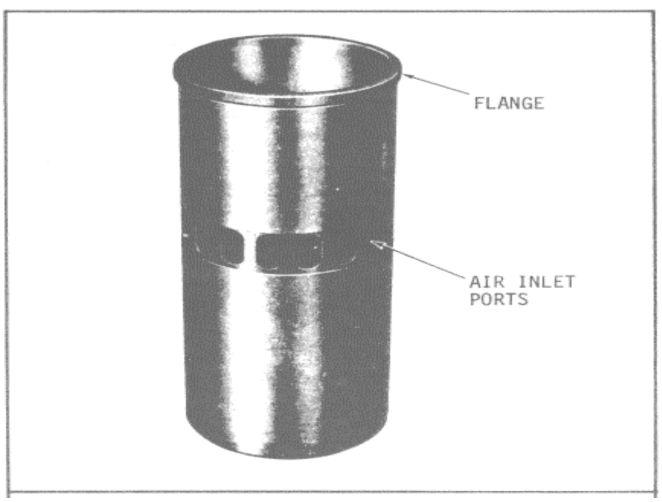


*Fig. 1*
*Typical Cylinder Liner*

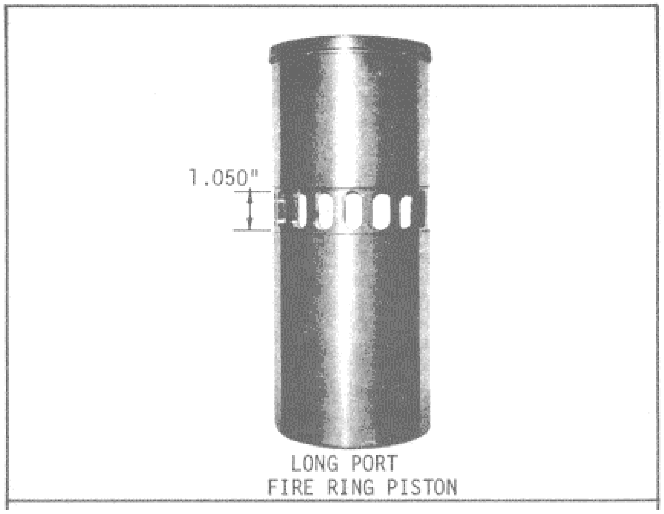


*Fig. 2*
*Cylinder Liner*

attempt to push the liner out by inserting a bar in the liner ports and rotating the crankshaft, otherwise the piston may be damaged or the upper ring groove may collapse.

Remove a cylinder liner from the block as follows:

(1) Remove the piston and connecting rod assembly -as outlined in SM6-5-19. 0.

(2) Remove the cylinder liner with tool J 1918-02 as follows:

  (a) Slip the lower puller clamp up on the puller rod and off the tapered seat. Cock the clamp so it will slide down through the liner. The clamp will drop back on the tapered seat after it clears the bottom of the liner. Then slide the upper puller clamp down against the top edge of the liner.

  (b) With the tool in place, strike the upset head on the upper end of the puller rod a sharp blow with the puller weight, thus releasing the liner (Fig.3).

  (c) Remove the tool from the liner. Then remove the liner from the block.

  (d) Remove the liner insert and shims (if used) from the counterbore in the block.

  (e) Tag the liner, insert and shims. If tool J 1918-02 is unavailable, tap the liner out with a hardwood block and hammer.

22.2 Inspect Used Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for:

Cracks
Scoring
Poor contact on outer surface
Flange irregularities
Inside diameter
Outside diameter
Out-of-round
Taper

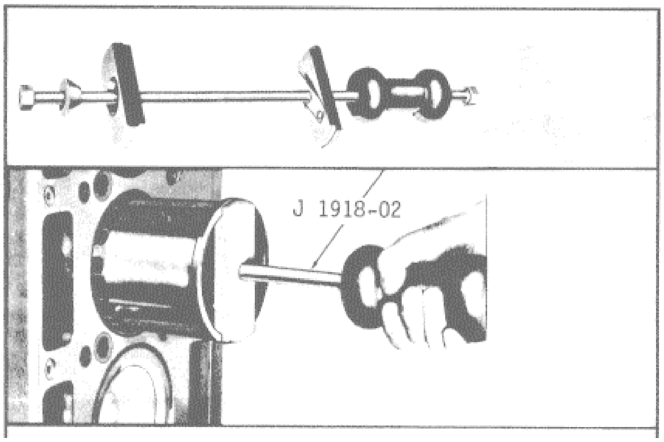


*Fig. 3*
*Removing Cylinder Liner*

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned up and reused.

Excessive liner-to-block clearance or block bore distortion will reduce heat transfer from the liner to the block and to the engine coolant. Poor contact between the liner and the block bore may be indicated by stains or low pressure areas on the outer surface of the liner (Fig.4).

Examine the outside diameter of the liner for fretting. Fretting is the result of a slight movement of the liner in the block bore during engine operation, which causes material from the block to adhere to the liner. These metal particles may be removed from the surface of the liner with a coarse, flat stone.

The liner flange must be smooth and flat on both the top and bottom surfaces. Check for cracks at the flange. The liner insert must also be smooth and flat on the top and bottom surfaces. Replace the insert if there is evidence of brinelling.

A used cylinder liner must be honed for the following reasons:

Note: Do not modify the surface finish in a new service liner. Since the liner is properly finished at the factory, any change will adversely affect seating of the piston rings.

(1) Break the glaze (Fig.5) due to the rubbing action of the piston rings which results after long periods of operation. Unless this glaze is removed, the time required to seat new piston rings will be lengthened.

(2) Remove the ridge (Fig.6) formed at the top by the piston ring travel. Otherwise, interference with the travel of the new compression rings may result in ring breakage.

Therefore, even though the taper and out-of-round are within the specified limits, the glaze and ridge must be removed by working a hone up and down the full length of the liner a few times.

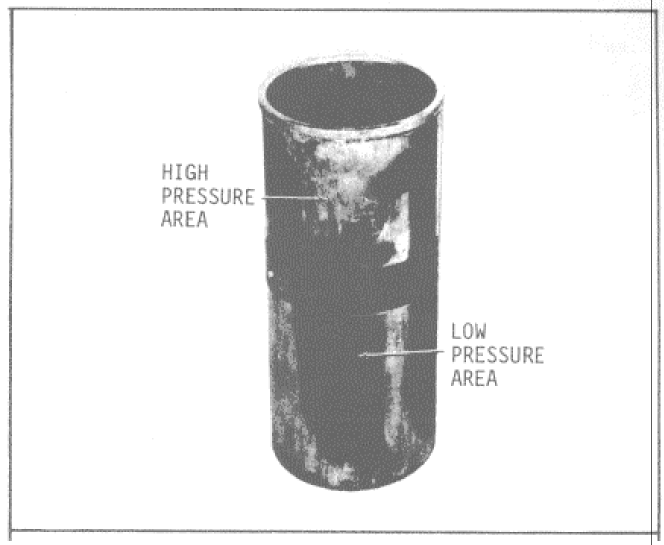


*Fig. 4*
*High and Low Pressure Contact Areas on Cylinder Liner*

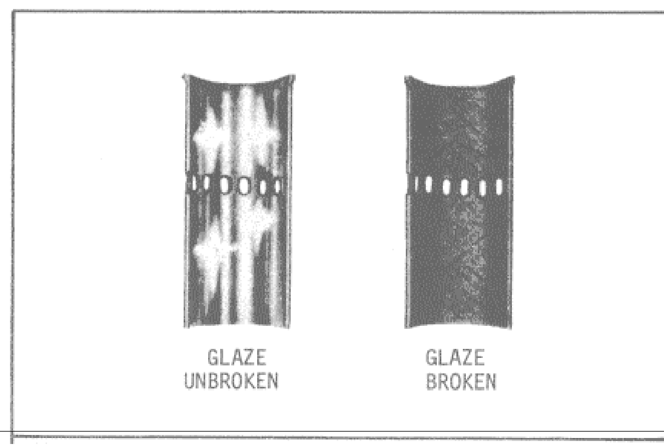


*Fig. 5*
*Glazed Surface of Cylinder Liner*

Place the liner in a fixture (a scrap cylinder block makes an excellent honing fixture). However, if it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

The hone J 5902-01, equipped with 120 grit stones J 5902-14, should be worked up and down the full length of the liner a few times in a criss-cross pattern that produces hone marks on a $45^{\circ}$ axis.

After the liner has been honed, remove it from the fixture and clean it thoroughly. Then dry it with compressed air and check the entire surface for burrs.

After honing, the liner must conform to the same limits on taper and out-of-round as a new liner and the piston-to-liner clearance must be within the specified limits (SM6-5- 71.0).

22.3 Liner Measurements

Measure the block bore and the outside diameter of the liner. If the liner-to-block clearance (with used parts) exceeds .0025" it will be necessary to bore the block for an oversize liner as outlined in SM6-5-2.0.

Install the liner in the proper the liner for taper and out-of-round. It is bore of the cylinder block. Measure the inside diameter of the liner at the various points shown in Fig. 7. Use cylinder bore gauge J 5347-01, which has a dial indicator calibrated in .0001" increments. Set the cylinder bore gauge on zero in master ring gauge J 5580-1. Also check not necessary to measure the inside diameter or taper of a new liner.

Note: Dial bore gauge master setting fixture J 23059-01 may be used in place of the master ring gauge.

The piston-liner clearance must be within the specified limits (SM6-5- 71.0). Also, the taper must not exceed .002" and the out-of-round must not exceed .0025" on a used liner. If the out-of-round exceeds .0025", rotate the liner 900 in the block bore and recheck.

New service liners, standard and oversize, have an inside diameter of 4.2495" to 4.2511" (long port liner).

Cylinder liners are available in .001", .005", .010", .020" and .030" oversize on the outside diameter. When an oversize liner is installed, stamp the amount of oversize on top of the cylinder bore adjacent to the liner counterbore.

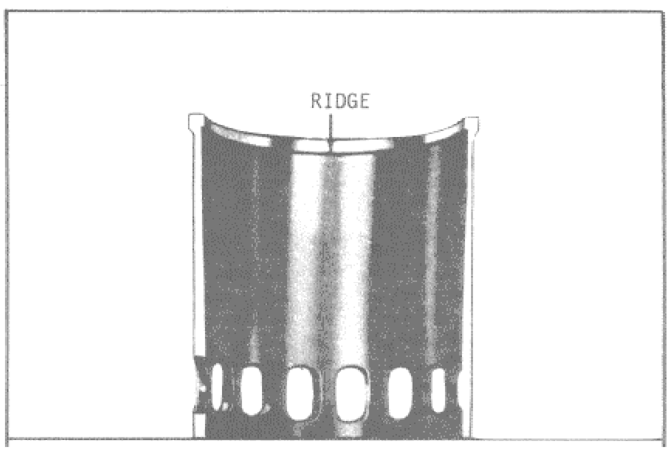


*Fig. 6 Cylinder Liner Ridge Due to Wear*

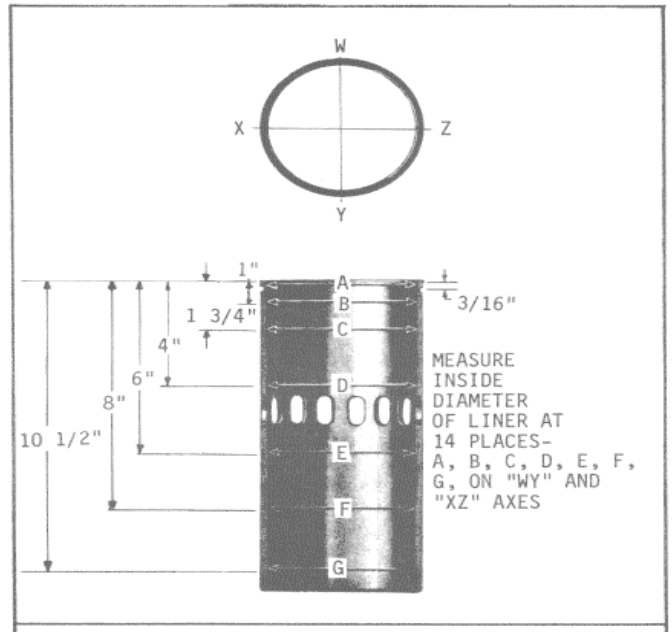


*Fig. 7 Cylinder Liner Measurement Diagram*

22.4 Selection of New Cylinder Liner

The cylinder bores in a new cylinder block are classified as #1, #2 or #3 (Table 1) designating the specific size range for each bore and the appropriate cylinder liner that may be fitted to each bore. The classification number is stamped on the fire deck of the cylinder block adjacent to each cylinder bore.

A new standard size cylinder liner is also classified as #1, #2 or #3 as illustrated in Fig. 9 and Table 1.

Although the block bores and liners should be measured to determine the liner-to-block clearance, the selection of a liner is narrowed down to only those in the appropriate classifications or possibly a .001" oversize liner.

Before installing a liner in a used cylinder block, always lightly hone the block bore (refer to SM6-5-2.0).

After honing the block bore, check the bore measurements to determine if a standard liner (classification #1, #2 or #3) or possibly a .001" oversize liner can be used (refer to Tables 1 and 2). A push fit between the liner and the block is desirable. If an adequate push fit cannot be obtained, it may be necessary to bore the block to receive an oversize liner.

When it becomes necessary to install an oversize liner, the same care in selective tolerance fitting must be adhered to. However, it may be

| New Cylinder Liner To New Cylinder Block Bore Fits | | | | |
|---|---|---|---|---|
| Classification Number Stamped Adjacent to Each Cyl. Bore | Cylinder Bore Classification Diameter (I.D.) | Standard Cylinder Liner Diameters and Liner-to-Block Clearances When Properly Matched | | |
| | | Liner (O.D.) Classification | Liner (O.D.) Diameter | Liner/Block Clearance |
| CAST IRON BLOCK | | | | |
| #0 | 4.6256"/4.6259" | #1 | 4.6250"/4.6255" | .0001"/.0009" |
| #1 | 4.6260"/4.6265" | #1<br>#2 | 4.6250"/4.6255"<br>4.6256"/4.6260" | .0005"/.0015"<br>.0000"/.0009" |
| #2 | 4.6266"/4.6270" | #2<br>#3 | 4.6256"/4.6260"<br>4.6261"/4.6265" | .0006"/.0014"<br>.0001"/.0009" |
| #3 | 4.6271"/4.6275" | #3 | 4.6261"/4.6265" | .0006"/.0014" |
| Metric | | | | |
| #0 | 117.490/117.498 mm | #1 | 117.475/117.488 mm | .002/.023 mm |
| #1 | 117.500/117.513 mm | #1<br>#2 | 117.475/117.488 mm<br>117.490/117.500 mm | .012/.038 mm<br>.000/.023 mm |
| #2 | 117.516/117.526 mm | #2<br>#3 | 117.490/117.500 mm<br>117.503/117.513 mm | .016/.036 mm<br>.003/.023 mm |
| #3 | 117.528/117,539 mm | #3 | 117.503/117.513 mm | .015/.036 mm |

more difficult to select an oversize liner since the size range is not broken down into classifications.

In deciding whether boring is necessary or not, keep in mind that each bore in a used block must not be out-of-round or tapered more than .002". If the average block bore is over 4.6285" (cast iron block) the cylinder block should be bored oversize.

To determine what size to rebore the cylinder block for an oversize liner, each service liner used must be measured on the outside diameter for size in three places (under the flange, between the flange and the ports, and above the ports). The cylinder bore size will be deter- mined by the average liner measurement taken at the three positions.

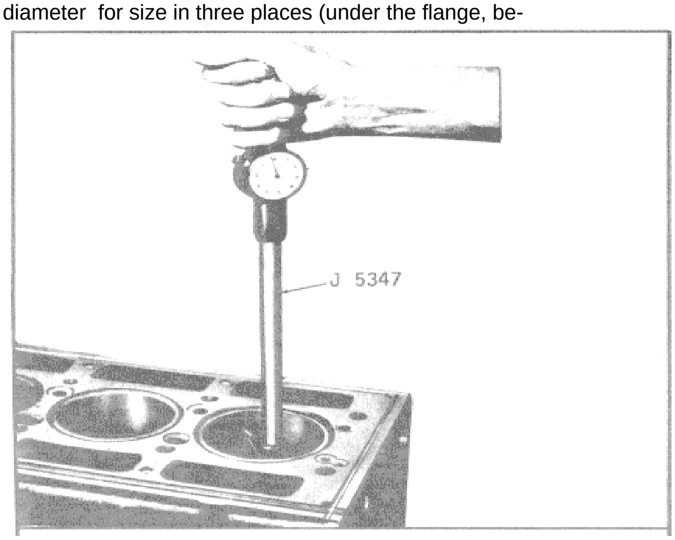


*Fig. 8 Checking Bore of Cylinder Line Using Tool J 5347-01*

EXAMPLE:

Service liner O.D. measures 4.6280".
O.D. size = 4.6280"
plus clearance = .0005"
bore size = 4.6285"

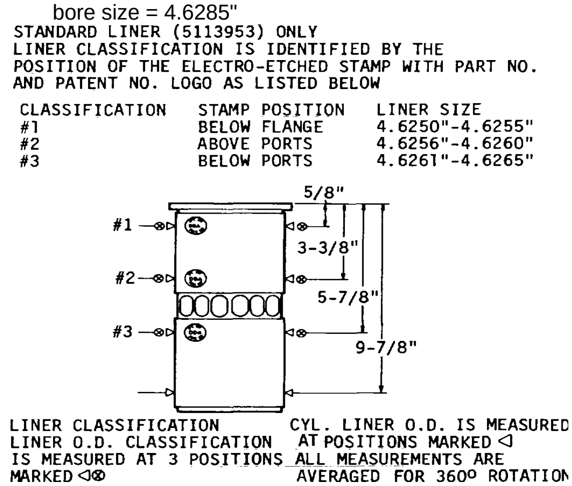


*Fig. 9 Cylinder Liner Classification*

| OVERSIZE SERVICE CYLINDER LINERS | | | |
|---|---|---|---|
| Service Liner Oversize | Liner Outside Diameter | | Liner/Block Clearance Req'd After Boring Block |
| | inches | mm | |
| .001" | 4.6280 | 117.551 | .0005"/.0015" |
| (.0254 mm) | 4.6265 | 117.513 | (.013/.038 mm) |
| .005 | 4.6315 | 117.640 | .0005"/.0015" |
| | 4.6300 | 117.602 | (.013/.038 mm) |
| .010" | 4.6365 | 117.767 | .0005"/.0015" |
| | 4.6350 | 117.729 | (.013/.038 mm) |
| .020" | 4.6465 | 118.021 | .0005"/.0015" |
| | 4.6450 | 117.983 | (.013/.038 mm) |
| .030" | 4.6565 | 118.275 | .0005"/.0015" |
| | 4.6550 | 118.237 | (.013/.038 mm) |

Then, 4.6285" + .001" boring tolerance will allow a bore size of 4.6285" to 4.6295" and a possible liner-to-block clearance of .0005" to .0015". The clearance tolerance is the dimensional difference between the liner O.D. and the block bore I.D.

22.5 Fitting Cylinder Liner in Block Bore

(1) Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean.

(2) Place a standard size cylinder liner insert (.1795"-.1800" thick) in the block counter- bore (Fig. 10).

(3) Push the cylinder liner into the cylinder block until the liner flange rests on the insert. Do not use excessive force to in- stall the liner. The liner should slide smoothly in place with hand pressure. If a new liner cannot be pushed in place, light honing of the block bore may be necessary to obtain the desired fit for best heat transfer.

(4) Install a cylinder liner hold-down clamp as illustrated in Fig. 11.

(5) Measure the distance from the top of the liner to the top of the block with a dial indicator (Fig. 11). The liner flange must be .045" to .050" below the surface of the block. However, even though all of the liners are within these specifications, there must not be over .002" difference in depth between any two adjacent liners when measured along the cylinder longitudinal center line.

Note: <u>A .002" thick shim is available for adjusting the liner height (in the current "high" block only). The shim must be in- stalled underneath the liner insert. Do not cut the shim for installation. Liner inserts which are .0015" thicker or thinner than standard are also available for service In addition, the .004" and .008" thinner inserts (also available in .0015" thicker and thinner sizes), which are provided for use with resurfaced cylinder blocks, can also be used to adjust the liner height.</u>

(6) Matchmark the liner and the cylinder block with a felt pen so the liner may be rein- stalled in the same position in the same block bore. The matchmarks should be toward the blower side of the engine.

(7) Remove the hold-down clamp and the cylinder liner.

Note: <u>Do not remove the liner insert</u>.

22.6 Install Piston and Connecting Rod Assembly

(1) With the piston assembled to the connecting rod and the piston rings in place as out- lined in SM6-5-19.0 and 6-5-20.0, apply clean engine oil to the piston rings and the inside surface of the piston ring compressor J 3272-03.

Note: Inspect the ring compressor for nicks or burrs, especially at the non-tapered in- side diameter end. Nicks or burrs on the inside diameter of the compressor will result in damage to the piston rings.

(2) Place the piston ring compressor on a wood block, with the tapered end of the ring compressor facing up.

(3) Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of the oil control ring expanders are not overlapped.

(4) Start the top of the piston straight into the ring compressor. Then push the piston down until it contacts the wood block ("Operation 1" of Fig. 12).

(5) Note the position of the matchmark and place the liner, with the flange end down, on the wood block.

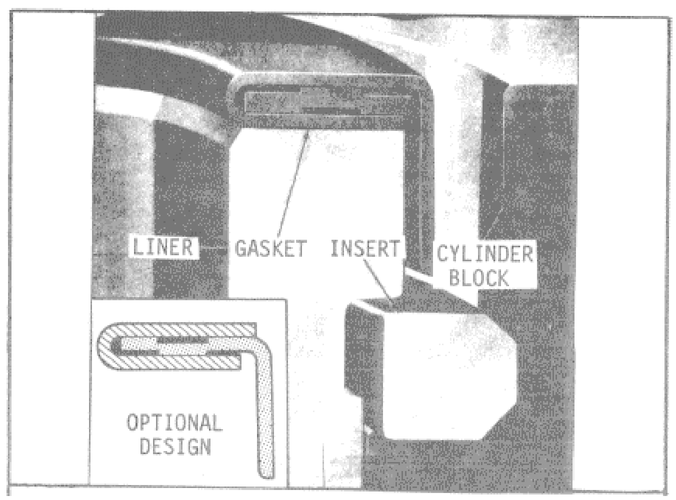


*Fig. 10 Cylinder Liner Mounting in Block*

(6) Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner ("Operation 2" of Fig. 12).
Note: The numbers on the side of the connecting rod and cap (Fig. 13) identify the rod with the cap and Indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification numbers must be stamped in the same location as on the connecting rod that was replaced.

(7) Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.
Note: Do not force the piston into the liner. The peripheral abutment type expanders apply considerably more force on the oil ring than the standard expander. There- fore, extra care must be taken during the loading operation to preventing breakage.

(8) Remove the connecting rod cap and the ring compressor. Then push the piston down until the compression rings pass the cylinder liner ports.

22.7 Install Cylinder Liner, Piston and Connecting Rod Assembly
After the piston and connecting rod assembly have been installed in the cylinder liner, in- stall the entire assembly in the engine as follows:

(1) If any of the pistons and liners are already in the engine, use hold-down clamps to retain the liners in place when the crankshaft is rotated.

(2) Rotate the crankshaft until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel. Wipe the journal clean and lubricate it with clean engine oil.

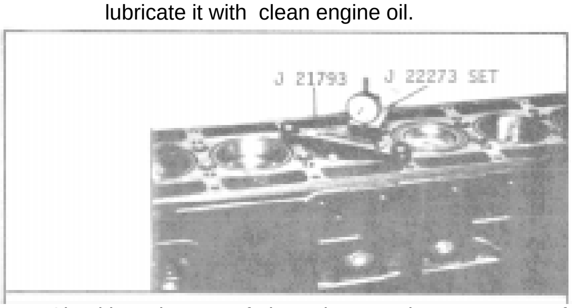


*Fig . 11 Checking Distance of Liner Flange Below Top Face of Block*

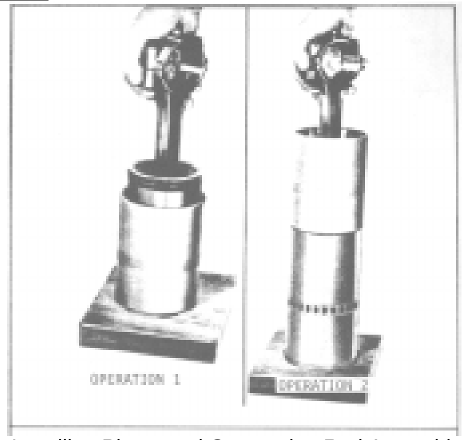


*Fig. 12 Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner*

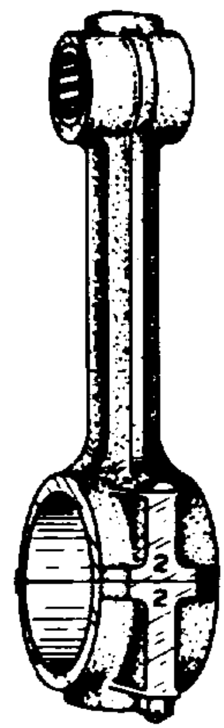


*Fig. 13 Typical Connecting Rod Markings*

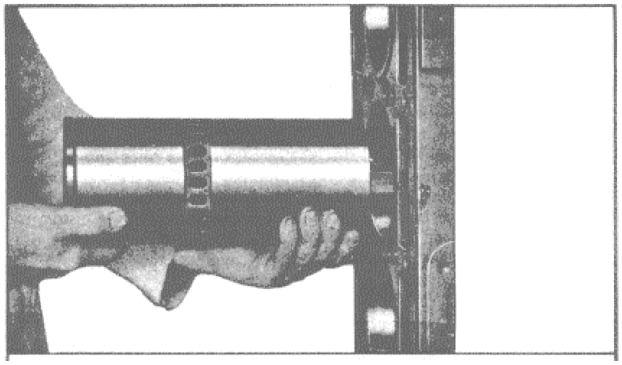

*Fig. 14 Installing Piston, Rod and Liner Assembly in Cylinder Block*

(3) Install the upper bearing shell, the one with a short oil groove at each parting line, in the connecting rod. Lubricate the bearing shell with clean engine oil.

(4) Position the piston, rod and liner assembly in line with the block bore (Fig. 14) so the identification number on the rod is facing the blower side of the engine and the match- marks on the liner and the block are in alignment. Guide the end of the connecting rod through the block bore carefully to avoid damaging or dislodging the bearing shell. Then slide the piston, rod and liner assembly straight into the block bore until the liner flange rests against the insert in the counterbore in the block.

(5) Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

(6) Place the lower bearing shell, the one with the continuous oil groove from one parting line to -the other, in the connecting rod cap, with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.

(7) Install the bearing cap and the bearing shell on the connecting rod with the identification numbers on the cap and the rod adjacent to each other. Tighten the connecting rod bolt nuts to 60-70 ft-lbs (81-95 Nm) torque (lubrite nut) or 67-75 ft-lbs (88-102 Nm) torque (castellated nut).

Note: After the oil pump piping is installed, bar the engine overfor a clearance check. In the event interference occurs, loosen the pipe or item involved and retighten it while holding it away from the point of interference.

(8) Check the connecting rod side clearance. The clearance must be .006" to .012".

(9) Install the remaining liner, piston and rod assemblies in the same manner. Use hold- down clamps to hold each liner in place.

(10) After all of the liners and pistons have been installed, remove the hold-down clamps.(

(11) Install new compression gaskets and water and oil seals as outlined in SM6-5-5.0. Then install the cylinder head and any other parts which were removed from the engine.

(12) After the engine has been completely reassembled, refer to the Lubricating Oil Specifications in Operator's Manual and refill the crankcase to the proper level on the dipstick.

(13) Close all of the drains and fill the cooling system.

(14) If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the run-in schedule given in SM6-5-67.0.

Both rotating and reciprocating forces are completely balanced in the engines. The eccentric rotating masses of the crankshaft and connecting rods are balanced by counterweights on the crankshaft cheeks.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple by virtue of an arrangement on the crankshaft in which reciprocating masses, though equal, are not opposite. This unbalanced couple, which tends to rock the engine from end to end, is balanced by an arrangement of rotating counterweights, mounted at the front and rear ends of the camshaft and balance shaft, which produce a couple equal and opposite in magnitude. Consequently the engine will operate smoothly and in balance throughout its entire speed range.

Each set of weights (weights on one shaft comprise a set) rotates in an opposite direction with respect to the other. WIhen the two weights at either end of the engine are in a vertical plane, their centrifugal forces are in-the same direction and oppose the un- balanced couple; when they are in a horizontal plane, the centrifugal forces of these balance weights are opposite and are therefore cancelled. The front balance weights are eccentric in a direction opposite to the rear balance weights. Therefore, rotation will result in the desired couple effective only in a vertical plane.

The balance weights consist of two eccentric weights at each end of the engine. Additional weights are attached to the gears.

The front balance weights are keyed to the front end of the camshaft and the balance shaft (Fig. 1). Balance weights are of one-piece construction. The balance weight bushing oscillates on the hardened surface of the hub during engine operation. Torque variations are transmitted from the hub to the weight through the spacer and spring leaves.

23.1 Remove Front Balance Weights

(1) Remove the balance weight cover.
(2) Place a block of wood between the balance weights to prevent rotation (Fig. 2).
(3) Loosen the balance weight retaining nuts on the camshaft and balance shaft with a 1-1/2" socket wrench and remove the nuts and internal tooth lockwashers.
(4) Force the balance weight off the end of each shaft with two heavy screwdrivers or

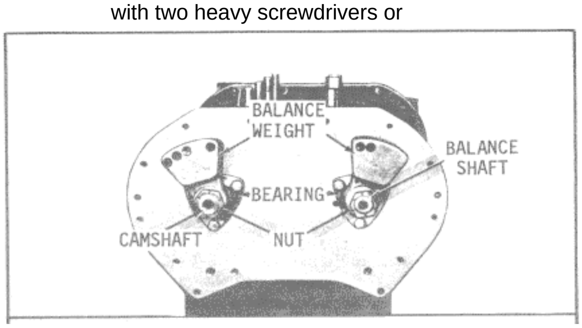


*Fig. 1 Typical Front Balance Weight Mounting*

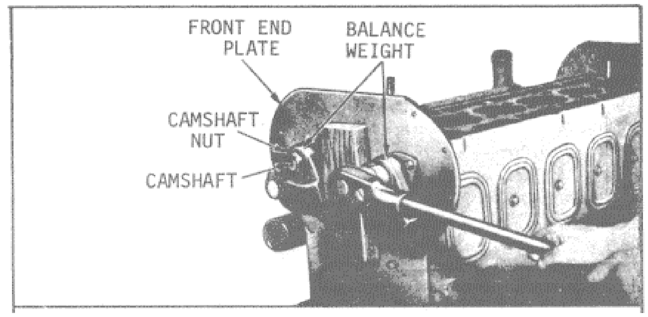


*Fig. 2 Loosening Nut on Camshaft or Balance Shaft*

pry bars between the heads of the bearing retaining bolts and the balance weight (Fig. 3).

23.2 Inspection

> **WARNING**
>
> Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
>
> Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean all of the parts thoroughly with fuel oil and dry them with compressed air.

If the thrust surface (side facing the camshaft or balance shaft thrust washers) of the balance weight hub is damaged or the bushing is worn, it will be necessary to install a pair of new balance weights.

The clearance between a balance weight bushing and the balance weight hub is from .0005" to .0035" with new parts and .006" with used parts. The clearance between the weight and the hub should be from .010" to .023".

23.3 Install Front Balance Weights

(1) Apply heavy cup grease to the steel faces of the thrust washers and install the washers up against the camshaft and balance shaft and bearings.
(2) Install Woodruff keys in the keyways at the front end of the camshaft and the balance shaft.
(3) Align the keyway in the balance weight hub with the key in the shaft and slide the balance weight on the camshaft.
(4) Install the balance weight on the balance shaft in the same manner.
(5) Slip an internal tooth lockwasher over the end of each shaft. Start the nuts on both shafts.

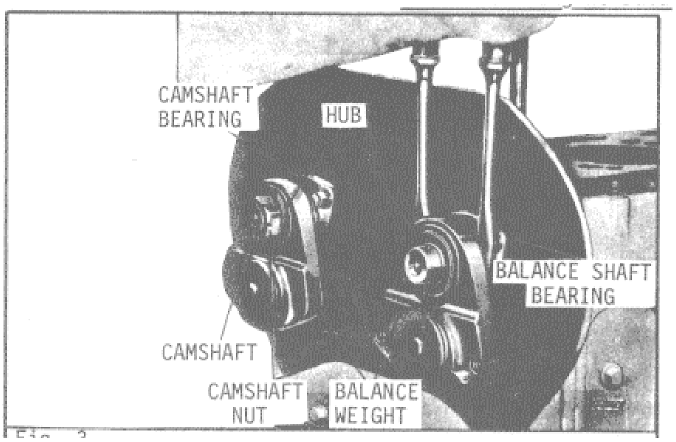


*Fig. 3 Removing Balance Weight Assemblies*

(6) Place a block of wood between the balance weights as shown in Fig. 2 and tighten the retaining nuts to 300-325 ft-lbs (407-441 Nm) torque.

(7) Install the balance weight cover, using a new gasket.

24.1 Gear Train

A completely enclosed train of five helical gears is located at the rear end of the engine as shown in Fig. 1. A gear bolted to the crankshaft flange drives the camshaft and balance shaft gears, as well as the blower drive gear, through an idler gear mounted between the crankshaft and balance shaft gears on the engine.

The camshaft gear and balance shaft gear mesh with each other and run at the same speed as the crankshaft gear. Since these two gears must be in time with each other, and the two as a unit in time with the crankshaft gear, the letter "0" is placed on one tooth of one of the gears with a corresponding mark at the root of the mating teeth of the other gear.

The camshaft and balance shaft gears are keyed to their respective shafts and held securely against the shoulder on the shaft by a nut. Viewing the engine from the flywheel or gear train end, the right-hand gear, on the camshaft, has left-hand helical teeth (Fig. 1).

The idler gear rotates on a double-row, tapered roller bearing mounted on a stationary hollow hub. This hub is accurately located on the cylinder block end plate at the left-hand side of the engine as viewed from the gear train end. A blower drive gear is located on the blower side to transmit power to the blower, governor, fuel pump and water pump.

Since the camshaft must be in time with the crankshaft, identification marks are located on two teeth of the idler gear with corresponding match marks stamped on the crankshaft gear and the camshaft gear as shown in Fig. 1.

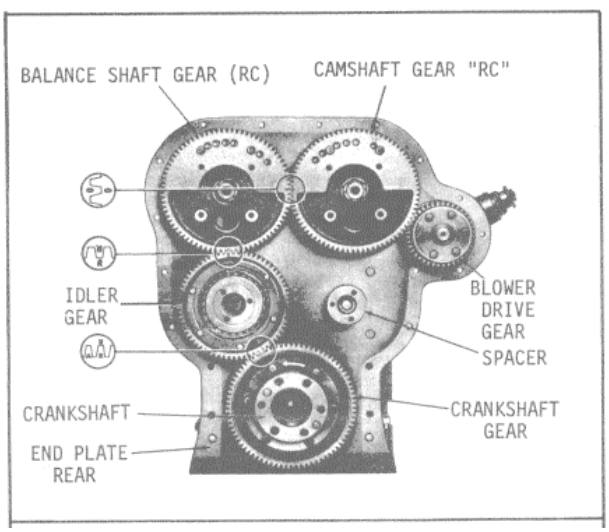


*Fig. 1 Gear Train and Timing Marks - Right-Hand Rotation Engine (Standard Timing Shown)*

| CAMSHAFT TIMING |
|---|
| Standard Timing |
| All Four-Valve Models With N55 Injectors |

Table 1

However, the timing is advanced on certain engines by aligning the "A" on the crankshaft gear with the "R" on the idler gear.

Before removing or replacing any of the gears, it is advisable to line up and make a sketch indicating the position of the timing marks. To do this, rotate the crankshaft until the timing marks are aligned on the camshaft gears. Then check whether the "A" and "R" timing mark on the crankshaft gear is aligned with the "R" on the idler gear and record this information for re- assembly purposes. Refer to Table 1 as a guide.

Balance weights, one fastened to the inner face of each gear (camshaft and balance shaft) are important in maintaining perfect engine balance. These are in addition to the weights cast integral with the gears.

Gear train noise is usually an indication of excessive gear lash, scoring, pitting or excessive bearing wear. Therefore, when noise develops in a gear train, the flywheel housing should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash whereas a whinning noise is a result of too little gear lash.

Excessive wear and scoring may result from abrasive substances or foreign material in the oil, introduced in the engine by such means as removal of the valve rocker cover without first cleaning away the dirt.

The backlash between the various mating gears in the 190 helix steel gear train is from .003" to .008" with new parts and .010" with used parts.

Since the camshaft and balance shaft gears each have the same number of teeth as the crankshaft gear, they will turn at crankshaft speed. How- ever, as the blower drive gear has only about half as many teeth as the camshaft or balance shaft gear, it turns at approximately twice the speed of the crankshaft.

| Gear | Number of Teeth 19° |
|---|---|
| Crankshaft | 78 |
| Idler | 68 |
| Cam or Balance Shaft | 78 |
| Blower Drive | 40 |

Table 2

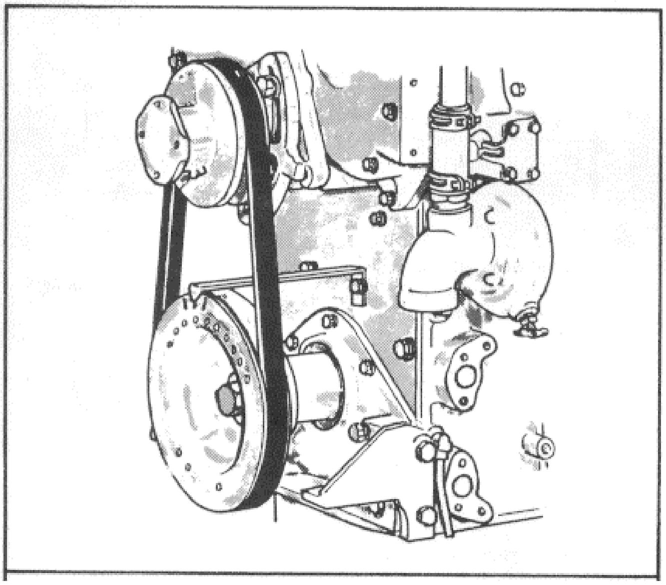

*Fig. 2 Pointer Installation for Marking Top-Dead-Center*

24.2 Lubrication

The gear train is lubricated by overflow oil from the camshaft and balance shaft pockets spilling into the gear train compartment. A certain amount of oil also spills into the gear train compartment from the camshaft and balance shaft end bearings and the idler gear bearing. The blower drive gear bearing is lubricated through an external pipe leading from the main cylinder block oil gallery to the gear hub bearing sup- port. The idler gear bearing is pressure lub- ricated by oil passages in the idler gear hub which connect to the oil gallery in the cylinder block.

24.3 Engine Timing

The correct relationship between the crankshaft and camshaft must be maintained to properly con- trol fuel injection, the opening and closing of the exhaust valves and engine balance. The crankshaft timing gear can be mounted in only one position since one attaching bolt hole is offset. The camshaft gear can also be mount- ed in only one position due to the location of the keyway relative to the cams. Therefore, when the engine is properly timed, the timing marks on the various gears will match as shown in Fig. 1.

An engine which is out of time may result in pre-ignition, uneven running and a loss of power.

When an engine is suspected of being out of time due to an improperly assembled gear train, a quick check can be made without having to remove the flywheel and flywheel housing by following the procedure outlined above.

24.4 Check Engine Timing

Access to the vibration damper or crankshaft pulley, to mark the top-dead-center position of the selected piston, and to the front end of the crankshaft or flywheel for turning the crankshaft is necessary when performing the timing check. Then proceed as follows:

(1) Clean and remove the valve rocker cover.
(2) Select any cylinder for the timing check -- it is suggested that a cylinder adjacent to one of the valve rocker cover bolt or stud holes be chosen since the stud or bolt may be used to mount a dial indicator.
(3) Remove the injector as outlined in SM6-5-33.0.
(4) Carefully slide a rod, approximately 12" long, through the injector tube until the end of the rod rests on top of the piston.
(5) Place the throttle in the no-fuel position. Then turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.
(6) Select a dial indicator with .001" graduations and with a spindle movement of at least one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also select suitable mounting attachments for the indicator so that it can be mounted over the injector tube in the cylinder head.

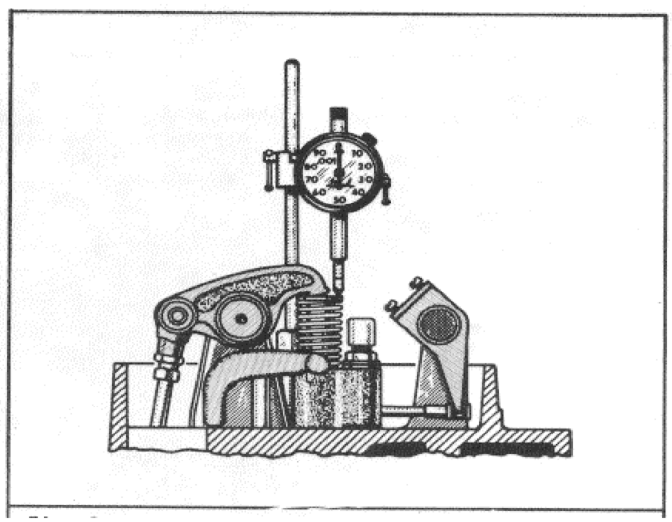

*Fig. 3 Checking Engine Timing By Measuring Injector Depression*

| Engine | Indicator Reading | | |
|---|---|---|---|
| | Correct | Retarded I-Tooth | Advanced I-Tooth |
| | Standard Timing | | |
| (1) 3, 4, 6-71 | .230” | .197” | .262” |

*Indicator readings shown are nominal values.
The allowable tolerance is * .005 in.
(1) Low velocity type injector cam.

Table 3

(7) Mount the indicator over the injector tube. The indicator mounting may be threaded into the rocker cover stud or the tapped hole in the cylinder head. Make sure that the indicator spindle is free in the injector tube and is free to travel at least one inch.

(8) Attach a suitable pointer to the crankshaft front cover or engine front end plate as illustrated in Fig. 2. The pointer should extend over the vibration damper (or crank- shaft pulley).

(9) Turn the crankshaft slowly in the direction of engine rotation until the indicator hand stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

(10) Reset the dial indicator to zero. Turn the crankshaft until the indicator reading is .010".

(11) Scribe a line on the vibration damper (or crankshaft pulley) in line with the end of the pointer.

(12) Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

(13) Set the dial to zero. Then turn the crankshaft until the indicator reading is .010".

(14) Scribe a second line on the vibration damper (or crankshaft pulley) in line with the end of the pointer.

(15) Scribe a third line halfway between the first two lines. This is top-dead-center. The three scribed lines are shown on the crankshaft pulley in Fig. 2. Remove the indicator and rod from the engine.

Note: <u>If the crankshaft pulley retaining bolt has loosened, tighten it to the specified torque (SM6-5-15.0).</u>

(16) Install the injector as outlined in SM6-5-33.0. Then refer to SM6-5-68.0 and adjust the valve clearance and time the injector.

(17) Turn the crankshaft, in the direction of engine rotation, until the exhaust valves in the cylinder selected are completely open. Reinstall the dial indicator so the indicator spindle rests on top of the injector follower (Fig. 3). Then set the indicator on zero. Next turn the crankshaft slowly in the direction of engine rotation until the center mark on the pulley is in line with the pointer.

(18) Note the indicator reading and compare it with the dimensions listed in Table 3. (19) After completing the timing check, remove the dial indicator. Also remove the pointer from the crankshaft front cover.

(20) Install the valve rocker cover.

The camshaft and the balance shaft are located just below the top of the cylinder block (Fig. 1). The camshaft actuates the exhaust valve and injector operating mechanism.

The accurately ground cams ensure efficient, quiet cam follower roller action. They are also heat treated to provide a hard wear surface.

Both ends of the cam and balance shaft are supported by bearing assemblies, each consisting of a flanged housing and two bushings. In addition, intermediate two-piece bearings support the camshaft at uniform intervals throughout its length. The intermediate bearings are secured to the camshaft by lock rings, thereby permitting them to be inserted into the cylinder block with the shaft. Each intermediate bearing is secured in place, after the camshaft is installed, with a lock screw threaded into a counter- bored hole in the top of the cylinder block.

The engine is equipped with a low velocity, low lift injector cam lobe and a long closing ramp exhaust cam lobe design camshaft.

On both the camshaft and the balance shaft, the gear thrust load is absorbed by two thrust washers, one on each end of the front end shaft bearings of the engine. The thrust washers bear against thrust shoulders on the shafts.

A helical drive gear with a counterweight is secured to each shaft with a Woodruff key (Fig. 2), nut, nut retainer, retainer bolts and lockwashers. The drive gears are attached to the rear end of the shafts on all engines.

25.1 Service

Use the offset key to service a standard timed engine.

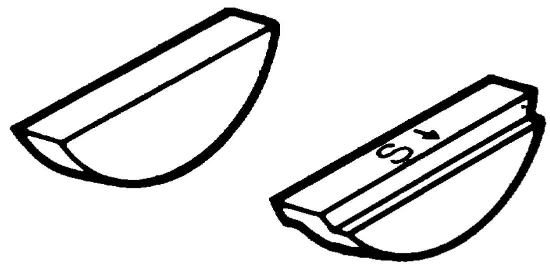


*Fig. 2 Woodruff Keys for Camshafts*

Note: The offset key is identified with an S (standard) and an arrow stamped on the face of the key. With the keyways up, always install the offset keys with the arrow pointing inboard toward the center of the engine.

25.2 Lubrication

Lubricating oil is supplied under pressure to the bearings from the main oil gallery through a horizontal transverse passage at each end of the cylinder block, then up the connecting vertical passages in each corner of the block to the camshaft and balance shaft end bearings. The camshaft intermediate bearings are lubricated by the oil from the end bearings passing through the drilled passage in the shaft.

The lower halves of the camshaft intermediate bearings are grooved along the horizontal surface that mates with the upper halves of the bearings (Fig. 3). Oil from the passage in the camshaft is forced through the milled slots in the bearing and then out the grooves to furnish

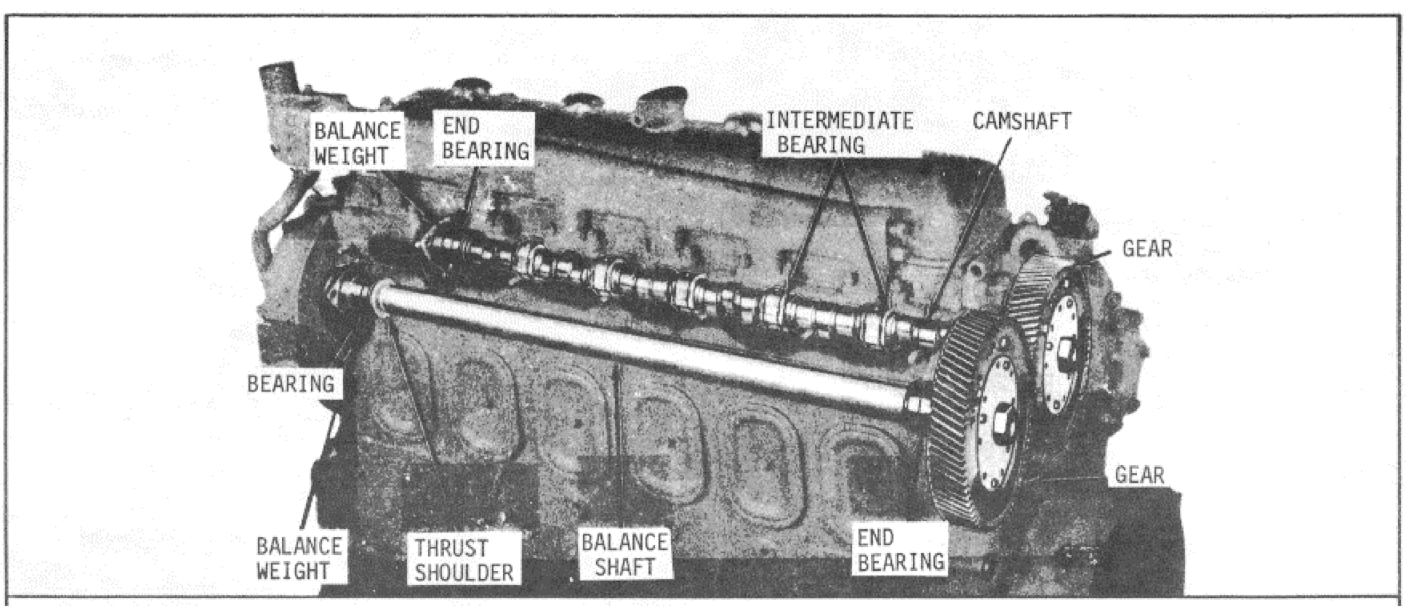


*Fig. 1 Camshaft and Balance Shaft Assemblies*

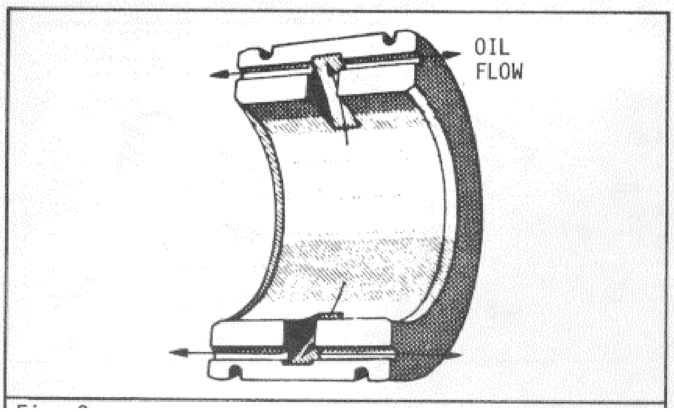


*Fig. 3 Camshaft Intermediate Bearing (Lower Half)*

additional oil to the cam follower rollers. This permits the cam pocket to be filled rapidly to the operating oil level immediately after starting the engine.

25.3 Remove Camshaft or Balance Shaft

Whenever an engine is being completely reconditioned or the camshaft, gears, bearings or thrust washers need replacing, remove the shafts from the engine as follows:

(1) Drain the engine cooling system.
(2) Remove all of the accessories and assemblies necessary to facilitate mounting the engine on an overhaul stand (SM6-5-2.0).
(3) Mount the engine on the overhaul stand. Be sure the engine is securely mounted on the overhaul stand before releasing the lifting sling.
(4) Rmove the cylinder head (refer to SM6-5-5.0).
(5) Remove the flywheel and flywheel housing (refer to SM6-5-16.0 and 6-5-18.0).
(6) Remove the front balance weight cover and place a wood block between the balance weights (Fig. 4) or wedge a clean rag be- tween the camshaft and balance shaft drive gears at the rear of the engine.
*(7)* Remove the gear nut retaining plates.
(8) Remove the gear retaining nuts on the gear end of the camshaft and the balance shaft. Remove the nut and lockwasher from the balance weight end of each shaft.
(9) Remove the front balance weights.
(10) Remove the thrust washers between the bearings and the balance weight hubs.
(11) Remove the lock screws that secure the camshaft intermediate bearings.
(12) Rotate the gears as required to reveal the end bearing retaining bolts. Remove the bolts as shown in Fig. 5.
(13) Withdraw the camshaft bearing and gear assembly and the balance shaft and gear from the rear end of the cylinder block. If the thrust washers, located between the bearings and thrust shoulders at the front end of the shafts of the engine, are not re- moved with the shafts, they should be pulled out when removing the bearings.

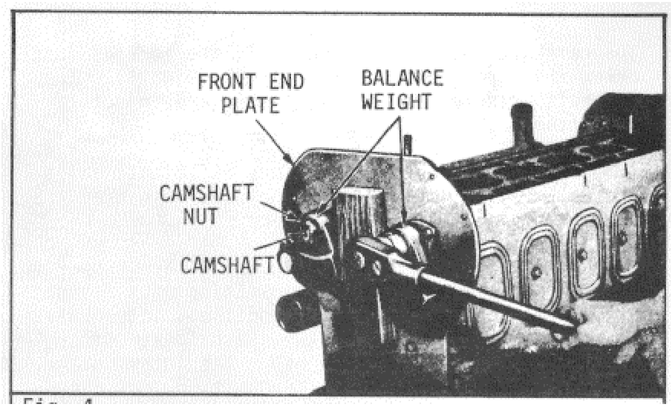


*Fig. 4 Loosening Nut on Camshaft or Balance Shaft*

(14) The cam and balance shaft front end bearings and thrust washers may be removed after taking out the bolts that hold the bearings to the end plate and cylinder block. If necessary, use a pry bar under the bearing flange.

25.4 Remove Camshaft (Flywheel Housing and Torque Converter in Place)

The camshaft may be removed and replaced without removing the flywheel housing and disconnecting the torque converter if there is space enough to slide the shaft out through the front of the engine.

(1) Drain the engine cooling system.
(2) Remove the parts, accessories and assemblies that are necessary to facilitate the removal of the flywheel housing hole cover over the camshaft and the front balance weight cover.
(3) Remove the cylinder head.
(4) Remove the front balance weight cover and place a wood block between the balance weights (Fig. 4).
(5) Remove the gear nut retainer after removing the bolts. Remove the tachometer drive adaptor, if used.
(6) Loosen and remove the nut at each end of the camshaft.

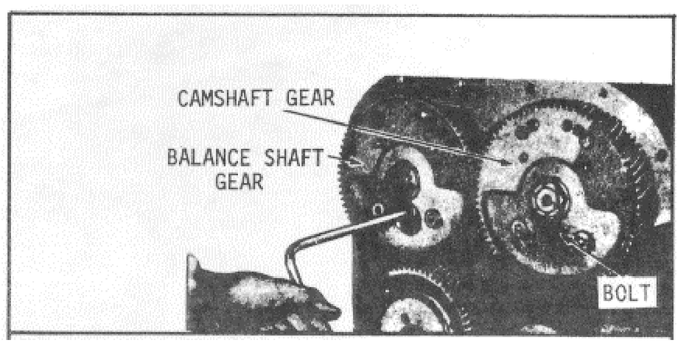


*Fig. 5 Removing or Installing Shaft Bearing Retainer Bolts*

(7) Remove the front balance weights.
(8) Remove the thrust washer between the bearing and the balance weight hub.
(9) Remove the lock screws that secure the camshaft intermediate bearings.
(10) Remove the three bolts that secure the camshaft bearing to the front end plate.
(11) Install the camshaft gear puller J 1902-01, four spacers J 6202-2 and camshaft gear puller adaptor plate J 6202-1 on the camshaft gear (Figs. 6 and 7).
(12) Turn the center screw of the puller clock-wise to disengage the camshaft from the camshaft gear.

Note: Do not remove the puller on the adaptor plate until the camshaft is reinstalled. The adaptor plate, secured to both the flywheel housing and the camshaft gear, will hold the gear securely in place and in alignment which will aid in the reinstallation of the camshaft.

(13) Remove the front bearing from the camshaft and pull out the inner thrust washer. Then pull the camshaft and intermediate bearings from the cylinder block.

25.5 Disassemble Camshaft and Balance Shaft

(1) Remove the gear from the shaft (refer to SM6-5-26.0).
(2) Slide the rear bearing off of the shaft.
(3) Remove the lock rings from the camshaft intermediate bearings and free the two halves of each bearing.
(4) To facilitate the removal of any foreign material lodged behind the plugs, remove the end plugs from each camshaft as follows:
   (a) Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shaft.
   (b) Make an indentation in the center of the camshaft end plug with a 1/4" drill (carboloy tip).
   (c) Punch a hole as deeply as possible with a center punch, to aid in breaking through

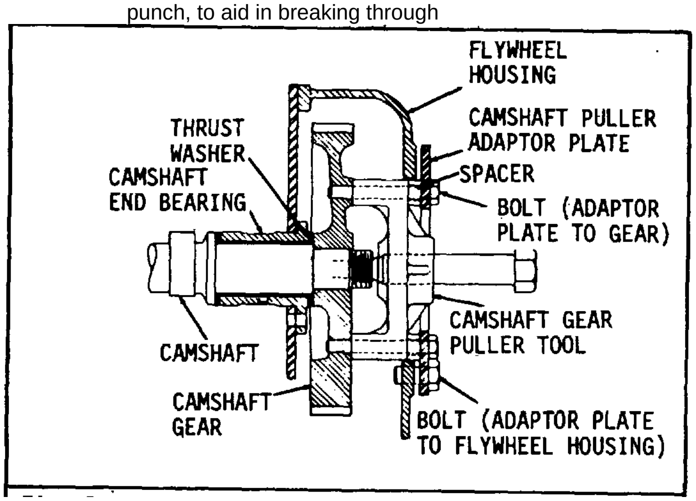


*Fig. 6*
*Removing Camshaft with Camshaft Gear Puller J 1902-01 and Adaptor Plate Set J 6202*

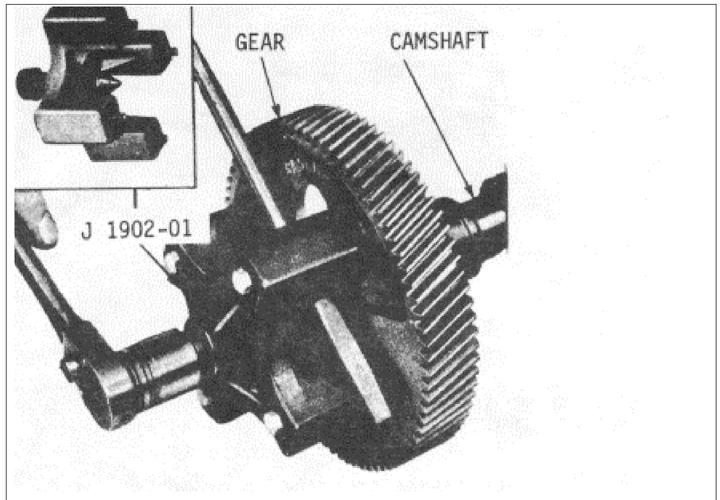


*Fig. 7*
*Removing Gear (Camshaft of Balance Shaft Gear Puller J 1902-01)*

   (d) Then, drill a hole straight through the center of the plug with a 1/4" drill (carboloy tip).
   (e) Use the 1/4" drilled hole as a guide and redrill the plug with a 5/16" drill (carboloy tip).
   (f) Tap the drilled hole with a 3/8"-16 tap.
   (g) Thread the 3/8"-16 adaptor J 6471-2 into the plug. Then attach the slide hammer J 2619-5 to the adaptor. Remove the plug by striking the weight against the handle.
   (h) Insert a .375" diameter steel rod into the camshaft oil gallery and drive the remaining plug out.

   Note: If a steel rod is not available, remove the remaining plug as outlined in steps "a" through "g"

6

25.6 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Soak the camshaft in clean fuel oil. Then, run a wire brush through the oil gallery to remove any foreign material or sludge. Clean the exterior of the camshaft and blow out the gallery and the oil holes with compressed air. Clean the gears, camshaft bearings-and related parts with fuel oil and dry them with compressed air.

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam followers as outlined in SM6-5-6.0. Also, inspect the camshaft keyways and threads for damage.

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**Service Manual** SM6-5-25.0 Camshaft, Balance Shaft and Bearings

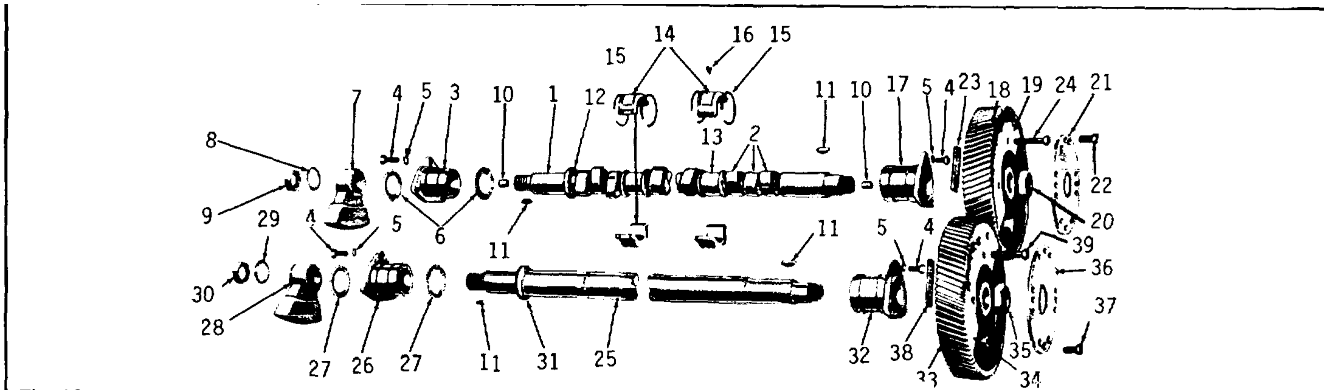

*Fig. 10*
*Typical Camshaft and Balance Shaft Details and Relative Location of Parts*

(1) Camshaft
(2) Cam
(3) Bearing - Camshaft Front
(4) Bolt - Bearing Retainer
(5) Lock Washer
(6) Washer - Camshaft Thrust
(7) Balance Weight Assy. - Camshaft Front
(8) Lock Washer
(9) Nut - Camshaft Front
(10) Plug - Camshaft
(11) Key
(12) Thrust Shoulder - Camshaft
(13) Journal - Camshaft Intermediate
(14) Bearing - Camshaft Intermediate
(15) Lock Ring - Intermediate Bearing
(16) Set Screw - Intermediate Bearing
(17) Bearing - Camshaft Rear
(18) Gear - Camshaft L.H. Helix
(19) Weight - Camshaft Integral Balance
(20) Nut - Camshaft Rear
(21) Retainer - Camshaft Gear Nut
(22) Bolt - Gear Nut Retainer
(23) Balance Weight - Camshaft Rear
(24) Bolt - Weight Retaining
(25) Balance Shaft
(26) Bearing - Balance Shaft Front
(27) Washer - Balance Shaft Thrust
(28) Balance Weight Assy. - Balance Shaft Front
(29) Lock Washer - Balance Shaft Nut
(30) Nut - Balance Shaft Front
(31) Thrust Shoulder - Balance Shaft
(32) Bearing - Balance Shaft Rear
(33) Gear - Balance Shaft R.H. Helix
(34) Weight - Balance Shaft Integral Balance
(35) Nut - Balance Shaft Rear
(36) Retainer - Balance Shaft Gear Nut
(37) Bolt - Gear Nut Retainer
(38) Balance Weight - Balance Shaft Rear
(39) Bolt - Weight Retaining

25.7 Assemble camshaft and Balance shaft

Refer to Fig. 10 and assemble the camshaft and balance shaft as follows:

(1) Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940" to 2.060" (Fig. 12).
(2) Lubricate the rear camshaft and balance shaft bearing journals and slide the rear end bearings on each shaft, with the bolting flange of the bearing toward the outer (gear) end of the shaft.
(3) Install the gears on the shafts.
(4) Lubricate the camshaft intermediate bearing journals. Then place the two halves of each intermediate bearing on a camshaft journal and lock the halves together with two lock rings. Assemble each lock ring with the gap over the upper bearing and the ends an equal distance above the split line of the bearing.

25.8 Install Camshaft and Balance Shaft

(1) Insert the front end of the camshaft into the opening on the blower side of the engine. Push the camshaft into the cylinder block until the camshaft gear teeth almost engage the teeth of the mating gear. Use care when installing the camshaft to avoid damaging the cam lobes.

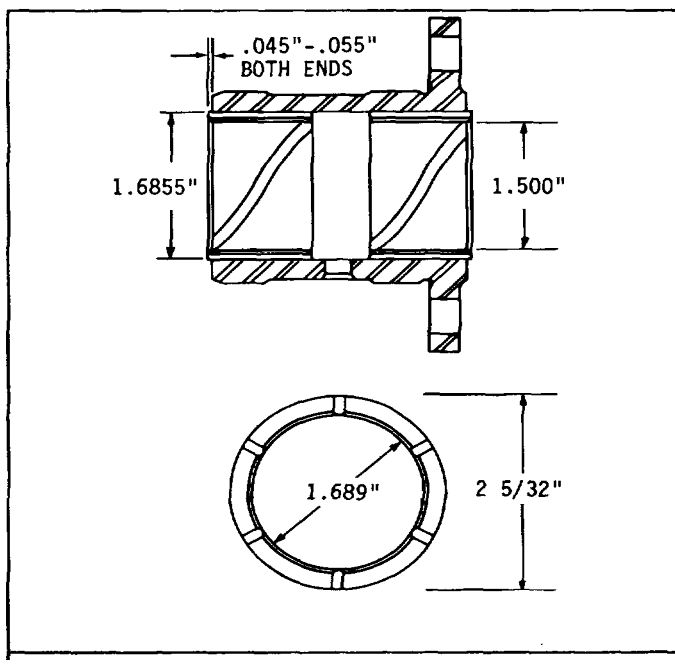


*Fig. 11*
*End Bearings and Thrust Washers*

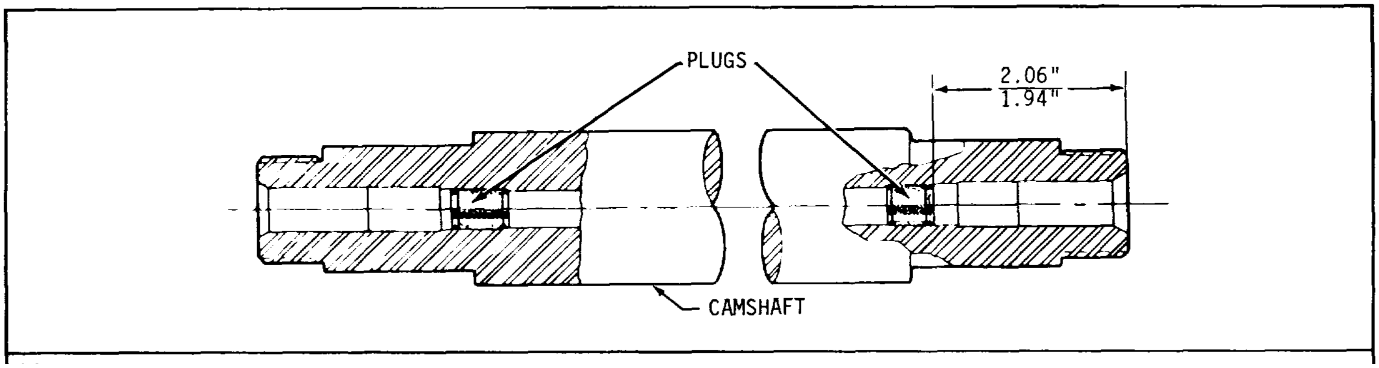


*Fig. 12*
*Camshaft Plug Installation*

Note: The right-hand gear (Viewing the engine from the flywheel end), whether it is attached to the camshaft or the balance shaft, has left-hand helical teeth.

(2) Align the timing marks on the mating gears as shown in Fig. 1 of SM6-5-24.0 and slide the camshaft gear in place.

(3) Secure the camshaft rear end bearing to the cylinder block with the three bolts and lock washers. Rotate the camshaft gear as required to install the bolts through the hole in the gear web (Fig. 5). Tighten the bolts to 35-40 ft-lbs (47-54 Nm) torque.

(4) Insert the balance shaft in the bore in the cylinder block and push it in until the teeth of the balance shaft gear almost engage the camshaft gear teeth.

(5) Align the timing marks on the mating gears as shown in Fig. 1 of SM6-5-24.0 and slide the balance shaft gear into place.

(6) Secure the balance shaft rear end bearing. Use the same procedure as outlined for the camshaft rear end bearing (Step 3).

(7) Apply grease to the steel face of each thrust washer. Then place a thrust washer against the inner end of the camshaft and balance shaft front end bearing. The steel face of the thrust washer must be against the bearing.

(8) Install the camshaft and balance shaft front end bearings with the bolts and lockwashers. Tighten the bolts to 35-40 ft-lbs (47-54 Nm) torque.

Note: Install the front bearings with care to avoid dislodging the thrust washers. Do not hammer the bearings into the cylinder block.

(9) Apply grease to the steel face of each thrust washer and place them so that the steel faces are against the outer end of the camshaft and balance shaft front bearings.

(10) Turn the camshaft intermediate bearings until the holes in the bearings are in alignment with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15-20 ft-lbs (20-27 Nm) torque.

Note: When the camshaft intermediate bearings are locked into position with the lock screw, the bearing must have slight movement in the block bore.

(11) Install the front balance weights on the shafts.

(12) Place an internal tooth lockwasher on the end of each shaft and start the nuts on both shafts.

(13) Use a wood block (Fig. 4) between the balance weights or wedge a clean cloth between the camshaft and balance shaft gears to prevent their turning. Tighten the nuts to 300-325 ft-lbs (407-441 Nm) torque.

(14) Install the camshaft and balance shaft gear nut retainers with bolts and lockwashers. Tighten the bolts to 35-39 ft-lbs (47-53 Nm) torque.

(15) Check the clearance between the thrust washer and the thrust shoulder of both the camshaft and balance shaft. The specified clearance is .004" to .012" with new parts or a maximum of .018" with used parts.

(16) Check the backlash between the mating gears. The specified backlash between new gears is .003" to .008" or a maximum of .010" between worn gears.

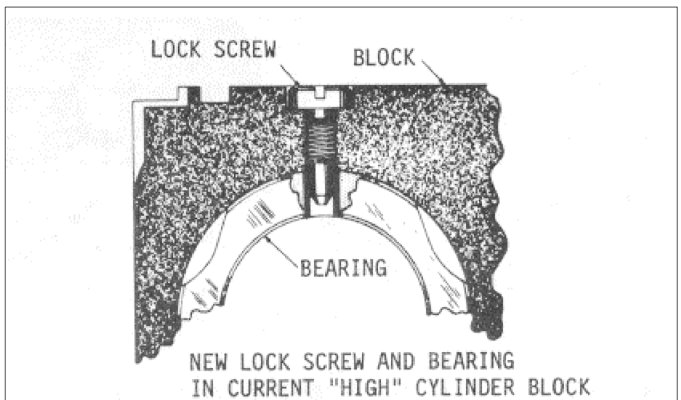


*Fig. 13*
*Camshaft Intermediate Bearing Lock Screws*

(17) Install the flywheel housing and other parts or assemblies that were removed from the engine as outlined in their respective section of this manual.
(18) Refill the cooling system.

25.9 Install Camshaft (Flywheel Housing and Torque Converter in Place)

(1) Install a Woodruff key in the drive gear end of the camshaft and insert this end into position from the front end of the engine. Push the shaft in until it slides into the rear end bearing. Use care in the installation of the camshaft to prevent damage to the cam lobes.
(2) Align the key in the shaft with the keyway in the camshaft drive gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.
(3) Remove the camshaft gear puller, spacers and adaptor plate. Finger tighten the gear retaining nut on the shaft.
(4) Install the front end bearing and thrust washers with the bolts and lockwashers. Tighten the bolts to 35-40 ft-lbs (47-54 Nm) torque.

Note: Apply grease to the steel faces of the thrust washers and insure that the steel faces are towards the bearing.

(5) Install the balance weight on the front end of the camshaft.
(6) Start the balance weight retaining nut and lockwasher on the camshaft (Fig. 8). Place a wood block between the balance weights (Fig. 4). Tighten the gear retaining nut and the balance weight nut to 330-325 ft-lbs (407-441 Nm) torque.
(7) Align the holes in the camshaft intermediate bearings with the tapped holes in the top of the cylinder block (Fig. 13). Install and tighten the lock screws to 15-20 ft-lbs (20-27 Nm) torque.
(8) Reinstall the parts, accessories and assemblies that were removed from the engine as outlined in their respective sections in this manual.
(9) Refill the cooling system.

The camshaft and balance shaft gears, located at the flywheel end of the engine, mesh with each other and run at the same speed as the crankshaft (Fig. 1) The balance gear is driven from the crankshaft timing, gear, through an idler gear. Viewing the engine from the flywheel or gear train end, the right-hand gear has left-hand helical teeth and the left-hand gear has right-hand helical teeth. The idler gear mates with the left-hand gear.

Since the camshaft and balance shaft gears must be in time with each other, the letter "O" is stamped on one tooth of one of the gears with a corresponding mark at the root of the mating tooth of the other gear. Also, since these two gears as a unit must be in time with the crankshaft, identification marks (letter "R") are located on either the camshaft gear or balance shaft gear and the mating idler gear (refer to SM6-5-24.0).

The camshaft and balance shaft gears are keyed to their respective shafts and held securely against the shoulder on the shaft by a nut. A gear nut retainer, with a double hexagon hole in the center, fits over the nut and prevents loosening of the nut. The retainer is attached to the gear by bolts thread ed into tapped holes in the gear.

26.1 Remove Camshaft and Balance Shaft Gears

(1) Remove the camshaft and balance shaft from the engine as outlined in SM6-5-25.0.
(2) Support the camshaft suitably in the soft jaws of a bench vise, being careful not to damage the cams.
(3) Remove the nut retaining the gear on the camshaft.
(4) Back out the puller screw of tool J 1902-01 and attach the puller to the outer face of the gear with four bolts (Fig. 2).
(5) Turn the puller screw down against the end of the shaft to remove the gear.
(6) Remove the gear from the balance shaft in a similar manner.
(7) If necessary, remove the two weight retaining bolts and remove the balance weights from each gear.
(8) If necessary, remove the keys from the camshaft and balance shaft.

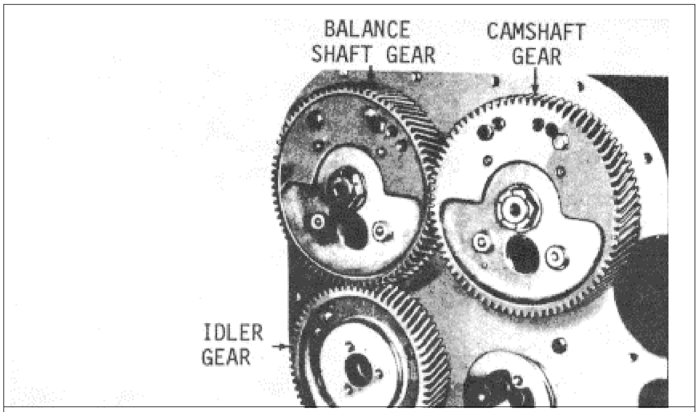


*Fig. 1*
*Camshaft and Balance Shaft Gears*

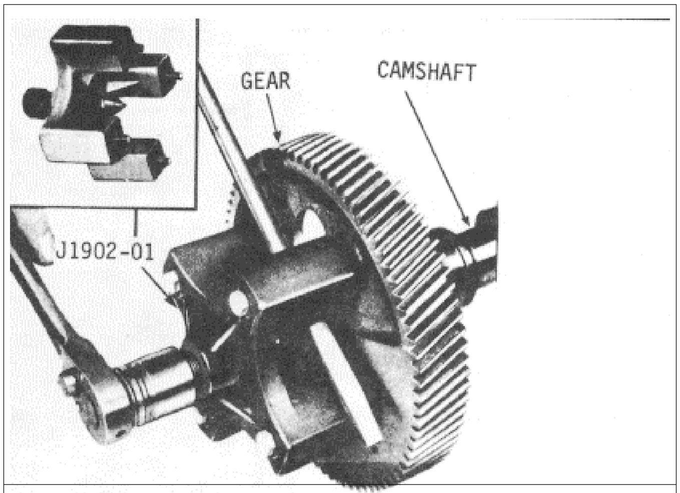


*Fig. 2*
*Removing Gear (Camshaft or Balance Shaft)*

26.2 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Clean the gears with fuel oil and dry them with compressed air. Then examine the gear teeth for evidence of scoring, pitting and wear. If severely damaged or worn, install a new gear. Also check the other gears in the gear train.

26.3 Install Camshaft and Balance Shaft Gears

(1) Install the balance weights, if removed, on the gears.
(2) Lubricate the shaft journals and place the camshaft and balance shaft end bearings in place, with the bolting flanges facing toward the gear ends of the shafts.

Note: Be sure the steel faces of the thrust washers are next to the bearings.

(3) Install the Woodruff keys for the gears in both shafts.
(4) Note that the teeth on one gear from a right-hand helix and on the other a left-hand helix. When viewing the engine from the flywheel end, the gear with right-hand helical teeth is located on the left-side and the gear with left-hand helical teeth is located on the right-side of the engine. With this in mind, rest the non-gear end of the camshaft on a wood block and start the gear on the other end of the shaft by hand so the keyway aligns with the key and with the flat finished face of the gear away from the bearing.
(5) Use gear installer J 1903 as shown in Fig. 3 to drive the gears on the camshaft and balance shaft.

**Service Manual** SM6-5-26.0 Camshaft and Balance Shaft Gears

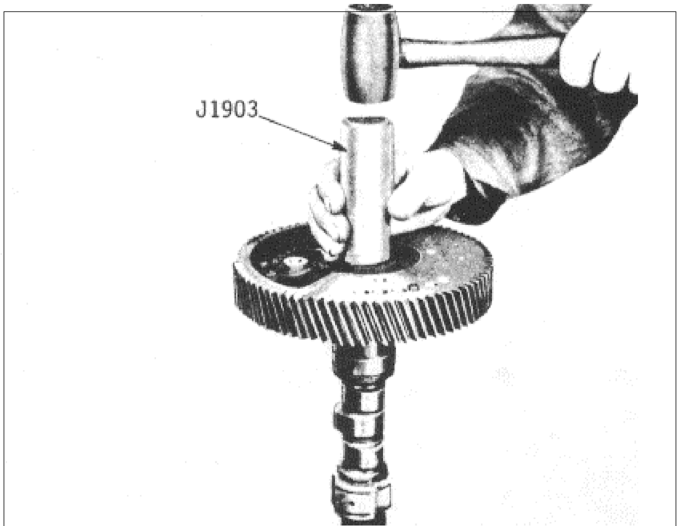


*Fig. 3*
*Replacing Gear (Camshaft Shown)*

(6) Start the gear retaining nuts on their respective shafts by hand. Tighten the nuts after the shafts have been installed in the cylinder block.
(7) Install the camshaft and balance shaft in the engine as outlined in SM6-5-25.0.
(8) With the shafts and the front balance weights installed, wedge a clean cloth between the camshaft and balance shaft gears and tighten the gear retaining nuts to 300-325 ft-lbs (407-441 Nm) torque.
(9) Secure the nuts with retainers, retainer bolts and lockwashers.
(10) Check the backlash between the mating gears. The backlash should be .003"-.008" with new parts or .010" maximum with used parts.

The idler gear is mounted on a double row, tapered roller bearing which, in turn, is supported on a stationary hub. This hub is secured directly to the cylinder block by a bolt which passes through the hub and rear end plate. A hollow dowel serves a two- fold purpose; first, as a locating dowel it positions the hub and prevents it from rotating and, second, conducts oil under pressure from an oil gallery in the cylinder block through a passage in the gear hub to the roller bearing.

The idler gear bearing consists of two cups, two cones and an outer and inner spacer ring.

The inner and outer cones of the idler gear bearing are pressed onto the gear hub and, therefore, do not rotate. Spacer rings or a spacer, separate the cones. The bearing cup(s) has a light press fit in the idler gear and is held against a flanged lip inside the idler gear on one side and by a bearing retainer secured with six bolts and three bolt locks on the other side.

A left-hand helix gear is provided for right-hand rotation engines (Fig. 1 in SM6-5-24.0)

An idler gear hole spacer (dummy hub) is used on the side opposite the idler gear. NO gasket is used between the idler gear hub or dummy hub and the flywheel housing. The flywheel housing bears against the inner races of the idler gear bearing and also against the dummy hub. Three self-locking bolts and steel washers are used to attach the flywheel housing at the idler gear and dummy hub locations. The washers seat in 7/8" spot faces at the flywheel housing attaching bolt holes, thus preventing oil leakage at these locations.

To minimize oil leakage into the flywheel housing, a idler gear spacer (dummy hub) is used (Fig. 1).

Flanged hex head bolts with a self-locking sealing patch are used with the spacer.

Service Note: <u>The service idler gear assemblies will not include the new "seal patch" bolts.</u>

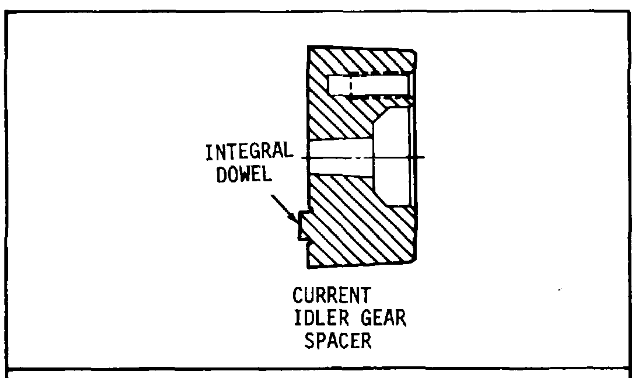


*Fig. 1*
*Idler Gear Spacer*

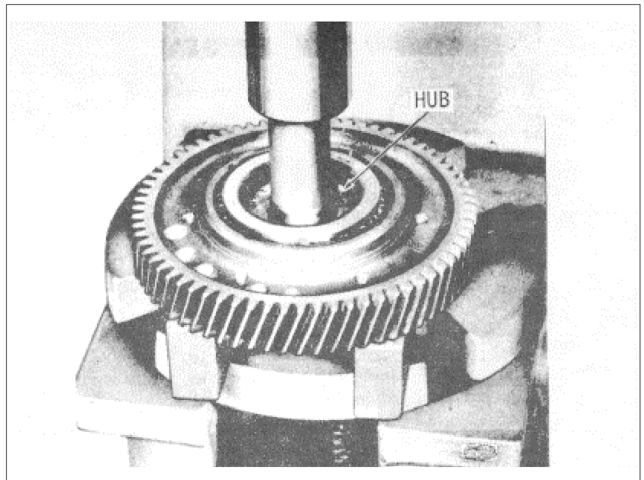


*Fig. 2*
*Pressing Hub Out of Bearing*

27.1 Remove Idler Gear, Hub and Bearing Assembly and Idler Gear Hole Spacer (Flywheel Housing Previously Removed)

(1) Remove the idler gear hub to cylinder block bolt and washer and withdraw the assembly from the cylinder block rear end plate. 6

Note: <u>Before removing the idler gear check the idler gear, hub and bearing assembly for any perceptible wobble or shake when pressure is applied; by firmly grasping the rim of the gear with both hands and rocking in relation to the bearing. The bearing must be replaced if the gear wobbles or shakes. If the gear assembly is satisfactory, it is only *necessary* to check the pre-load before reinstallation.</u>

27.2 Disassemble Idler Gear, Hub and Bearing Assembly

While removing or installing an idler gear bearing, the bearing MUST be rotated to avoid the possibility of damaging the bearing by brinelling the bearing cones. Brinelling refers to the marking of the cones by applying a heavy load through the rollers of a non-rotating bearing in such a way that the rollers leave impressions on the contact surfaces of the cones. These impressions may not be easily discerned during normal inspection. For example, a bearing may be brinelled if a load were applied to the inner cone of the bearing assembly in order to force the outer cone into the idler gear bore, thus transmitting the force through the bearing rollers. A brinelled bearing may have a very short life.

Refer to Fig. 3 for the location and identification of parts and disassemble the bearing as follows:

(1) Remove the six bolts and three bolt locks which secure the bearing retainer to the idler gear, and remove the bearing retainer.

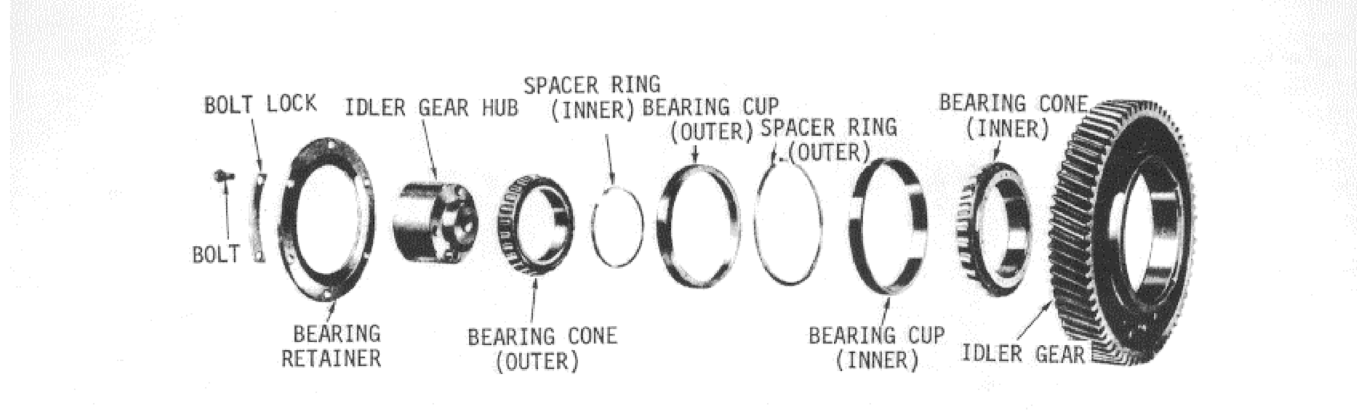


*Fig. 3*
*Idler Gear Details and Relative Locating Parts*

Note: The component parts of the idler gear bearing are matched; therefore, match-mark the parts during disassembly to ensure reassembly of the parts in their original positions.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

(2) Clean the idler gear and bearing assembly with fuel oil and dry it with compressed air.
(3) Place the idler gear and bearing assembly in an arbor press with the bearing cone or inner race supported on steel blocks as shown in Fig. 2. While rotating the gear assembly, press the hub out of the bearing. Remove the gear assembly from the arbor press and remove the bearing cones and spacers.
(4) Tap the bearing cups and spacer rings from the idler gear by using a brass drift alternately at four notches provided around the shoulder of the gear.

27.3 Inspection

WARNING

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Wash the idler gear, hub, and bearing component thoroughly in clean fuel oil and dry with compressed air.

Check the idler gear hub and spacer. The three flywheel housing mounting bolt holes were not drilled through on early design hubs and spacer Consequently, these hubs must be inspected to assure that no chips or foreign material is deposited in the holes so as to cause interference with the flywheel housing attaching bolts,

Inspect the bearings carefully for wear, pitting, scoring or flat spots on the rollers or cones. Replace the bearing if it is defective.

Examine the gear teeth for evidence of scoring, pitting and wear. If severely damaged or worn, replace the gear. Also, inspect the other gears in the gear train.

27.4 Assemble Idler Gear, Hub and Bearing
Current Bearing

Refer to Fig. 4 and assemble the bearing components in their original positions (refer to identification marks made during disassembly) as outlined below:
Note: The idler gear bearing is a matched assembly. Do not mix components.

(1) Support the idler gear, shoulder down, on the bed of an arbor press. Start one of the bearing cups, numbered side up, squarely into the bore of the gear. Then press the bearing cup against the shoulder of the gear. Use a flat steel plate (pre-load test plate) between the ram of the press and the bearing cup.
(2) Lay the outer spacer ring on the face of the bearing cup.
(3) Start the other bearing cup, numbered side down, squarely into the bore of the gear. Then press the cup tight against the spacer ring. Use a flat steel plate (pre-load test plate) between the ram of the press and the bearing cup.
(4) Press the inner bearing cone (numbered side up) on the idler gear hub, flush with the inner hub mounting face. Use the pre-load test plate (with the large center hole) between the ram of the press and the bearing.
(5) Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 1800 from the gap in the inner spacer ring.
(6) Position the gear with both cups over the hub and the inner bearing cone.
(7) Press the outer idler gear bearing cone over the hub while rotating the gear to seat the rollers properly between the cones. The

**Service Manual** SM6-5-27.0 Idler Gear and bearing Assembly

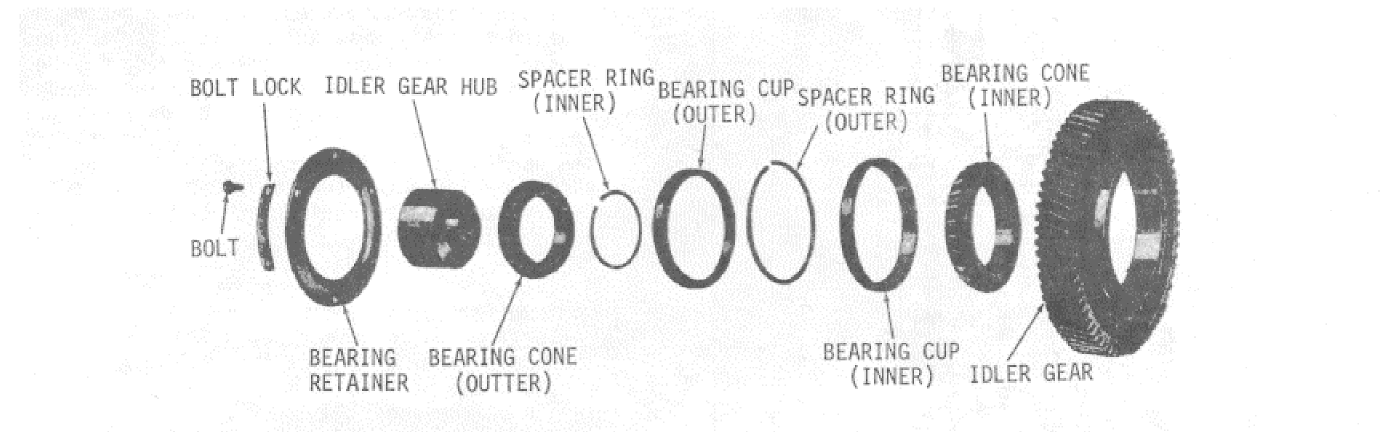


*Fig. 4*
*Idler Gear Details and Relative Location of Parts*

bearing cones must be supported so as no load the bearing rollers during this operation (Fig. 5).

(8) Before installing the gear and bearing assembly, check the preload.

27.5 Check Pre-Load of Bearing

The rollers of the bearing are loaded between the bearing cup and bearing cones in accordance with design requirements to provide a rigid idler gear and bearing assembly. As the bearing cones are moved toward each other in a taper roller bearing assembly, the rollers will be more tightly held between the cones and cup. In the idler gear bearings, a slight pre-load is applied by means of a selected spacer ring between the bearing cones, to provide rigidity of the gear and bearing assembly when it is mounted on its hub. This method of pre-load is measured, in terms of pounds-pull, by the effort required at the outer diameter of the gear to turn the bearing cup in relation to bearing cones.

Any time an idler gear assembly has been removed from an engine for servicing or inspection, while performing engine overhaul or other repairs the pre-load should be measured as pal of the operation.

The idler gear bearing must be clean and lubricated with light engine oil prior to the preload test. Idler gear assemblies which include new bearings should be worked in by grasping the gear firmly by hand and rotating the gear back and forth several times.

After the idler gear, hub, and bearing are assembled together, the bearing should be checked to ascertain that the gear may be rotated on its bearing without exceeding the maximum torque specifications, nor be so loose 2 to permit the gear to be moved in relation to the hub by tilting, wobbling or shaking the gear.

If the mating crankshaft and balance shaft gears are not already mounted on the engine, the torque required to rotate the idler gear may be checked by mounting the idler gear in position on the engine, using a steel plate 4" square (pre-load test plate) against the hub and cone as outlined below.

(1) Mount the idler gear assembly on the engine.
(2) Install the center bolt and washer through the gear hub and into the cylinder block. Tighten the bolt to 80-90 ft-lbs (108-122 Nm) torque.
(3) Place steel plate (lower plate shown in Fig. 7) against hub and bearing. Insert three 3/8"-16 bolts through the plate and thread them into the hub. Tighten the bolts to 24-40 ft-lbs (34-54 Nm) torque.
(4) Tie one end of a piece of lintless 1/8" cord around a 1/8" round piece of wood (or soft metal stock). Place the wood between the teeth of gear, then wrap the cord around the periphery of the gear several times. Attach the other end of the cord to spring scale, J 8129 (Fig. 8). Maintain a straight steady pull on the cord and scale, 90' to the axis of the hub, and note the pull, in

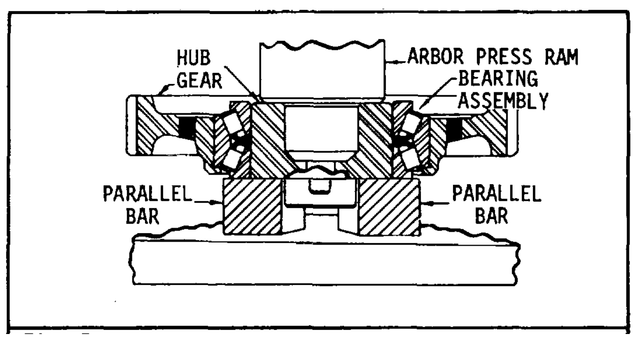


*Fig. 5*
*Pressing Hub into Bearing*

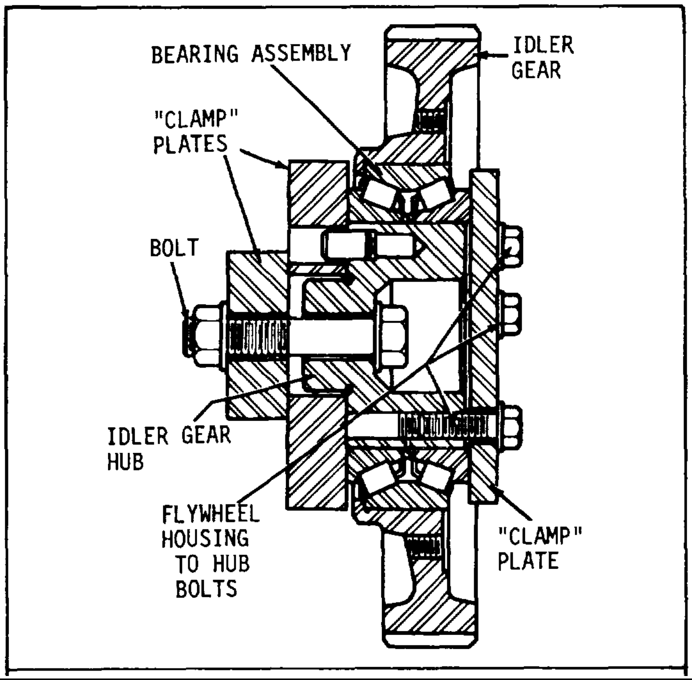


*Fig. 6*
*Fixture for Testing Bearing Pre-Load*

pounds and ounces, required to start the gear rotating. Make several checks to obtain an average reading. If the pull is within 1/2 lb. minimum to 4 lbs. Maximum and does not fluctuate more than 2 lbs. 11 ounces, the idler gear and bearing assembly are satisfactory for use.

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture, which may be held in a vise, can be made as shown in Fig. 6. Three plates (shown in Fig. 7) a 1/2"-13 x 2-3/4" bolt and a plain washer are used with a 1/2"-13 nut and plain washer for mounting. One of the plates is used to take the place of the flywheel housing, and the other two plates, the cylinder block. Engine-mounted conditions are simulated by tightening the nut to 80-90 ft-lbs (108-122 Nm) torque and tightening the three plate-to-hub attaching bolts to 25-40 ft-lbs (34-54 Nm) torque.

Check the pre-load as follows:

(1) Attach the plates (two upper plates shown in Fig. 7) to the idler gear with 1/2"-13 bolt, washers and nuts as shown in Fig. 5. Tighten the bolt to 80-90 ft-lbs (108-122 Nm) torque.
(2) Attach the third plate to the idler gear hub with three 3/8"-16 bolts. Tighten the bolts to 25-40 ft-lbs (34-54 Nm) torque.
(3) Clamp the idler gear assembly and fixture in vise (Fig. 8).
(4) Attach the cord to the idler gear and spring scale and check the pre-load as outlined in Step 4 of the previous method.

If the scale reading is within the specified 1/2 to 4 lbs., but fluctuates more than the permissible 2 lbs. 11 ounces, the idler gear and bearing assembly must NOT be installed on the engine. Fluctuations in scale reading may be caused by the cones or races not being concentric to each other, damaged cones or races or rollers, or dirt or foreign material within the bearings. In these cases, the bearing should be inspected for the cause of fluctuation in the scale readings and corrected or a new bearing installed.

A scale reading which exceeds the specified maximum indicates binding of the bearing rollers, or rollers improperly installed. When the scale reading is less than the specified minimum, the bearing is more likely worn and should be replaced.

After the pre-load test is completed, remove the steel plates and install the bearing retainer as follows:
(1) Attach the bearing retainer to the idler gear with six bolts and three bolt locks. Tighten the bolts to 24-29 ft-lbs (33-39 Nm) torque.

Important: <u>New locking bolts should always be used when attaching the bearing retainer to the idler gear.</u>

(2) Bend the ears of each bolt lock against the flat side of the attaching bolt heads to secure the bolts.

27.6 Install Idler Gear, Hub and Bearing Assembly
(1) Position the crankshaft gear and either the balance shaft so that the timing marks will align with those on the idler gear (refer to

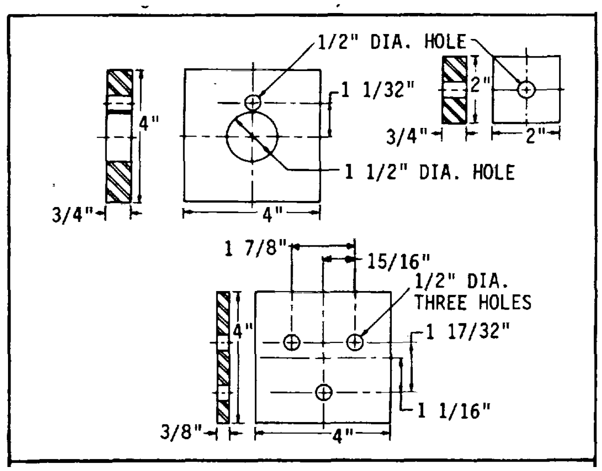


*Fig. 7*
*Plates for Bearing Test Fixture.*

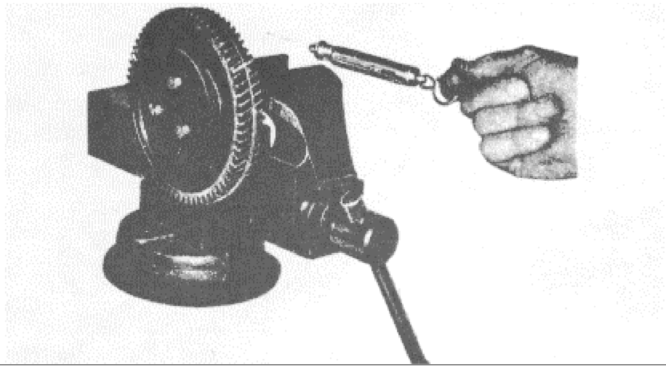

*Fig. 8*
*Checking Pre-Load of Idler Gear Bearing*

(2) With these marks in alignment, start the idler gear into mesh with the crankshaft gear and either the camshaft or balance shaft gear, and simultaneously rotate the gear hub so that the hollow dowel at the inner face of the hub registers with the oil hole in the end plate.

(3) Roll the idler gear into position, align the hollow dowel with the hole in the end plate, and gently tap the hub until it seals against the end plate. Thus the hollow dowel in the hub will conduct oil through the end plate and into the hub where it flows through a drilled passage to the roller bearing.

(4) After making sure that the hub is tight against the end plate, secure the idler gear assembly with a 1/2"-13 bolt and special washer. Tighten the bolt to 80-90 ft-lbs (108-122 Nm) torque.

(5) If previously removed, install the idler gear hole spacer (dummy hub). Secure the spacer to the cylinder block end plate and cylinder block with a 1/2"-13 bolt and special washer. Tighten the bolt to 80-90 ft-lbs (108-122 Nm) torque.

(6) Lubricate the idler gear and bearing liberally with clean engine oil.

(7) Check the backlash between the mating gears. The backlash must be .002" to .008" between new gears and must not exceed .010" between used gears.

(8) No gasket is used between the roller bearing type idler gear assembly and the flywheel housing.

Note: Make sure the oil passage in the cylinder block is plugged at the dummy hub location.

Install the flywheel housing as outlined in SM6-5-18.0.

**Service Manual** SM6-5-28.0 Crankshaft Timing Gear

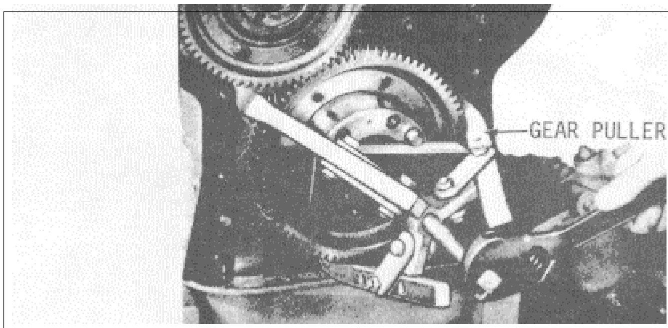


*Fig. 1*
*Removing Crankshaft Timing Gear*

The crankshaft timing gear is bolted to the flange at the rear end of the crankshaft and drives the balance shaft gear through an idler gear.

Since the camshaft must be in time with the crankshaft timing marks are located on two teeth of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft and balance shaft gears (refer to SM6-5-24.0).

28.1 Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft gear is a press fit on the crank-shaft. Remove the gear as follows:

(1) Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.
(2) Remove the six bolts and lockwashers securing the gear to the crankshaft.
(3) Provide a base for the puller screw by placing a steel plate across the cavity in the end of the crankshaft. Then remove the gear with a suitable puller as shown in Fig. 1.

28.2 Inspection

**WARNING**

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Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Clean the gear with fuel oil and dry it with compressed air. Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also check the other gears in the gear train.

28.3 Install Crankshaft Timing Gear

(1) Position the gear on the rear end of the crankshaft with the flat finished hub of the gear facing toward the cylinder block and with all six bolt holes in the gear aligned with the tapped holes in the crankshaft. One bolt hole is offset so the gear can be attached in only one position.
(2) Align the proper timing mark on the crank-shaft gear tooth with the corresponding mark on the idler gear (refer to SM6-5-24.0).
(3) Start the six 3/8"-24 bolts with lockwashers through the gear and into the crankshaft. Then draw the gear tight against the shoulder on the crankshaft. Tighten the bolts to 35-39 ft-lbs (47-53 Nm) torque.
(4) Check the backlash with the mating gear. The backlash should be .003" to .008" with new gears or .010" maximum with used gears.

**Service Manual** SM6-5-29.0 Blower Drive Gear and Support Assembly

The blower drive gear is mounted on the blower drive gear support and in addition to driving the blower, drives the governor, water pump and fuel pump. The drive is cushioned by a spring-loaded flexible coupling, see Figs. 1 and 5 which insures a uniform rotation of the blower rotors.

The right-hand helix blower drive gear is driven by the camshaft gear, see Fig. 1 in SM6-5-24.0.

The ratio of blower speed to engine speed on the 71N engine is 1.69:1. This reduction in the ratio is possible through an additional set of blower rotor gears (see SM6-5-44.0).

29.1 Remove and Install Blower Drive Shaft

If the blower drive shaft is not broken, it may be removed as follows:

(1) Remove the six bolts (94 and 95) that secure the flywheel housing small hole cover (92), see Fig. 1.

(2) Refer to Fig. 4 and remove the snap ring and pull the blower drive shaft out of the drive assembly.

Note: Some shafts have a tapped hole in the end which can be used as an aid in removing the shaft.

If the blower drive shaft is broken and it is not possible to remove all of the pieces, it will be necessary to remove the blower, see SM6-5-44.0.

A broken drive shaft indicates an unusual loading which may have been caused by a bearing failure or other malfunction. Inspect the blower drive, blower rotors and the housing before replacing the drive shaft. See the blower inspection procedure in SM6-5-44.0. Reverse Steps 1 and 2 for the installation of the blower drive shaft.

29.2 Remove Blower Drive Gear and Support Assembly (Flywhee Housing Removed)

Removal of the flywheel housing is not necessary when removing the blower drive gear, however, an inspection of the gear train is advisable when any one of the gears requires service. The procedures for the removal of the flywheel and flywheel housing are found in SM6-5-16.0 and 6-5-18.0.

Before removing the blower drive gear, the blower drive shaft must be removed as previously outlined.

(1) Remove the blower as outlined in SM6-5-44.0.

(2) Remove the blower drive oil line, see Fig. 3.

(3) Straighten the ears on the lockwasher (58) and loosen the drive gear hub nut (57), Fig. 5.

(4) Remove the blower drive support attaching bolts.

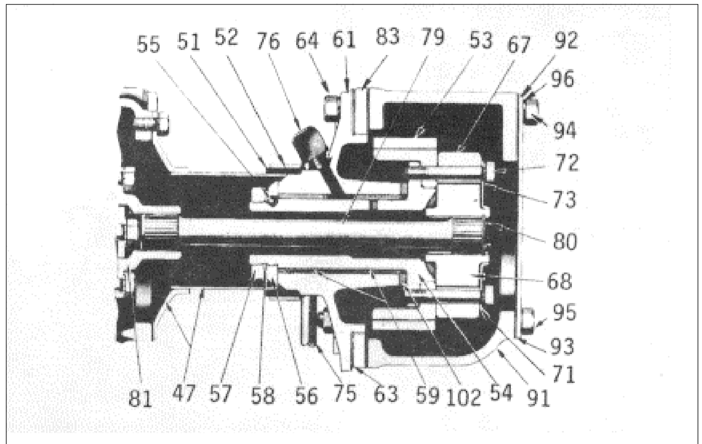


*Fig. 1*
*Typical Blower Drive Gear and Support Assembly*

47. Cover--Blower Drive 73. Lockwasher
51. Seal--Drive Cover 75. Pipe--Drive Bearing
52. Clamp--Cover Seal Oil
53. Gear--Blower Drive 76. Elbow--Oil Pipe
54. Hub--Drive Gear 79. Shaft--Blower Drive
55. Lock Ball 80. Ring--Blower Drive
56. Washer--Drive Gear Shaft
Hub Thrust81. Hub--Blower Rotor
57. *Nut--Drive* Gear Hub Gear
58. Lockwasher 83. End Plate--Cylinder
59. Bearing--Drive Gear Block-Rear
Hub 91. Housing--Flywheel
61. Support--Drive Gear 92. Cover--Flywheel
Hub Housing (Small Hole)
63. Gasket 93. Gasket--Cover
64. Bolt--Drive Gear Hub 94. Bolt--3/8"-16 x 7/8"
Support Cover
67. Support--Drive Coupling 95. Bolt--3/8"-24 x 5" -
68. Cam--Drive Coupling Cover
71. Retainer--Drive 96. Lockwasher
Coupling 102. Thrust Washer
72. Bolt--Drive Coupling

(5) *Loosen the blower* drive *support by tapping* it lightly and withdraw the support from the cylinder block rear end plate. Take care to prevent damage to the blower drive gear teeth. Discard the gasket.

29.3 Disassemble Blower Drive Gear and Support Assembly

(1) Secure the blower drive gear and support as- sembly in a vise with soft jaws.

(2) Take out the drive coupling bolts (72) and remove the retainer (71) and coupling support (67), see Fig. 5.

(3) Remove the drive gear hub nut (57), lock-washer (58), lock ball (55) and thrust washer (56) and withdraw the blower drive gear hub.

(4) Remove the thrust washer (Fig. 2) from the blower drive gear hub.

(5) Press the gear hub out of the blower drive gear.

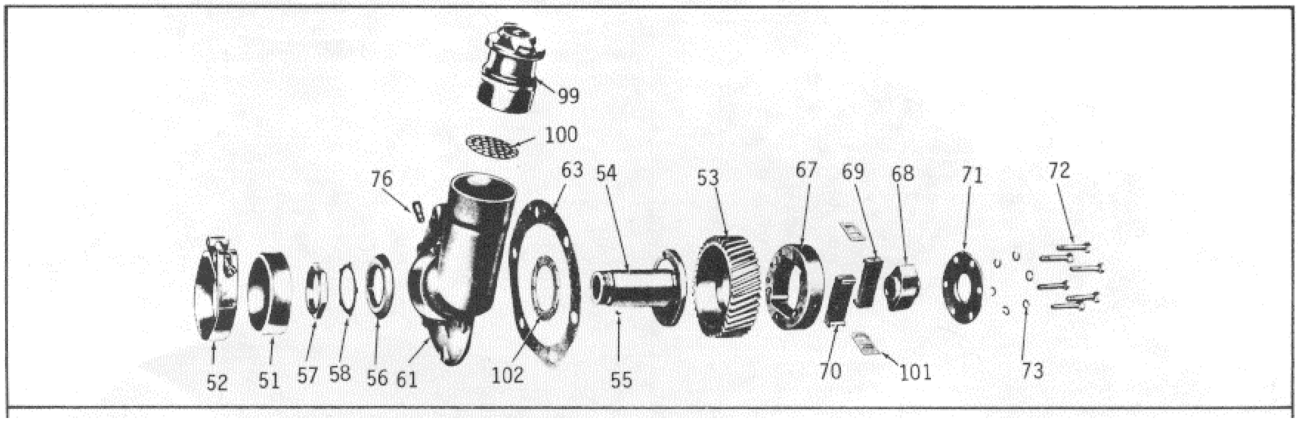


*Fig. 5*
*Typical Blower Drive Gear Details and Relative Location of Parts*

51. Seal--Drive Cover
52. Clamp--Cover Seal
53. Gear--Blower Drive Hub
54. Hub--Drive Gear
55. Lock Ball
56. Washer--Drive Gear Hub Thrust
57. Nut--Drive Gear Hub
58. Lockwasher
61. Support--Drive Gear
63. Gasket
67. Support--Drive Coupling
68. Cam--Drive Coupling
69. Spring (Pack)—Drive Coupling
70. Seat--Coupling Spring
71. Retainer--Drive Coupling
71. Bolt—Drive Coupling (6 Req'd)
73. Lockwasher (6 Req'd)
76. Elbow--Oil Pipe
99. Cap--Oil Filler
100. Strainer--Oil Filler
101. Seat--Coupling Spring End (2 Req'd)
102. Washer--Thrust

(6) Install a new lockwasher (58) and finger tighten the nut (57) on the hub. Install two bolts into the threaded holes in the drive gear hub. Place a suitable holding bar across the bolts to keep the hub from rotating and tighten the hub nut to 50-60 ft-lbs torque. Bend the ears of the lock-washer against the nut to lock the nut in place. Remove the two bolts.

(7) Assemble the blower drive coupling.

(a) Place the drive coupling support (67) on wood blocks as shown in Fig. 6.

(b) Install the spring end seats (101) and place the spring seats (70) in each corner of the drive coupling support.

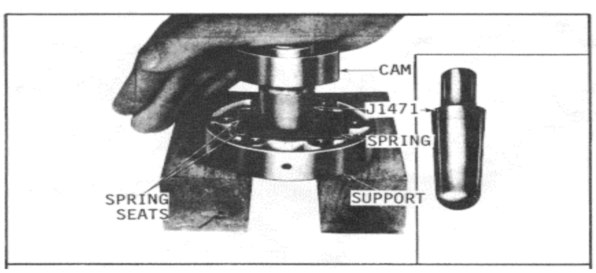


*Fig. 6 Inserting Blower Drive Cam*

(c) Apply engine oil to the drive coupling springs (there are 21 leaves in each spring pack) and insert them in the coupling support.

(d) Place the blower drive cam (68) on the installer J 1471, insert the round end of the tool between the spring packs (69) and press the cam into position. See Fig. 6.

(8) Place the coupling support against the drive gear with the blower drive shaft ring groove in the cam facing away from the drive gear. Then, place the drive coupling retainer (71) against the coupling support with the flared edge away from the support. Revolve the coupling assembly on the hub flange until the cam lobes are in line with the oil grooves in the gear hub (Fig. 7) to ensure proper lubrication.

(9) Install the drive coupling bolts.

**29.6 Install Blower Drive Gear and Support Assembly**

(1) Check the clearance (Fig. 2) between the drive support and gear hub thrust washer before installing the blower drive gear support assembly. The clearance must be .006" to .014".

(2) Place a new gasket (63) on the mounting face of the hub support (Fig. 5).

(3) Attach the blower drive gear and support assembly to the cylinder block rear end plate with the two 3/8"-24 x 7/8 bolts.

(4) Connect the oil line (Fig. 3).

(5) Install the blower as outlined in SM6-5-44.0 and secure the seal (51) and clamp (52) shown in Fig. 5.

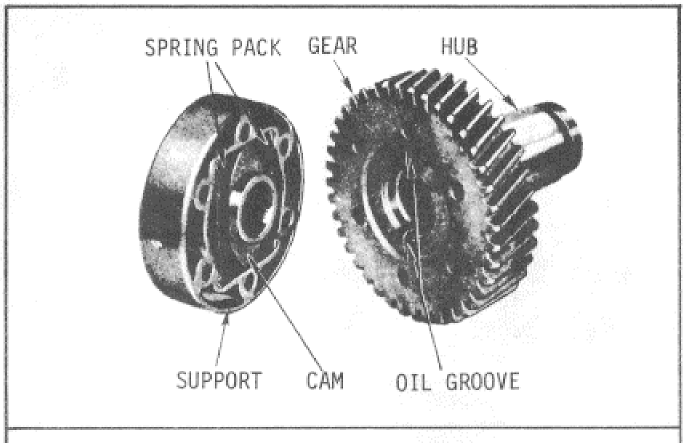


*Fig. 7 Relation of Blower Drive Cam to Oil Grooves in Gear Hub*

(6) Insert the blower drive shaft into the blower rotor gear hub. The end without the groove for the ring must be inserted first.

(7) Lock the drive shaft in place by installing the ring in the groove provided in the coupling cam.

(8) Reinstall the flywheel and flywheel housing as described in SM6-5-16.0 and 6-5-18.0 and install the remaining bolts that secure the blower drive gear and support assembly.

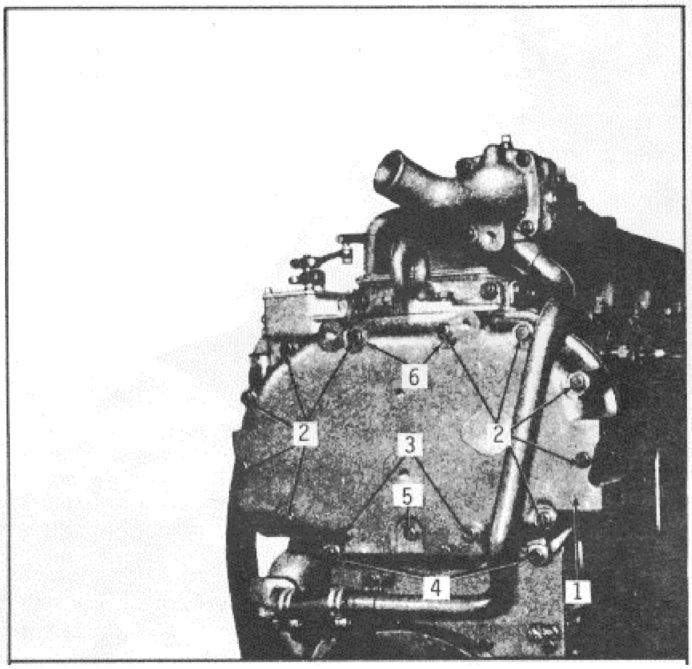


*Fig. 1 Balance Weight Cover Mounting*

The front balance weight cover (Fig. 1) encloses the front engine balance weights and also serves as a support for various equipment such as the cooling fan support bracket.

The balance weight cover requires no servicing. However, when an engine is being completely reconditioned or the camshaft, balance shaft or front balance weights need replacing, the balance weight cover must be removed.

## 30.1 Remove Cover

(1) Drain the cooling system.
(2) Loosen the hose connections between the radiator and the engine.
(3) Remove the radiator.
(4) Remove the fan, fan hub and adjusting bracket.
(5) Remove the fifteen bolts, lockwashers, and plain washers (Fig. 1) which secure the balance weight cover to the cylinder block and the front end plate. Remove the cover and gasket.
(6) Remove all traces of the old gasket material from the cover and the end plate.

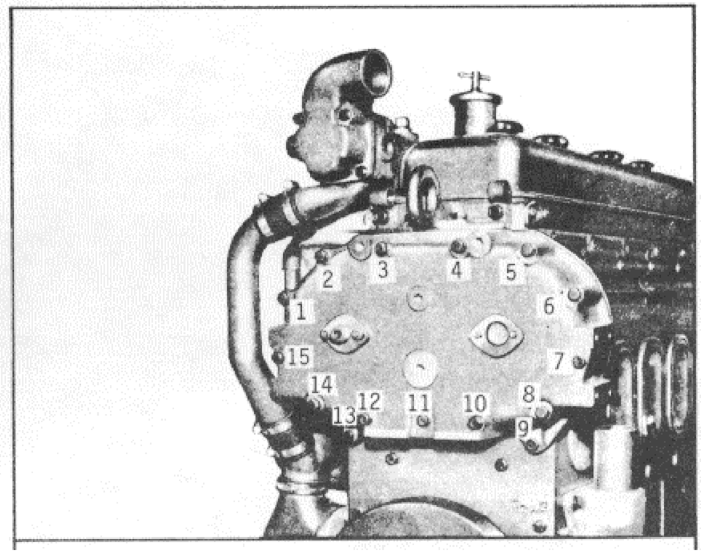


*Fig. 2 Balance Weight Cover Bolt Tightening Sequence*

## 30.2 Install Cover

(1) Affix a new gasket to the balance weight cover.
(2) Install the cover in place and install the fifteen attaching bolts, lockwashers and plain washers finger tight.
(3) Refer to Fig. 2 and tighten the bolts to 25-30 ft-lbs (34-41 Nm) torque.
(4) Install the various sub-assemblies that were previously removed.

## 31.1 Teflon Wrapped Pipe Plug

Pipe plugs with a baked teflon coating are available for service. However, pipe plugs can be hand wrapped satisfactorily with teflon tape to provide a better seal and facilitate plug removal. When a teflon wrapped plug is installed, it is extremely important that the specified torque not be exceeded.

Hand wrap a pipe plug with teflon tape as follows:

(1) Be sure the pipe plug is thoroughly clean and dry prior to applying the teflon tape. All dirt, grease, oil and scale must be removed.

(2) Start the tape one or two threads from the small or leading edge of the plug, joining the tape together with an overlap of approximately 1/8".

(3) Wrap the tape tightly in the same direction as you would turn a nut. The tape must con- form to the configuration of the threads (be pressed into the minor diameter of the threads) without cutting or ripping the tape.

(4) Hand tighten and hand torque the pipe plug and do not exceed the specified torque. Do not use power tools.

## 31.2 Checking Bearing Clearances

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially and is available in three sizes and colors. Type PG-1 (green) has a clearance range of .001" to .003", type PR-1 (red) has a range of .002" to .006" and type PB-1 (blue) has a range of .004" to .009". The plastic strip may be used for checking the bearing clearances as follows:

(1) Remove the bearing cap and wipe the oil from the bearing shell and the crankshaft journal.

Note: <u>When checking the main bearing clearances with the engine in a position where the main bearing caps are supporting the weight of the crankshaft and the flywheel, an erroneous reading, due to the weight of the crankshaft and flywheel, can be eliminated by supporting the weight of the crank- shaft with a jack under the counterweight adjoining the bearing being checked.</u>

(2) Place a piece of the plastic strip the full width of the bearing shell, about 1/4" off center (Fig. 1).

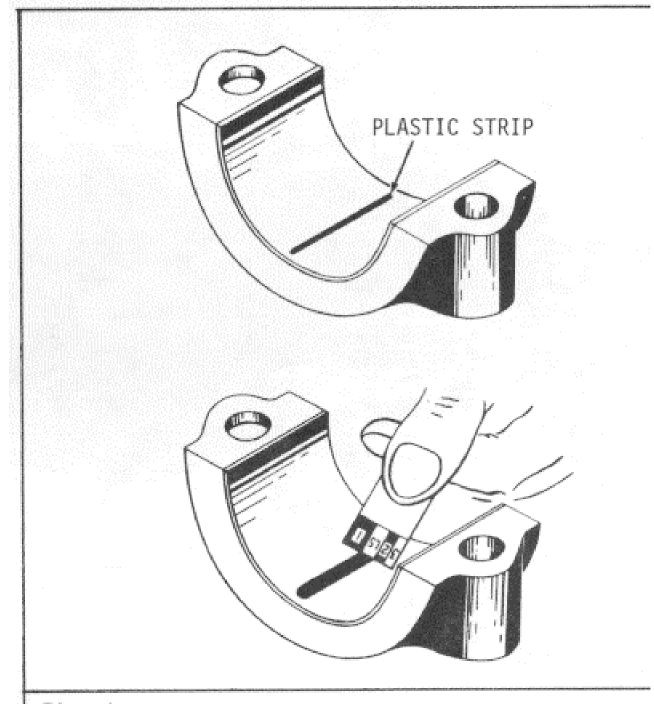


*Fig. 1 Using a Plastic Strip to Measure Bearing-to-Crankshaft Clearance*

(3) Rotate the crankshaft about 300 from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.

(4) Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.

(5) Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope (Fig. 1). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

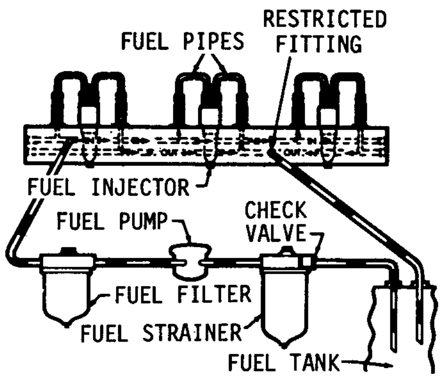


*Fig. 1 Schematic Diagram of Typical Fuel System*

The fuel system (Fig. 1) includes the fuel injectors fuel pipes (inlet and outlet), fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter and fuel lines.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter and into the inlet fuel manifold, then through fuel pipes into the inlet side of each fuel injector.

The fuel manifolds are identified *by* the words "IN" (top passage) and "OUT" (bottom passage) which are cast in several places in the side of the cylinder head. This aids installation of the fuel lines. Surplus fuel returns from the outlet side of the injectors to the fuel return manifold and then back to the supply tank.

All engines are equipped with a restrictive fitting in the fuel outlet manifold to maintain the fuel system pressure. Refer to SM6-7-70.0 for the size fitting required.

A check valve may be installed in the supply line between the fuel tank and the fuel strainer to pre- vent fuel from draining back when the engine is shut down.

The fuel injector (Figs. 1 and 2) is a lightweight compact unit which enables quick, *easy* starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air-fuel mixing or vaporizing devices are required.

The fuel injector performs four functions:

(1) Creates the high fuel pressure required for efficient injection.
(2) Meters and injects the exact amount of fuel required to handle the load.
(3) Atomizes the fuel for mixing with the air in the combustion chamber.
(4) Permits continuous fuel flow.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small ' quantity of accurately metered and finely atomized fuel oil into the cylinder.

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 3 illustrates the fuel metering from no-load to full-load by rotation of the plunger in the bushing.

Figure 4 illustrates the phases of injector operation *by* the vertical travel of the injector plunger.

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the helix angle of the plunger and the type of spray tip used. Refer to Fig. 5 for the identification of the injectors and respective plungers and spray tips.
Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

**CAUTION**

Do Not Intermix The Needle Valve, Injectors With Other Types Of Injectors In An Engine.

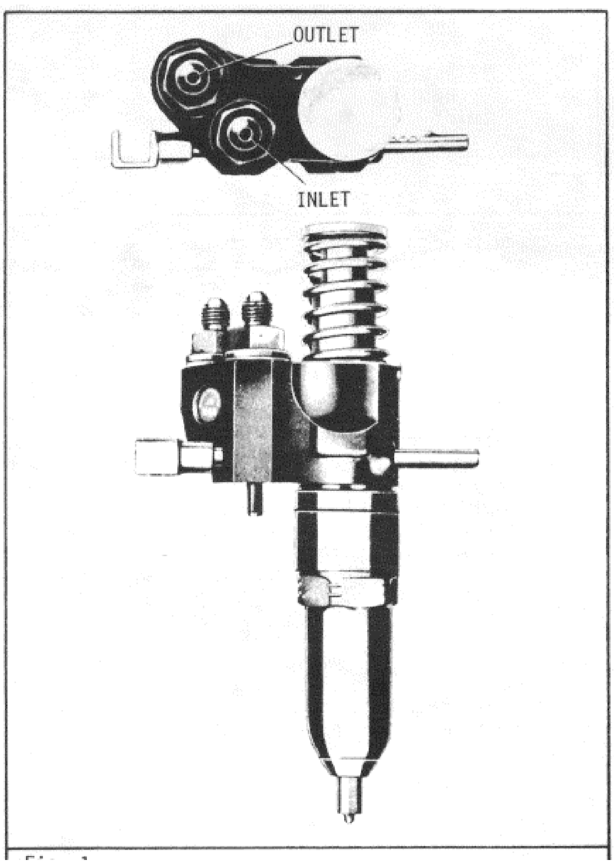


*Fig. 1 Fuel Injector Assembly*

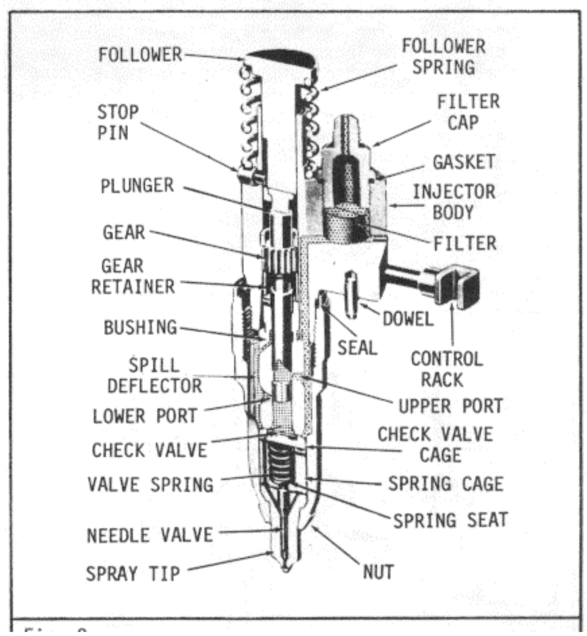


*Fig. 2 Cutaway View of Fuel Injector*

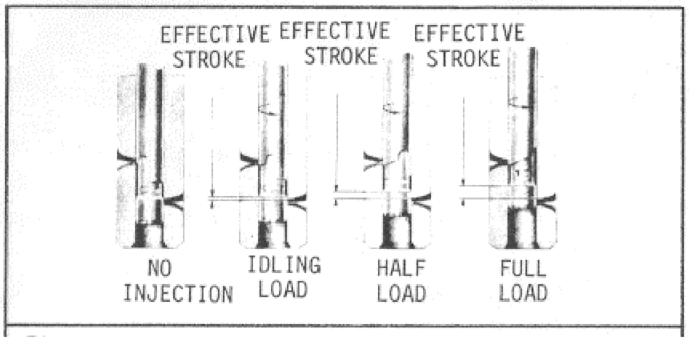


*Fig. 3 Fuel Metering from No-Load to Full-Load*

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 5). The identification tag indicates the nominal output of the injector in cubic millimeters.

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting of all injector racks.

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

33.1 Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (Fig. 2). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In

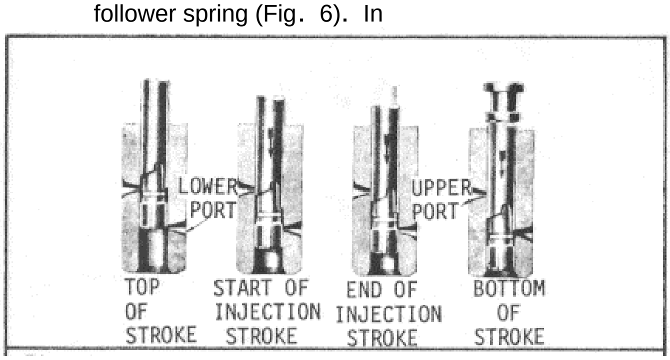


*Fig. 4 Phases of Injector Operation Through Vertical Travel or Plunger*

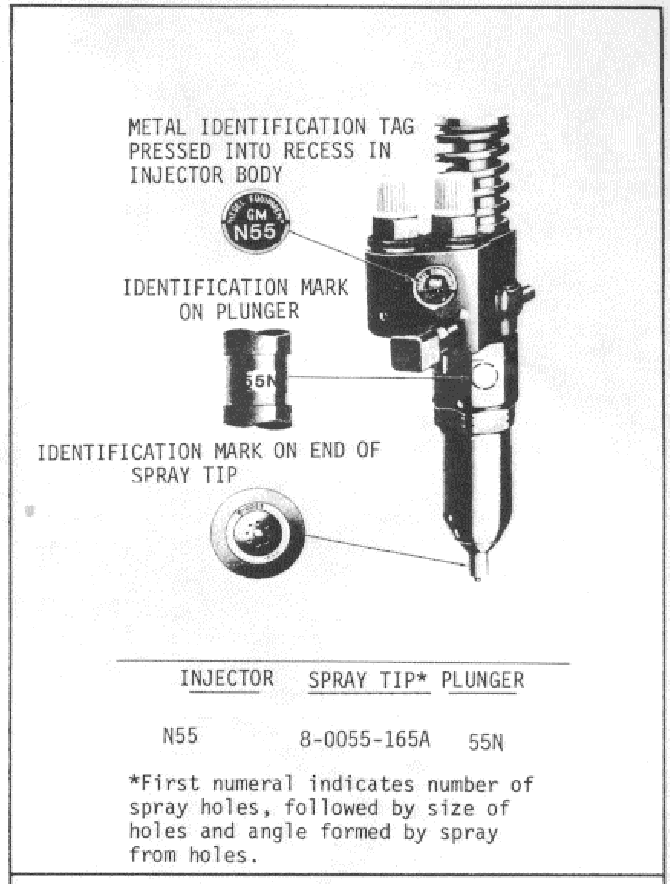


*Fig. 5 Injector Identification Chart*

addition to the reciprocating motion, the plunger can be rotated, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

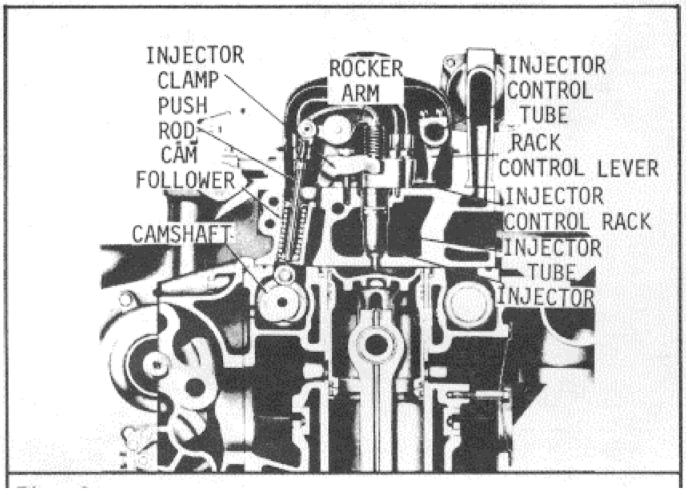


*Fig. 6 Fuel Injector Mounting*

When sufficient pressure is built up, it opens the flat, non-return check valve. The fuel in the check valve cage, spring cage, tip passages and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection

the spring cage to permit bleed-off of fuel leaking past the needle pilot in the tip assemble

A check valve, directly below the bushing, pre- vents leakage from the combustion chamber into the fuel injector in case the valve is accident- ally held open *by* a small particle of dirt. The injector plunger is then returned to its original position *by* the injector follower spring. Figure 4 shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it in-

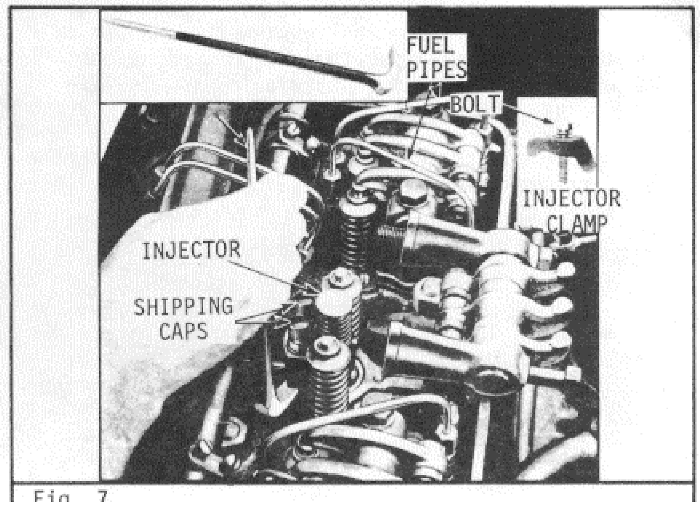


*Fig. 7 Removing Injector from Cylinder Head*

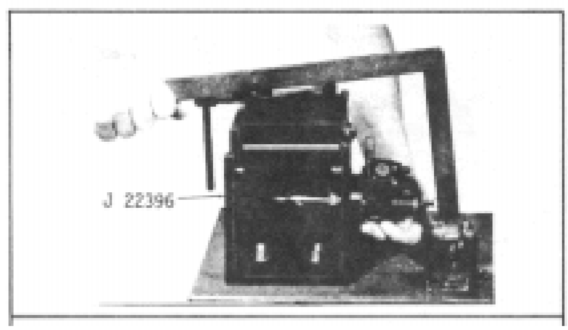


*Fig. 8 Checking Rack and Plunger for Free Movement*

creases or decreases the amount of fuel injected into the cylinder. Figure 3 shows the various plunger positions from no-load to full-load. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this no injection position to full injection position-(full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

### 33.2 General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure pre- vents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air. Also provide a source for 110 volt alternating current electric power.

Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust-proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning agent, usually clean fuel oil, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free cleaning tissue is a good, inexpensive material for wiping injector parts.

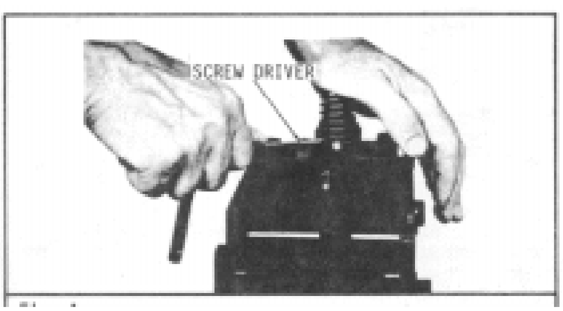


*Fig. 9 Removing Injector Follower Stop Pin*

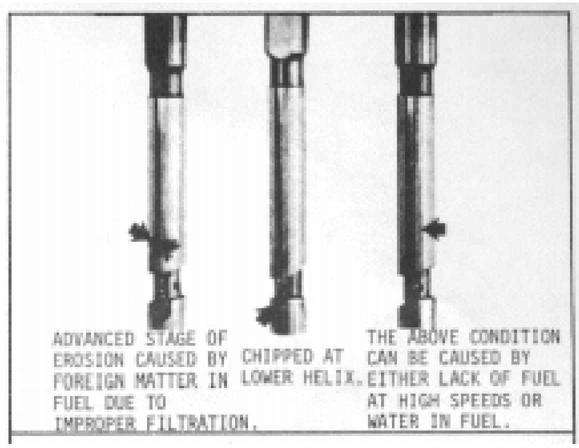


*Fig. 10 Unusable Injector Plungers*

When servicing an injector, follow the general instructions outlined below:

(1) Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors. Also protect the fuel pipes and fuel connectors from the entry of dirt or other foreign material.

(2) After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and assembly of an injector.

Note: <u>In the offset injector, a filter is used in the inlet side only. No filter is required on the outlet side (Fig. 34).</u>

(3) Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in SM6-5-68.0:

   (a) Time the injector.
   (b) Position the injector control rack.

(4) Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to Operator's Manual).

(5) When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. Do not use fuel oil. Install shipping caps on both filter caps immediately after filling. Store the injector in an upright position to prevent test oil leakage.

Note: <u>Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.</u>

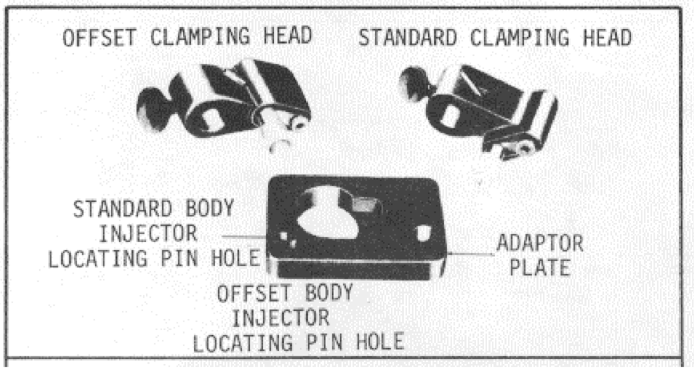


*Fig. 11 Injector Tester J 23010 Clamping Heads*

### 33.3 Remove Injector

(1) Clean and remove the valve rocker cover.
(2) Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

Note: Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also protect the fuel pipes and fuel connectors from entry of dirt or foreign material.

(3) Crank the engine to bring the outer end of the push rods of the injector and valve rocker arms in line horizontally.
(4) Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).
(5) Remove the injector clamp bolt, special washer and clamp.
(6) Loosen the inner and outer adjusting screws (certain engines have only one adjusting screw and locknut) on the injector rack control lever and slide the lever away from the injector.
(7) Lift the injector from its seat in the cylinder head.
(8) Cover the injector hole in the cylinder head to keep foreign material out.
(9) Clean the exterior of the injector with clean fuel oil and dry it with compressed air.

### 33.4 Test Injector

**WARNING**

The Fuel Spray From An Injector Can Penetrate The Skin. Fuel Oil Which Enters The Blood Stream Can Cause A Serious Infection. Therefore, Follow Instructions And Use The Proper Equipment To Test An Injector.

If inspection does not reveal any external damage, then perform a series of tests to deter- mine the condition of the injector to avoid unnecessary overhauling. Tests must be performed using injector test oil J 26400.

An injector that passes all of the test out- lined below may be considered to be satisfactory for service without disassembly, except for the visual check of the plunger.

However, an injector that fails to pass one or more of the tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct any one condition.

Identify each injector and record the pressure drop and fuel output as indicated by the fol- lowing tests.

### 33.5 Injector Control Rack And Plunger Movement Test

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center of the follower when the following spring is compressed.

With the injector control rack held in the no- fuel position, push the handle down and depress the follower to the bottom of its stroke. Then very slowly release the pressure on the handle while moving the control rack up and down as shown in Fig. 8 until the follower reaches the top of its travel. If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times, if necessary. Generally this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts.

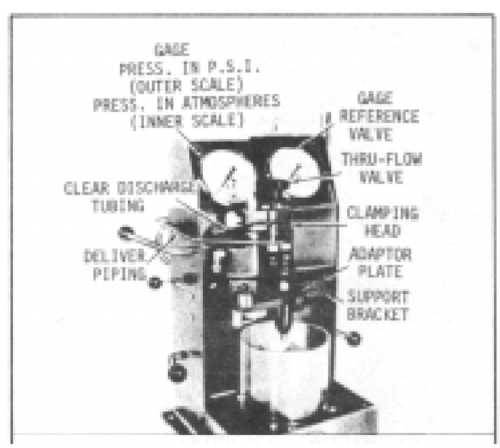


*Fig. 12 Injector Installed in Tester J 23010 with Clamping Head*

### 33.6 Visual Inspection of Plunger

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests.

Remove the plunger from the injector as follows

(1) Support the injector, right side up, in holding fixture J 22396.
(2) Compress the follower spring. Then raise the spring above the stop pin with a screw- driver and withdraw the pin (Fig. 9). Allow the spring to rise gradually.
(3) Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.
(4) Inspect the plunger. If the plunger is chipped (Fig. 10), replace the plunger and bushing assembly.
(5) Reinstall the plunger, follower and spring.

### 33.7 Installing Fuel Injector in Tester J 23010

(1) Select the proper clamping head (Fig. 11). Position it on the clamping post and tighter the thumbscrew into the lower detent position (Fig. 12).
(2) Connect the test oil delivery piping into the clamping head.
(3) Connect the test oil clear discharge tubing onto the pipe on the clamping head.
(4) Locate the adaptor plate on top of the support bracket by positioning the 3/8" diameter hole at the far right of the adaptor plate onto the 3/8" diameter dowel pin. This allows the adaptor plate to swing out for mounting the fuel injector.
(5) Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. 11).
(6) Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

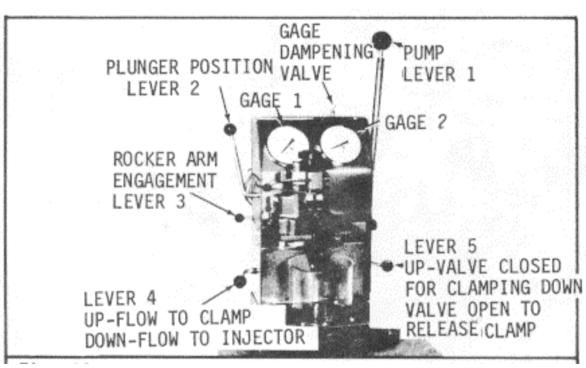


*Fig. 13 Injector in Position for Testing with Tester J 23010*

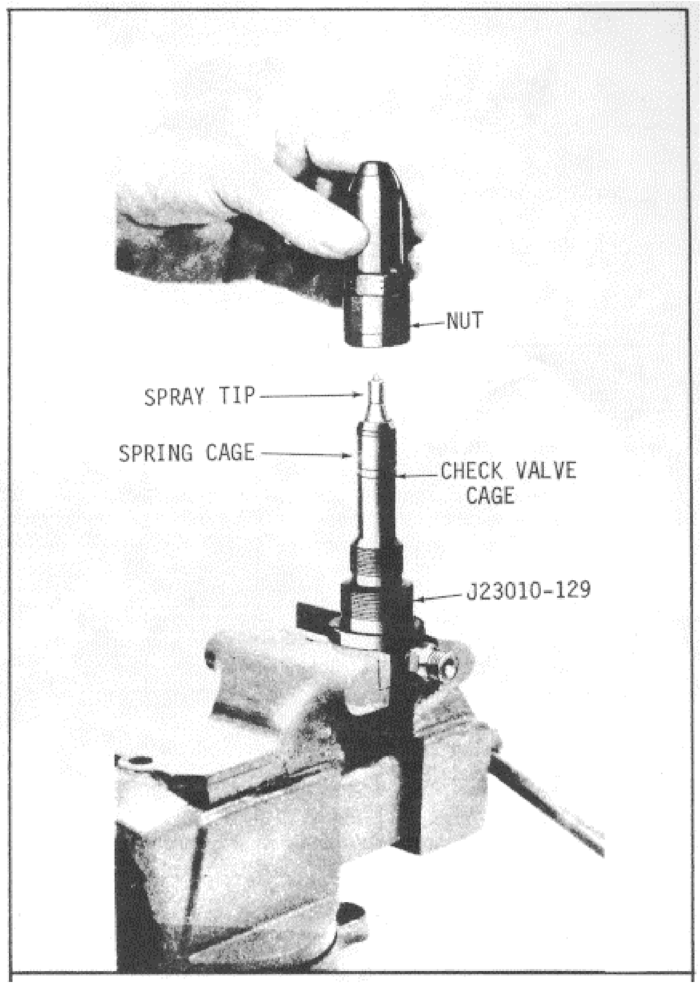


*Fig. 14 Assembling Injector Valve Parts on Tip Tester Adaptor J 23010-129*

### 33.8 Clamping the Fuel Injector

(1) Refer to Fig. 13 and position the injector tester levers as follows:
Lever 2 up and to the rear.
Lever 3 in the rear detent.
Lever 4 up (horizontal).
Lever 5 up (horizontal).
(2) Align the clamping head nylon seals over the injector filter caps.
(3) Back off the Thru-Flow valve about half-way to allow the self-aligning nylon seals to seat properly during the clamping operation.
(4) Hold the clamping head in position over the filter caps and with the left hand, operate pump lever 1 evenly to move the clamping head down to seal the filter caps.

Note: <u>The Thru-Flow valve should still turn freely. If it does not, turn the valve counterclockwise until it rotates freely and reapply clamping pressure.</u>

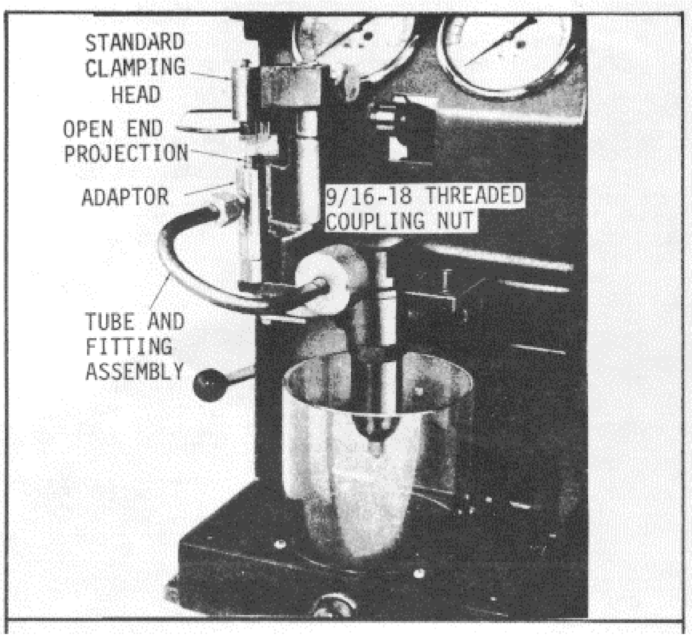


*Fig. 15 Adaptor and Tube Assembly on Injector Tester J 23010*

> **CAUTION**
>
> Excessive Force On Lever 1 During Clamping Can Damage The Seals In The Valves Operated By Levers 4 And 5.

### 33.9 Purging Air from the System

Move lever 4 down and operate pump lever I to produce a test oil flow through the injector. When air bubbles no longer pass through the clear discharge tubing, the system is free of air and is now ready for testing.

33.10 Injector Valve Opening and Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the injector valve opens and fuel injection begins.

(1) Clamp the injector properly and purge the air from the system.
(2) Move lever 4 down.
(3) Position the injector rack in the full-fuel position.
(4) Place pump lever 1 in the vertical position.
(5) Move lever 3 to the forward detent position. The highest pressure reference number shown on gauge 2 will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector. References values for Series 71 injectors are from 127 minimum to 146 maximum.

Note: The reference value obtained when pop testing the needle valve injectors is to be used as a trouble shooting and diagnosis aid. This allows comparative testing of injectors without disassembly. Exact valve opening pressure values can only be determined by the Needle Valve Tip Test using tester J 23010 and tip test adaptor J 23010-129 or auxiliary tester J 22640.

**33.11 Injector High Pressure Test**

This test checks for leaks at the filter cap gaskets, body plugs and nut seal ring.

(1) Clamp the injector properly and purge the air from the system.
(2) Close the Thru-Flow valve, but do not overtighten.

> **CAUTION**
>
> Make Sure Lever 4 Is In The Down Position Before Operating Pump Lever 1.

(3) Operate pump lever 1 to build up to 1600 to 2000 psi on gauge 1. Check for leakage at the injector filter cap gaskets, body plugs and injector nut seal ring.

### 33.12 Injector Pressure Holding Test

This test determines if the body-to-bushing mating surfaces in the injector are sealing properly and indicates proper plunger-to bushing fit.

(1) Clamp the injector properly and purge the air from the system.
(2) Close the Thru-Flow valve, but do not overtighten.
(3) Move lever 2 to the rear, horizontal position.
(4) Operate pump lever 1 until gauge 1 reads approximately 700 psi.
(5) Move lever 4 to the up position.
(6) Time the pressure drop between 450 to 250 psi. If the pressure drop occurs in le than 15 seconds, leakage is excessive.

Refer to the Trouble Shooting Charts in SM 6-5-72.0 if the fuel injector does not pass any of the preceding tests.

If the fuel injector passes all of the above tests, proceed with the Fuel Output Test.

### 33.13 Unclamping the Injector

(1) Open the Thru-Flow valve to release pressure in the system.
(2) Move lever 5 down to release the clamping pressure.

(3) Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clear of the injector filter caps.
(4) Carefully return lever 5 to the up (horizontal) position.

### 33.14 Needle Valve Tip Test (Using J 23010 Tester and Tip-Test Adaptor)

Assemble injector parts on tip test adaptor as follows:

(1) Clamp the flat sides of the tip test adapt J 23010-129 firmly in a vise and assemble the cleaned injector parts including the check valve cage, spring, spring seat, spring cage and spray tip assembly.
(2) Carefully pilot the injector nut over the spray tip and valve parts and thread it onto the adaptor (Fig. 14).
(3) Tighten the injector nut.
(4) Mount the adaptor and assembled injector parts in the support bracket (adaptor not needed). Refer to Fig. 15.
(5) Install the offset clamping head on the clamping post (on J 23010 testers without serial numbers, use the upper detent posi tion and on J 23010 testers numbered 1051 and higher, use the lower detent position)
(6) Select the (larger) 9/16"-18 threaded coupling nut J 23010-20 and thread it on tubing J 23010-75. Install the tubing and fitting to adaptor J 23010-167.
(7) Connect the tubing to tip test adaptor J 23010-129 by threading the coupling nut on the tip test adaptor.

### 33.15 Installing Adaptor and Tube Assembly on Tester J 23010

(1) Position the adaptor and tubing assembly with the solid projecting end located in the hole on the left side of the support bracket.

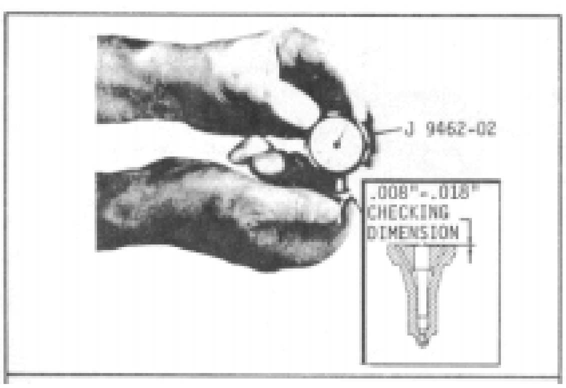


*Fig. 16 Checking Needle Valve Lift or (Needle Valve)*

(2) Swing the clamping head over the adaptor and clamp it with the oil supply outlet aligned over the open projecting end of the adaptor (Fig. 15).

Note: <u>Use the fuel injector clamping procedure to clamp adaptor J 23010-167 in the injector tester.</u>

### 33.16 Spray Tip Test

(1) Move lever 4 down and operate pump lever 1 with even strokes (Fig. 13).
(2) Note the pressure at which the needle valve opens on gauge 1. The valve should open between 2300 and 3300 psi. The opening and closing action should be sharp and produce a normal, finely atomized spray pattern.

If the valve opening pressure is below 2300 psi and/or atomization is poor, the cause is usually a weak valve spring or a poor needle valve seat.

If the valve opening pressure is within 2300-3300 psi, proceed to check for spray tip leakage as follows:

(a) Actuate pump lever 1 several times and hold the pressure at 1500 psi for 15 seconds.
(b) Inspect the spray tip for leakage. There should be no fuel droplets, although a slight wetting at the spray tip is permissable.

### 33.17 Needle Valve Lift Test

To measure the needle valve lift, use tool J 9462-01 (Fig. 16) as follows:

(1) Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.
(2) Place the spray tip and needle valve assembly tight against the bottom of the gauge with the quill of the needle valve in the hole in the plunger.
(3) While holding the spray tip and needle valve assembly tight against the gauge, read the needle valve lift on the indicator. The lift should be .008" to .018". If it exceeds .018", the tip assembly must be re- placed. If it is less than .008", inspect for foreign material between the needle valve and the tip seat.
(4) If the needle valve lift is within limits, install a new needle valve spring and re- check the valve opening pressure and valve action. Low valve opening pressure or poor atomization with a new spring and seat indicates the spray tip and needle valve assembly should be replaced.
(5) Reassemble the injector as outlined under Assemble Injector and check the injector output with calibrator J 22410.

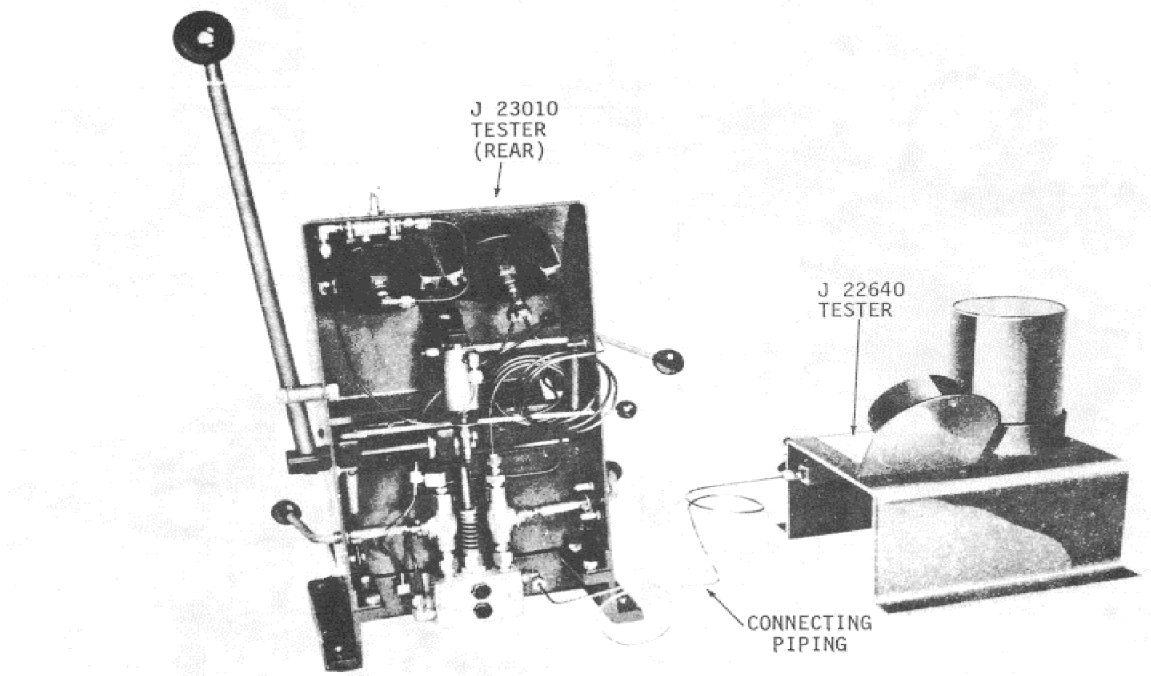


*Fig. 17*
*Injector Needle Valve Tester J 23010 with Auxiliary*

33.18 Needle Valve Tip Test (Using Auxiliary Tester J 22640)

(1)Connect the pipe from auxiliary tester J 22640 to the rear of the J 23010 tester at the connection located near the bottom of the tester (Fig. 17).
(2)Assemble cleaned injector parts, including the check valve cage, spring, spring seat, spring cage and spray tip assembly, on the auxiliary tester J 22640 (Fig. 18).
(3)Carefully pilot the injector nut over the spray tip and valve parts and thread it on the auxiliary tester.
(4)Tighten the injector nut.
(5)Open the valve on the auxiliary tester and place lever 4 in the up (horizontal) position.
(6)Install the shield on the auxiliary tester and operate pump lever 1 until the needle valve has opened several times to purge the air from the system.
(7)Operate pump lever 1 with smooth, even strokes and note the pressure on gauge 1 when the needle valve opens. The valve should open between 2300 and 3300 psi. The opening and closing action should be sharp and produce a finely atomized spray.

If the valve opening pressure is below 2300 psi and/or atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

If the valve opening pressure is within 2300-3300 psi, proceed to check for spray tip leakage as follows:

(a)Actuate the pump lever several times and hold the pressure at 1500 psi for 15 seconds.
(b)Inspect the spray tip for leakage. There should be no fuel droplets although a slight wetting at the spray tip is permissable.

Perform the needle valve lift test.

33.19 Fuel Output Test

Perform the injector fuel output test in calibrator J 22410.

When injectors are removed from an engine for fuel output testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

33.20 Calibrator J 22410

To check the fuel output, operate the injector in calibrator J 22410 (Fig. 21) as follows:

**Service Manual** SM6-5-33.0 Fuel Injector (Needle Valve)

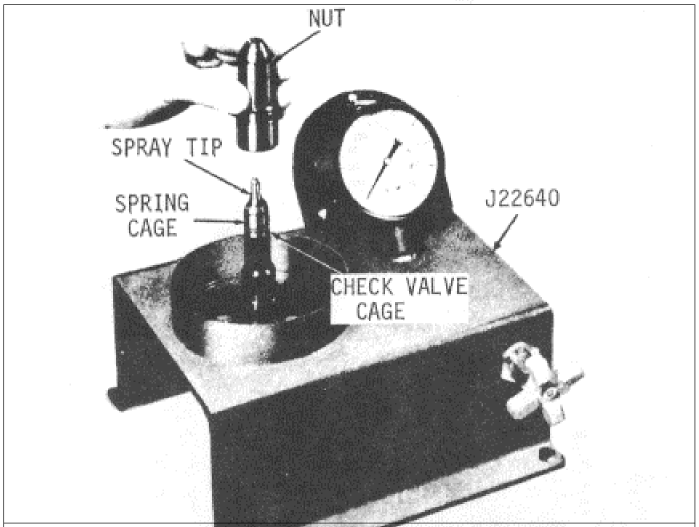


*Fig. 18*
*Installing Injector Valve Parts on Auxiliary Tester J 22640*

Note: Place the cam shift index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch and preheat the test oil to 95-150°F (35-400C).

(1) Place the proper injector adaptor between the tie rods and engage it with the fuel block locating pin. Then slide the adaptor forward and up against the fuel block face.
(2) Place the injector seat J 22410-226 into the permanent seat (cradle handle in vertical position). Clamp the injector into position by operating the air valve.

Note: Make sure the counter (Fig. 22) on the calibrator is preset at 1000 strokes. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and hold the reset lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

(3) Pull the injector rack out to the no-fuel position.
(4) Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

Note: The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

(5) After the calibrator has started, set the injector rack into the full-fuel position. Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.

| Injector | Calibrator J 22410 | |
|---|---|---|
| | Min. | Max. |
| N55 | 53 | 57 |

*Fig. 19*
*Fuel Output Chart*

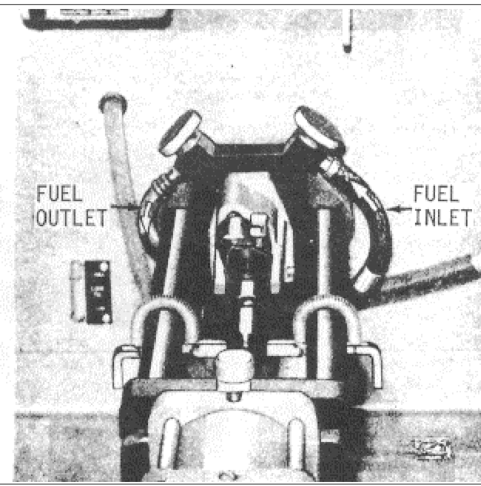


*Fig. 20*
*Position of Calibrator Fuel Flow Pipes*

(6) After the air is purged, press the fuel flow start button (red). This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after 1000 strokes.
(7) Shut the calibrator off (the calibrator will stop in less time at full-fuel).
(8) Observe the vial reading and refer to Fig. 19 to determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to Trouble Shooting Chart 6 in SM6-5-72.0 and Shop Notes in SM6-5-41.0 for the cause and remedy.

Note: Refer to SM6-5-41.0 for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

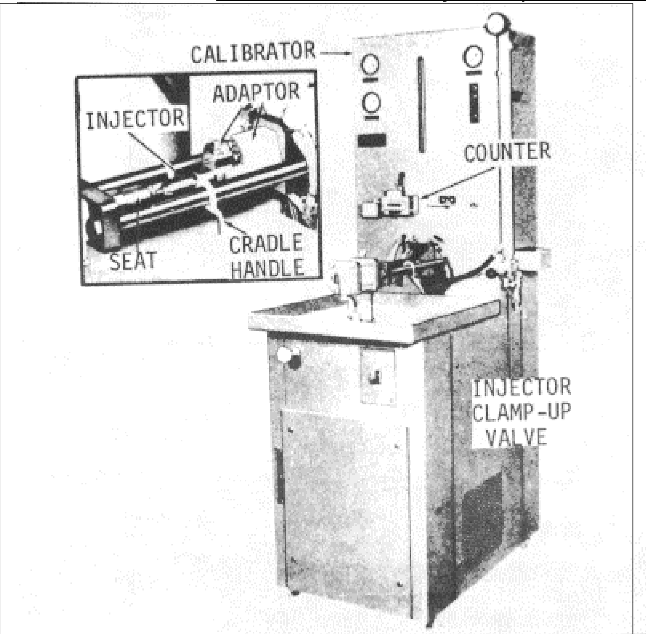


*Fig. 21*
*Injector in Calibrator J 22410*

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the test must be rebuilt and checked on the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

33.21 Disassemble Injector

If required, disassemble an injector as follows:

(1) Support the injector upright in injector holding fixture J 22396 (Fig. 23) and remove the filter caps, gaskets and filters.

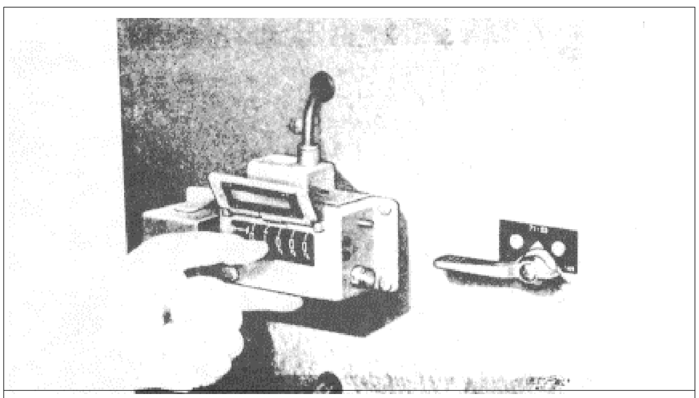

*Fig. 22*
*Setting Calibrator Stroke Counter*

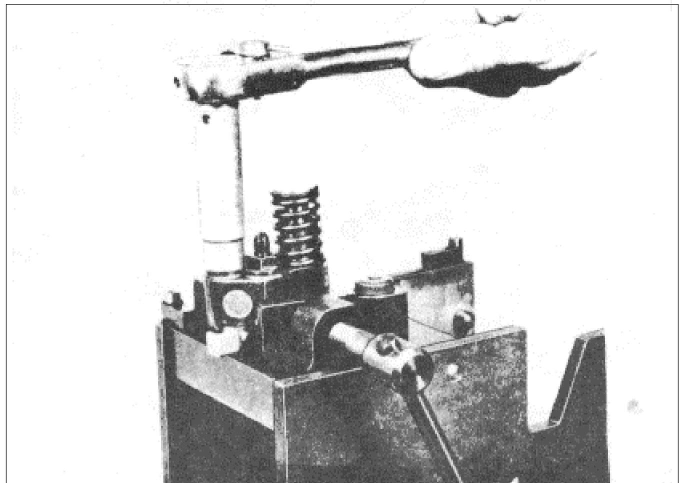

*Fig. 23*
*Removing or Installing Filter Cap*

Note: Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 34).

(2) Compress the follower spring as shown in Fig. 11. Then raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.

(3) Refer to Fig. 24 and remove the plunger follower, plunger and spring as an assembly.

(4) Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (Fig. 25).

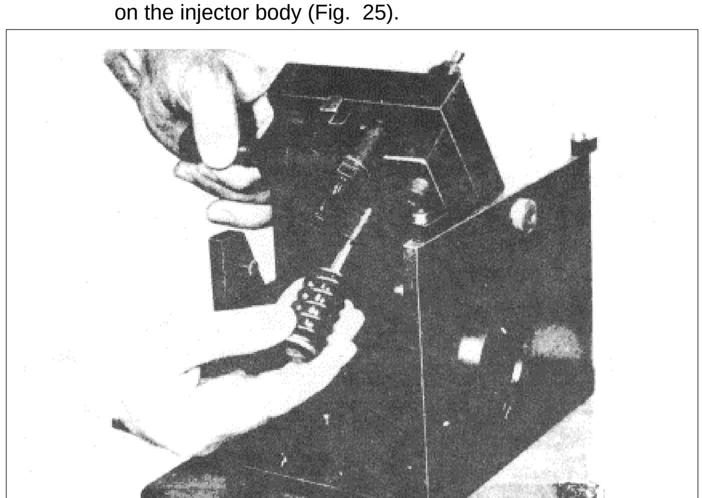

*Fig. 24*
*Removing or Installing Plunger Follower, Plunger and Spring*

## Service Manual SM6-5-33.0 Fuel Injector (Needle Valve)

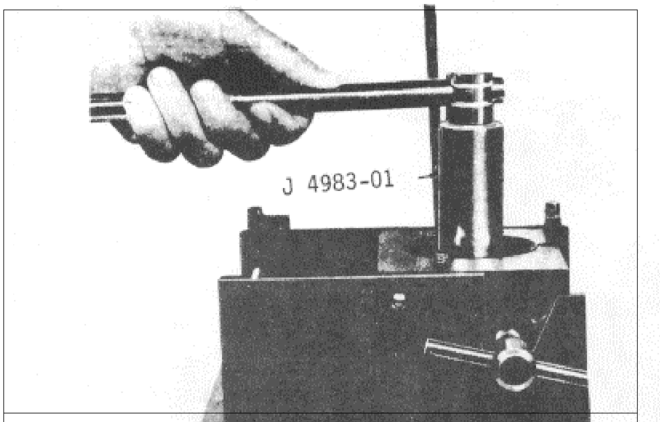


*Fig. 25*
*Removing Injector Nut*

(5) Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly.

When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291-02 as shown in Fig. 26.

(6) Refer to Fig. 36 and remove the spill deflector. Then lift the bushing straight out of the injector body.

(7) Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

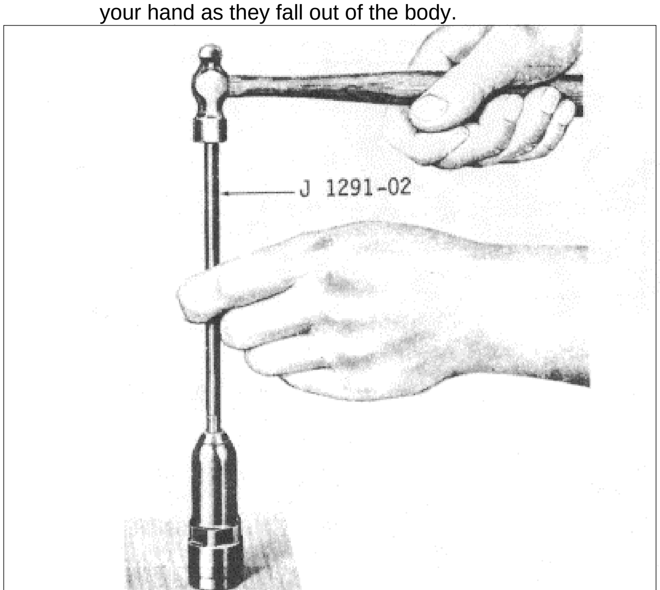


*Fig. 26*
*Removing Spray Tip from Injector Nut*

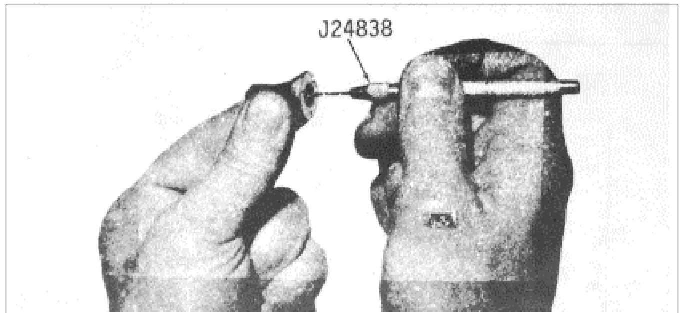


*Fig. 27*
*Cleaning Injector Spray Tip*

(8) Withdraw the injector control rack from the injector body. Also remove the seal ring from the body.

33.22 Clean Injector Parts

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Since most injector difficulties are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.
Wash all of the parts with clean fuel oil or a suitable cleaning solvent and dry them with clean, filtered compressed air. Do not use waste or rags for cleaning purposes. Clean out all of the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation. Methyl Ethyl Ketone J 8257 solution is recommended for this purpose.

Clean the spray tip with tool J 9464-01 (Fig. 27).

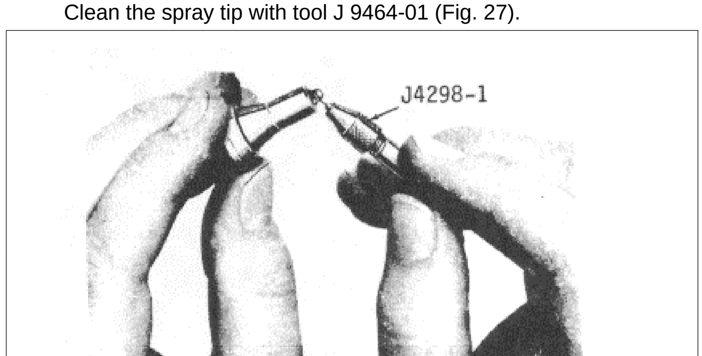


*Fig. 28*
*Cleaning Spray Tip Orifices*

**Service Manual** SM6-5-33.0 Fuel Injector (Needle Valve)

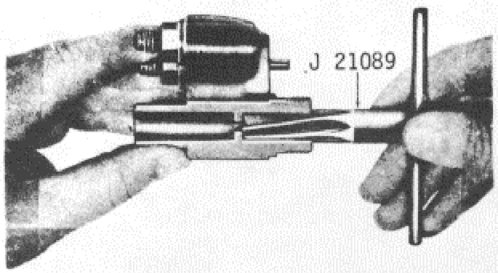


*Fig. 29*
*Cleaning Injector Body Ring*

**CAUTION**

Care Must Be Exercised When Inserting The Carbon Remover J 9464-01 In The Spray Tip To Avoid Contacting The Needle Valve Seat In The Tip.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wash the tip in fuel oil and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1 and the proper size spray tip cleaning wire. Use wire J 21460 to clean .0055" diameter holes and wire J 21461 to clean .006" diameter holes (Fig. 28).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16" with stone J 8170. Allow the wire to extend 1/8" from tool J 4298-1.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient

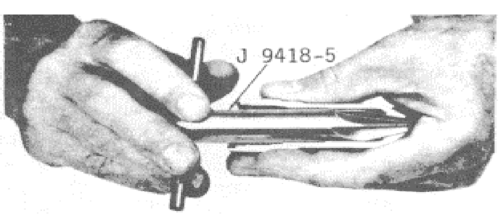


*Fig. 30*
*Cleaning Injector Nut Spray Tip Seat*

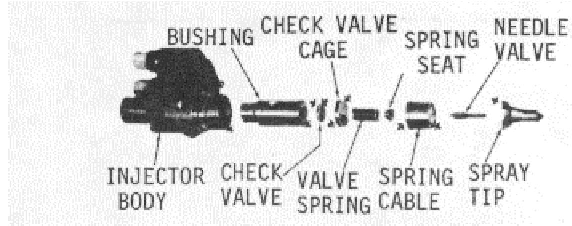


*Fig. 31*
*Sealing Surfaces which may Require Lapping*

method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

**CAUTION**

Do Not Buff Excessively. Do Not Use A Steel Wire Buffing Wheel Or The Spray Tip Holes May Be Distorted

When the body of the spray tip is clean, lightly buff the tip end in the same manner. This cleans the spray tip orifice area and will not plug the orifices.

Wash the spray tip in clean fuel oil and dry it with compressed air.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with com- pressed air.

Carefully insert reamer J 21089 in the injector body (Fig. 29). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

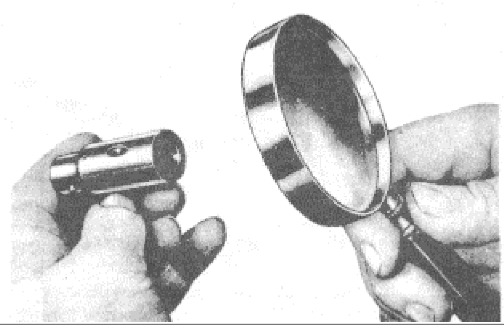

*Fig. 32*
*Examining Sealing Surface with a Magnifying Glass*

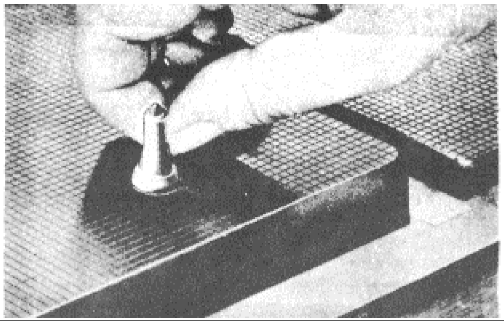

*Fig. 33*
*Lapping Spray Tip on Lapping Blocks J 22090*

Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.

Remove the carbon deposits from the lower inside diameter taper of the injector nut with carbon remover J 9418-5 (Fig. 30). Use care to minimize removing metal or setting up burrs on the spray tip seat.

Remove only enough metal to produce a clean uniform seat to prevent leakage between the tip and the nut. Carefully insert carbon remover J 9418-1 in the injector nut. Turn it clockwise to remove the carbon deposits on the flat spray tip seat.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wash the injector nut in clean fuel oil and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean fuel oil and dry them with compressed air.

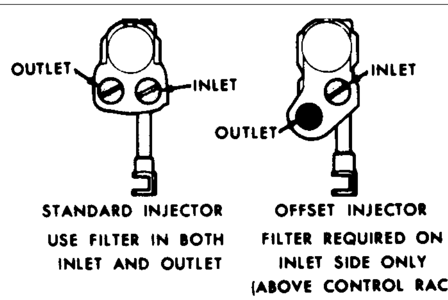


*Fig. 34*
*Location of Filter in Injector Body*

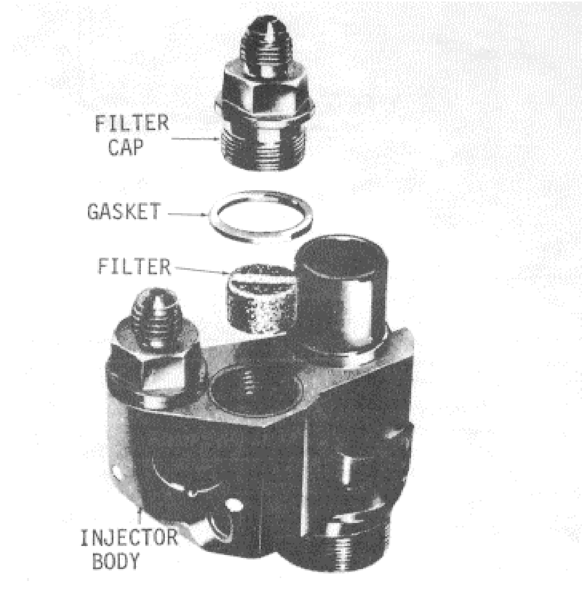


*Fig. 35*
*Details of Injector Filters and Caps and Their Relative Location*

Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. Keep the plunger and bushing together as they are mated parts.

After washing, submerge the parts in a clean receptable containing clean fuel oil. Keep the parts of each injector assembly together.

33.23 Inspect Injector Parts

Inspect the teeth on the control rack and the control rack gear for excessive wear or damage. Also check for excessive wear in the bore of the gear and inspect the gear retainer. Replace damaged or worn parts.

Inspect the injector follower and pin for wear. Refer to SM6-5-41.0.
Inspect both ends of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500 grit stone.

Inspect the follower spring for visual defects. Then check the spring with spring tester J 9666 and an accurate torque wrench.

The current injector follower spring (.142" diameter wire) has a free length of approximately 1.504" and should be replaced when a load of less than 70 lbs. will compress it to 1.028".

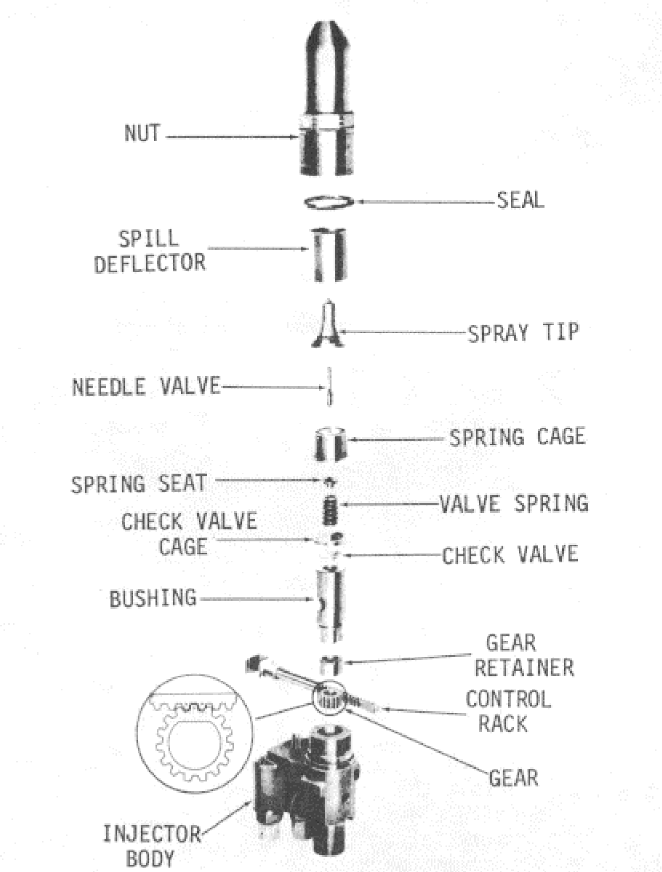


*Fig. 36*
*Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts*

It is recommended that at the time of overhaul, all injectors in an engine be converted to the current spring (.142" diameter wire) which will provide improved cam roller to shaft follow. However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Injector Bushing Inspectalite J 21471 can be used to check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and check for free movement. Replace the plunger and bushing as an assembly if any of the above damage is noted, since they are mated parts. Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

Examine the spray tip seating surface of the injector nut and spray tip for nicks, burrs, erosion or brinelling. Reseat the surface or replace the nut or tip if it is severely damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

Inspect the sealing surfaces of the injector parts indicated by arrows in Fig. 31. Examine the sealing surfaces with a magnifying glass as shown in Fig. 32 for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks erosion, cracks, chipping and excessive wear.

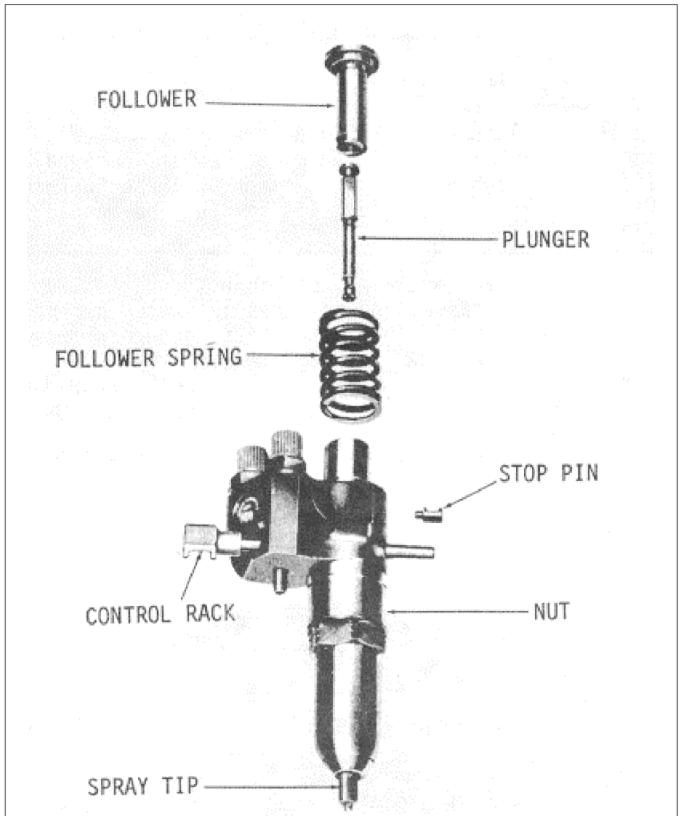


*Fig. 37*
*Injector Plunger, Follower and Relative Location of Parts*

**Service Manual** SM6-5-33.0 Fuel Injector (Needle Valve)

| Part Name | Minimum Thickness |
|---|---|
| Spray Tip (shoulder) | .199” |
| Check Valve Cage | .165”-.163” |
| Check Valve | .022” |
| Valve Spring Cage | .602” |

*Table 1 - Minimum Thickness (Used Parts)*

Also check for enlarged orifices in the spray tip. Replace damaged or excessively worn parts Check the minimum thickness of the lapped parts as noted in the chart.

Examine the seating area of the needle valve for wear or damage. Also examine the needle quill and its contact point with the valve spring seat. Replace damaged or excessively worn parts.

Examine the needle valve seat area in the spray tip for foreign material. The smallest particle of such material can prevent the needle valve from seating properly. Polish the seat area with polishing stick J 22964. Coat only the tapered end of the stick with polishing compound J 23038 and insert it directly into the center of the spray tip until it bottoms. Rotate the stick 6 to 12 times, applying a light pressure with the thumb and forefinger.

**CAUTION**

Be Sure That No Compound Is Accidentally Placed On The Lapped Surfaces Located Higher Up In The Spray Tip. The Slightest Lapping Action On These Surfaces Can Alter The Near-Perfect Fit Between The Needle Valve And Tip.

Before reinstalling used injector parts, lap all of the sealing surfaces indicated by the arrows in Fig. 31. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

33.24 Lapping Injector Parts

Lap the sealing surfaces indicated in Fig. 31 and Table 1 as follows:

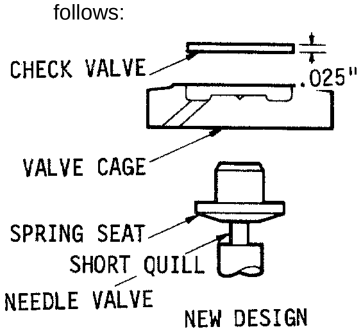


*Fig. 38 Injector Parts*

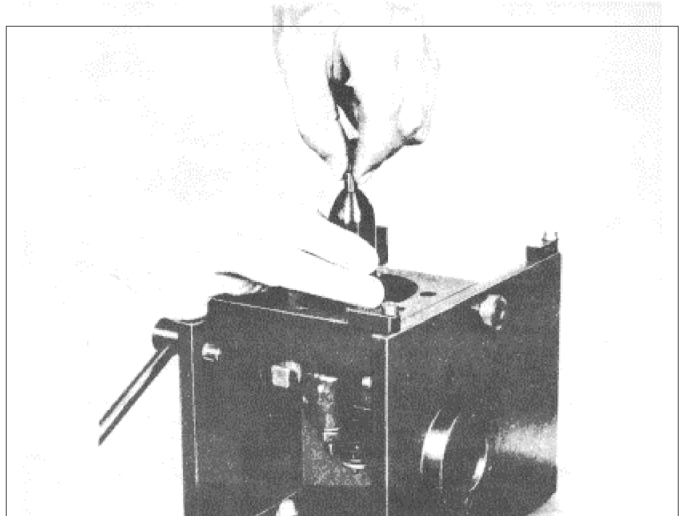

*Fig. 39*
*Tightening Injector Nut by Hand*

(1) Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.
(2) Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.
(3) Place the part to be lapped flat on the block as shown in Fig. 33 and, using a figure eight motion, move it back and forth across the block. Do not press on the part but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.
(4) After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. Do not lap excessively (refer to Table 1).

**WARNING**

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Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(5) When the part is flat, wash it in cleaning solvent and dry it with compressed air.

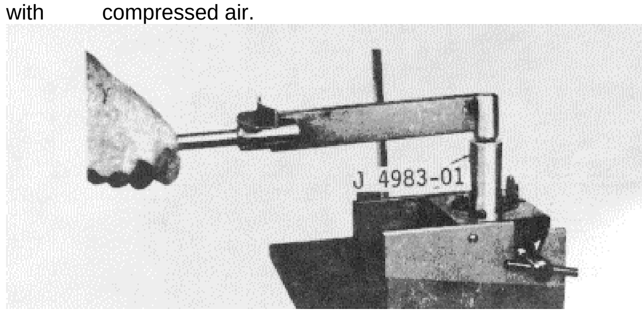


*Fig. 40*
*Tightening Injector Nut With Torque Wrench*

(6) Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. Do not lap excessively. Again wash the part in a cleaning solvent and dry it with compressed air.

(7) Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(8) Wash all of the lapped parts in clean fuel oil and dry them with compressed air.

33.25 Assemble Injector

Use an extremely clean bench to work on and to place the parts when assembling an injector. Also be sure all of the injector parts, both new and used, are clean.

Study Figs. 34 through 37 for the proper relative position of the injector parts, then proceed as follows:

33.26 Assemble Injector Filters

Always use new filters and gaskets when reassembling an injector.

(1) Insert a new filter, dimple end down, slotted end up, in each of the fuel cavities in the top of the injector body (Fig. 35).

Note<u>: Install a new filter in the inlet side (located over the injector rack) in a fuel injector with an offset body. No filter is required in the outlet side of the offset body injector (Fig. 34).</u>

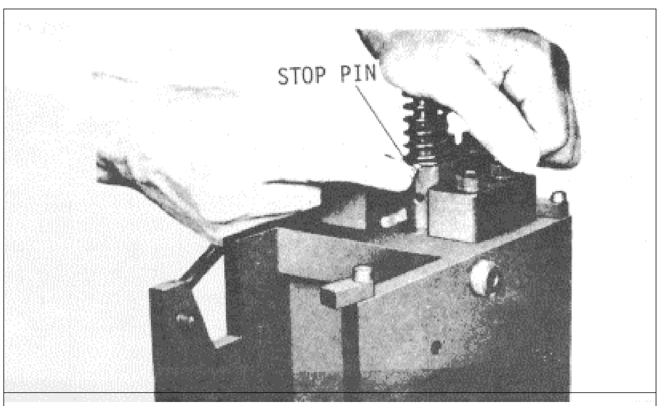


*Fig. 41*
*Installing Injector Follower Stop Pin*

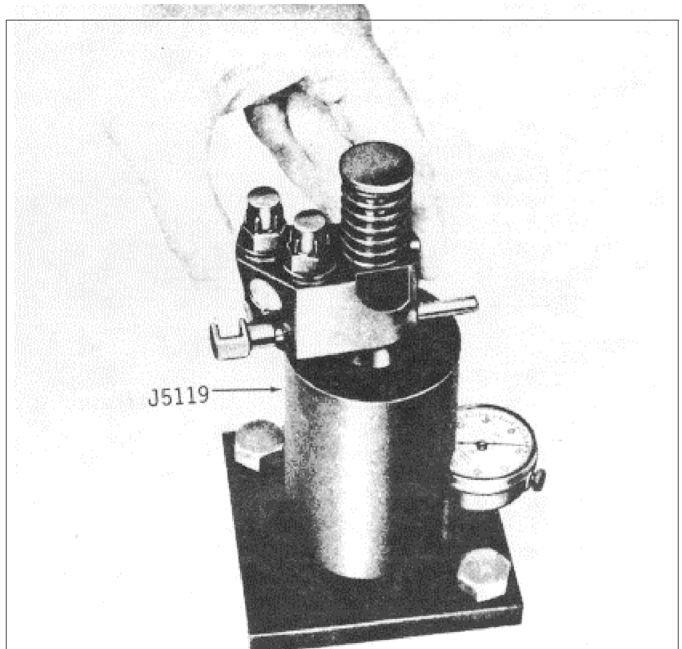


*Fig. 42*
*Checking Injector Spray Tip Concentricity*

(2) Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps to 65-75 ft-lbs (88-102 Nm) torque with a 9/16" deep socket (Fig. 23).
(3) Purge the filters after installation by directing compressed air or fuel through the filter caps.
(4) Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

33.27 Assemble Rack and Gears

Refer to Fig. 36 and note the drill spot marks on the control rack and gear. Then proceed as follows:
(1) Hold the injector body, bottom end up, and slide the rack through the hole in the body. Look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.
(2) Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 36).
(3) Place the gear retainer on top of the gear.
(4) Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

33.28 Assemble Spray Tip, Spring Cage and Check Valve Assemblies

Refer to Fig. 36 and assemble the parts as follows:
(1) Support the injector body, bottom end up, in injector holding fixture J 22396.
(2) Place a new seal ring on the shoulder of the body. Then place the spill deflector over the barrel of the bushing.

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(3) Place the check valve (without the .010" hole) centrally on the top of the bushing. Then place the check valve cage over the check valve and against the bushing.
(4) Insert the spring seat in the valve spring, then insert the assembly into the spring cage, spring seat first.
(5) Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.
(6) Insert the needle valve, tapered end down, inside of the spray tip (Fig. 2). Then place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.
(7) Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 39). Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.
(8) Use socket J 4983-01 and a torque wrench to tighten the injector nut to 75-85 ft-lbs (102-115 Nm) torque (Fig. 40).

Note: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

33.29 Assemble Plunger and Follower

(1) Refer to Fig. 37 and slide the head of the plunger into the follower.
(2) Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way in. Then place the follower spring on the injector body.
(3) Refer to Fig. 41 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. Then align the slot in the follower with the stop pin hole in the injector body. Next align the flat side of the plunger with the slot in the follower. Then insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

33.30 Check Spray Tip Concentricity

To assure correct alignment, check the concentricity of the spray tip as follows:
(1) Place the injector in the concentricity gauge J 5119 as shown in Fig. 42 and adjust the dial indicator to zero.
(2) Rotate the injector 3600 and note the total runout as indicated on the dial.
(3) If the total runout exceeds .008", remove the injector from the gauge. Loosen the injector nut, center the spray tip and tighten the nut to 75-85 ft-lbs (102-115 Nm) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

33.31 Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the test (except the visual inspection of the plunger) previously outlined under Test Injector.

The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble and test the injector again.

33.32 Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286-9, SM6-5-34.0 to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:
(1) Refer to Fig. 6 and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.
(2) Slide the injector rack control lever over so that it registers with the injector rack.
(3) Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20-25 ft-lbs (27-34 Nm) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

Note: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

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(4) Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in SM6-5-71.0.

**CAUTION**

There Is A Possibility Of Damaging The Exhaust Valves If The Exhaust Valve Bridge Is Not Resting On The Ends Of The Exhaust Valves When Tightening The Rocker Shaft Bracket Bolts. Therefore, Note The Position Of The Exhaust Valve Bridge Before, During and After Tightening The Rocker Shaft Bolts.

(5) Remove the shipping caps. Then install the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 ft-lbs (16-20 Nm) torque.

Important: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

**CAUTION**

An Indication Of Fuel Leakage At The Fittings Of The Fuel Injector Supply Lines And Connector Nut Seals Could Be Either Low Lubricating Oil Pressure (Dilution) Or Fuel Odor Coming From The Crankcase Breathers Or An Open Oil Filler Cap. When Any Of The Above Are Detected, Remove The Valve Rocker Cover. A Close Inspection Of The Rocker Cover, Cylinder Head, Fuel Lines And Connectors Will Usually Show If There Is A Fuel Leakage Problem. Under Normal Conditions, There Should Be A Coating Of Lubricating Oil Throughout The Cylinder Head Area And Puddles Of Oil Where The Fuel Pipes Contact The Connectors And Where The Fuel Connectors Contact The Cylinder Head. If These Areas Do Not Have The Normal Coating Of Lubricating Oil, It Is Likely That Fuel Oil Is Leaking And Washing Off The Lubricating Oil. Remove And Replace The Leaking Fuel Pipes And/Or Connectors. Reinstall The Rocker Cover. Then Drain The Lubricating Oil And Change The Oil Filter Elements. Refer To Operator's Manual And Refill The Crankcase To The Proper Level With The Recommended Grade Of Oil.

(6) Perform a complete engine tune-up as outlined in S!16-5-68.0.- However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control lever.

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Fig. 1. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at the top with a fluoroelastomer (Vinton) ring, and upset into a flare on the lower side of the cylinder head to create water-tight and gas-tight joints at the top and bottom.

Note: Do not use methoxy propanol based antifreeze in the cooling system of any Detroit Diesel engine.

34.1 Repair Leaking Injector Tube

To enable the repair of a leaking fuel injector hole tube at the seal ring, without removing the cylinder head from the cylinder block, a injector hole tube swaging tool J 28611 is available.

Before removing the fuel injector, pressurize the cooling system at the radiator to verify the injector tube seal ring leak. Then with the fuel injector removed, insert the swaging tool into the fuel injector hole tube. The tool is tapered and flanged to prevent damage to the cylinder head or injector tube. Hit the top of the tool moderately with a one pound hammer two or three blows seating the tool. This will cause the top edge of the injector hole tube to expand, thus increasing the crush on the injector tube seal ring and seal the leak. Install the fuel injector and again pressurize the cooling system to verify the leak has been stopped.

34.2 Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 22525 as follows:

(1) Remove, disassemble and clean the cylinder head as outlined in SM6-5-5.0.

(2) Place the injector tube installer J 5286-4 in the injector tube. Insert the pilot J 5286-5 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer (Fig. 1).

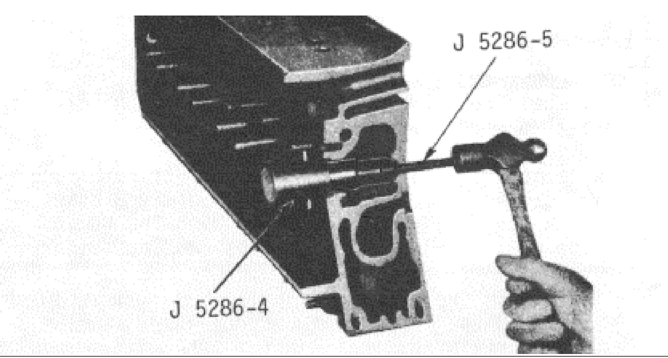


*Fig. 1*
*Removing Injector Tube*

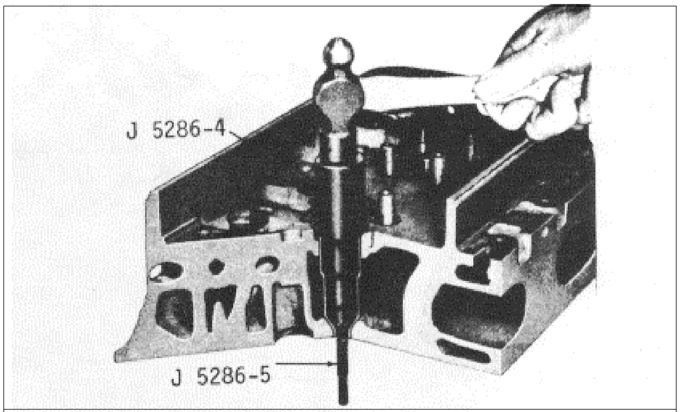


*Fig. 2*
*Installing Injector Tube*

(3) Tap on the end of the pilot to loosen the injector tube. Then lift the injector tube, installer and pilot from the cylinder head.

34.3 Install Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove dirt, burrs or foreign material that may prevent the tube from seating **6** at the lower end or sealing at the upper end. Then install the tube as follows:

(1) Place a new injector tube seal ring in the counterbore in the cylinder head.

(2) Place the installer J 5286-4 in the injector tube. Then insert the pilot J 5286-5 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig. 2).

(3) Slip the injector tube into the injector bore and drive it in place as shown in Fig. 2. Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.

(4) With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:

(a) Turn the cylinder head bottom side up, remove the pilot J 5286-5 and thread the upsetting die J 5286-6 into the tapped end of the installer J 5286-4 (Fig. 3).

(b) Then, using a socket and torque wrench, apply approximately 30 ft-lbs (41 Nm) torque on the upsetting die.

(c) Remove the installing tools and ream the injector tube as outlined below.

34.3 Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations: First, hand reamed, as shown in Fig. 4, to receive the injector body nut and spray tip; second, spot-faced to remove excess stock at the lower end of the injector tube; and third, hand reamed, as shown in Fig. 5, to provide a good seating surface for the bevel or

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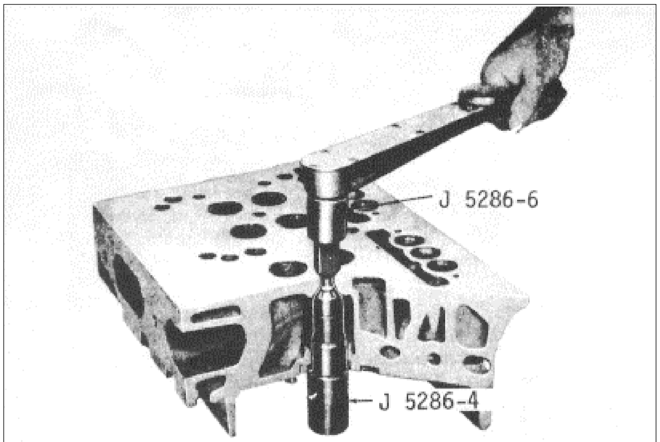



*Fig. 3*
*Upsetting Injector Tube*

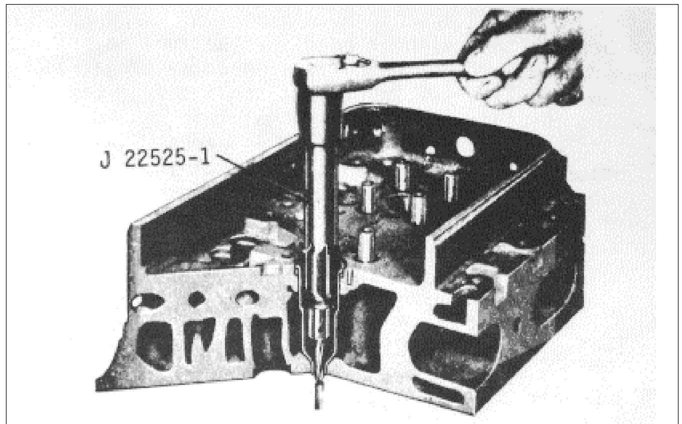



*Fig. 4*
*Reaming Injector Tube for Injector Body Nut and Spray Tip*

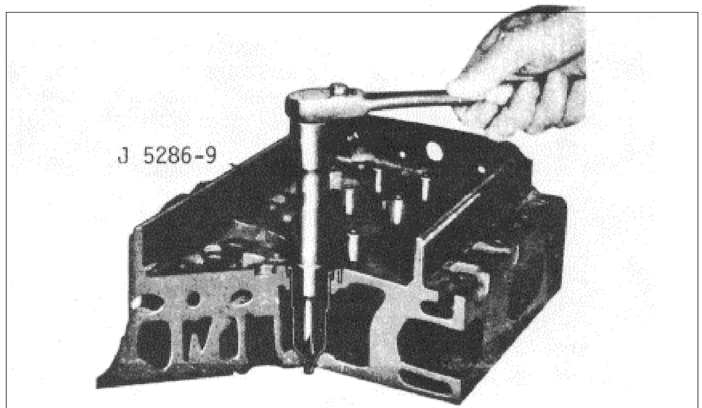



*Fig. 5*
*Reaming Injector Tube for Injector Nut*

the lower end of the injector nut. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

Note: The reamer should be turned in a clock- wise direction only, both when inserting and when withdrawing the reamer, because movement in the opposite direction will dull the cutting edges of the flutes.

(1) Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:
   (a) Place a few drops of light cutting oil on the reamer flutes, then carefully position the reamer J 22525-1 in the injector tube.
   (b) Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 4). Clean out all of the chips.

(2) Remove excess stock:
   (a) With the cylinder head bottom side up, insert the pilot of cutting tool J 5286-8 into the small hole of the injector tube.
   (b) Place a few drops of cutting oil on the tool. Then, using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to .005" below the finished surface of the cylinder head.

(3) Ream the bevel seat in the injector tube:

The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip In the combustion chamber. Therefore, to determine the amount of stock that must be reamed from the bevel seat of the tube, refer to Fig. 6.

Install gauge J 25521 in the indicator tube. Zero the sled gauge dial indicator J 22273 to the fire deck Gauge J 25521 should be flush to i .014" with the fire deck of the cylinder head (Fig. 7).

Note: Any fire deck resurfacing work must be done prior to final injector tube seat gauging. Refer to SM6-5-5.0 for resurfacing instructions.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

With the first reaming operating completed and the injector tube spot-faced, wash the interior of the injector tube with clean solvent and dry it with compressed air. Then perform the second reaming operation as follows:

(a) Place a few drops of cutting oil on the

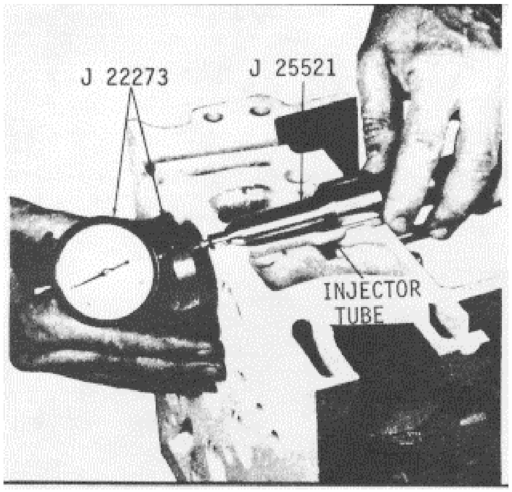



*Fig. 6 Measuring Relationship of Bevel Seat of Injector Tube to Fire Deck of Cylinder Head*

bevel seat of the tube. Carefully lower the reamer J 5286-9 into the injector tube until it contacts the bevel seat.

(b) Make a trail cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips and look at the bevel seat to see what portion of the seat has been cut.

(c) Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress.

(d) Remove the chips from the injector tube and, using gauge J 25521, continue the reaming operation until the shoulder of the spray tip is flush to i.014" with the fire deck of the cylinder head as shown in Fig. 7. Then wash the interior of the injector tube with clean solvent and dry it with compressed air.

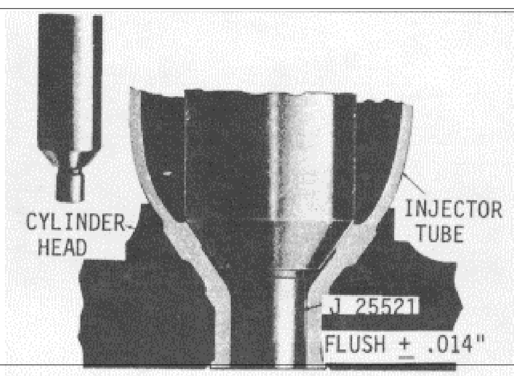



*Fig. 7*
*Measuring Relationship of Gauge to Fire Deck of Cylinder Head*

The positive displacement gear-type fuel pump (Fig.1) transfers fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return manifold and fuel return line.

The fuel pump is attached to the rear end plate cover of the blower assembly with three nylon patch bolts which prevents the oil in the blower cover from seeping out around the bolt threads. The' pump is driven off the end of the blower lower rotor by means of a drive coupling fork attached to the end of the pump drive shaft and mating with a drive disc attached to the blower rotor as shown in Fig. 2.

On certain applications, the fuel pump is attached to a special flywheel housing large hole cover. It is driven off of the balance shaft gear by means of a drive coupling fork attached to the end of the pump drive shaft and mating with a drive adaptor bolted to the balance shaft gear.

The fuel pump is right-hand rotation, and stamped "RH IN"

A high capacity fuel pump with 3/8" wide gears is used to increase fuel flow and reduce fuel spill temperature.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal-to-metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

The fuel pump body is recessed to provide running space for the pump gears (Fig. 3).Recesses are also provided at the inlet and outlet positions of the gears. The small hole "A" permits the fuel oil in . the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole "B" and provides for relief of excess discharge pressures. Fuel re-enters the inlet side of the pump through hole "C" when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole "C". The cavity "D" provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

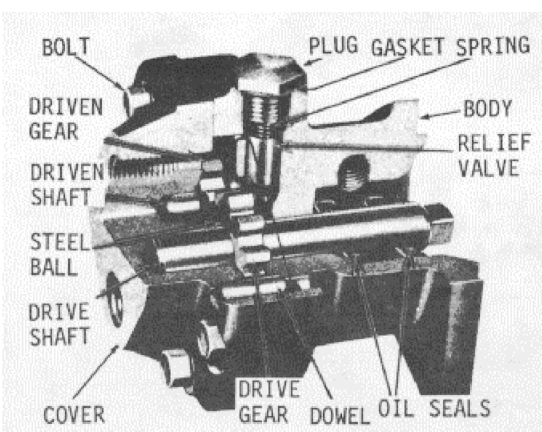



*Fig. 1*
*Typical Fuel Pump*

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the blower timing gear compartment (Fig. 4). The oil seals are installed with the lips of the seals facing toward the flanged end of the pump body. A small hole "E" (Fig. 3) serves as a vent passageway in the body, between the inner oil seal and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the inner seal.

However, in certain applications, where the fuel supply tank is mounted at a level higher than the fuel pump on the engine, the inner seal is installed -with the lip of the seal facing the gear pocket (Fig. 4). In this case, the inner seal will prevent seepage of fuel oil along the pump shaft and out the drain hole in the pump body, especially when the engine is shut down. Fuel pumps with this seal arrangement are identified by a "star" stamped on the ground face of the pump cover. However, a standard pump may be reworked for use in such applications by removing the two oil seals and installing new seals with the lips facing away from each other.

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seepage. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

The drive and driven gears are a line-to-line to .001" press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft (Fig. 2).

A spring-loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to the fuel filter) reaches approximately 65 psi (448

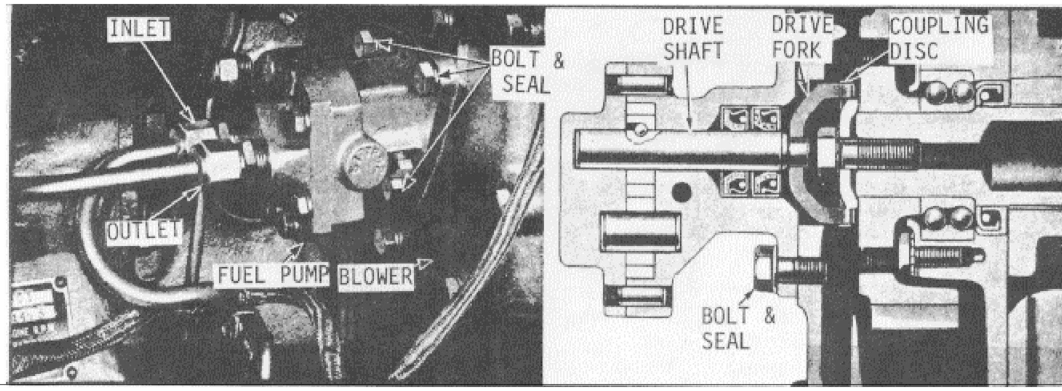



*Fig. 2*
*Typical Fuel Pump Mounting and Drive*

35.1 Operation

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by by-passing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 67 to 75 psi (448 to 517 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold as shown in SM6-5-71.0.

35.2 Remove Fuel Pump

(1) Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.
(2) Disconnect the drain tube, if used, from the fuel pump.
(3) Remove the three pump attaching bolts, using wrench J 4242, and withdraw the pump from the blower.
(4) Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

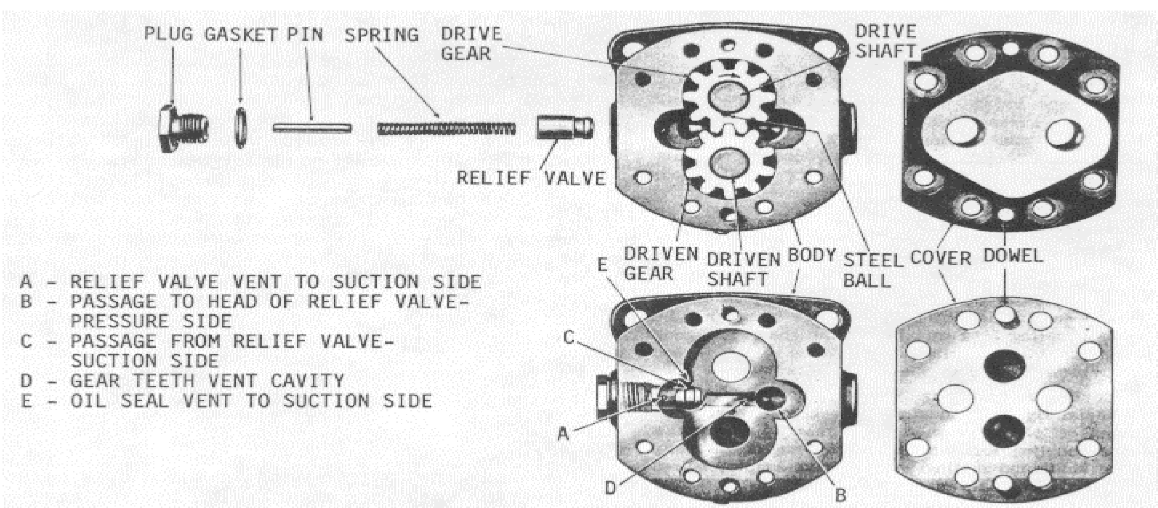



*Fig. 3*
*Fuel Pump Valving and Rotation (Right-Hand Pump)*

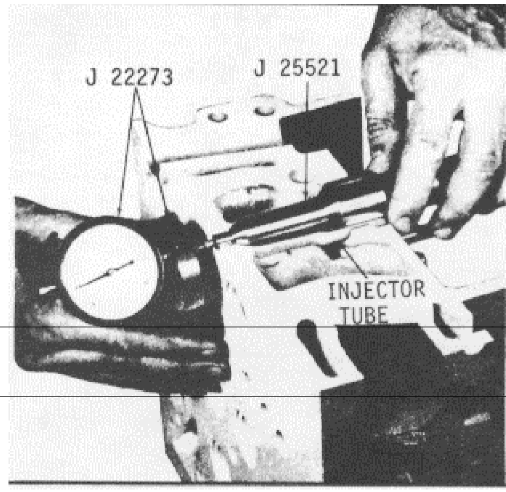



*Fig. 4*
*Fuel Pump Oil Seal Arrangements*

35.3 Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508-10 as shown in Fig. 5, refer to Figs. 1 and 7 and disassemble the pump as follows:

(1) Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.
(2) Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.
(3) Press the drive shaft just far enough to remove the steel locking ball. Then invert the shaft and gear assembly and press the shaft from the gear. Do not misplace the steel ball. Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.
(4) Remove the driven shaft and gear as an assembly from the pump body. Do not remove the gear from the shaft. The driven gear and shaft are serviced only as an assembly.

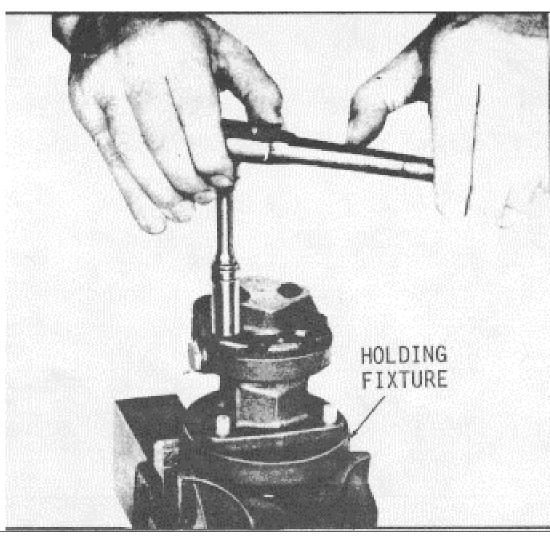



*Fig. 5*
*Removing Pump Cover*

(5) Remove the relief valve plug and copper gasket.
(6) Remove the valve spring, pin and relief valve from the valve cavity in the pump body.
(7) If the oil seals need replacing, remove them with oil seal remover J 1508-13 (Fig. 6). Clamp the pump body in a bench vise and tap the end of the tool with a hammer to remove the outer and inner seals.

Note: Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position.

35.4 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Clean all of the parts in clean fuel oil and dry them with compressed air.

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts if necessary. The driven shaft is serviced as a gear and shaft assembly only.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together.

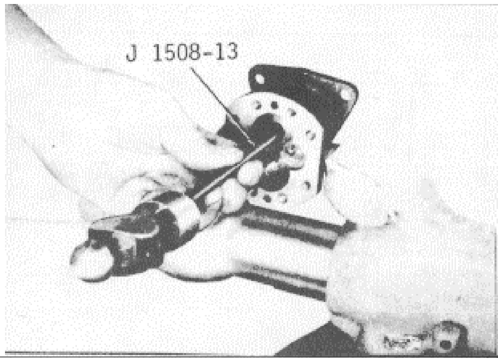



*Fig. 6*
*Removing Oil Seals*

Any scratches or slight damage may result in pressure leaks. Also check for wear at areas contacted by the gears and shafts. Replace the pump cover or body if necessary. The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

35.5 Assemble Fuel Pump

Refer to Figs. 1, 3 and 7 and assemble the pump as follows:

(1) Lubricate the lips of the oil seals with a light coat of vegetable shortening, then install the oil seals in the pump body as follows:

(a) Place the inner oil seal on the pilot of the installer handle J 1508-8 so that the lip of the seal will face in the same direction as the original seal which was removed, or according to the application as previously described.

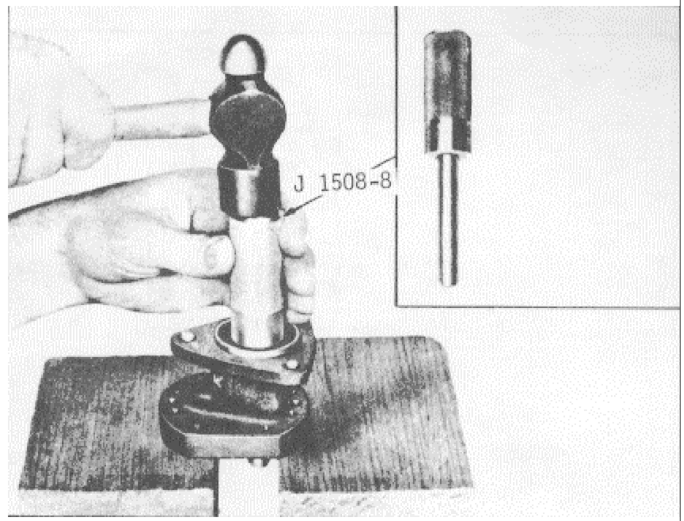



*Fig. 8*
*Installing Inner Oil Seal*

(b) With the pump body supported on wood blocks (Fig. 8), insert the pilot of the installer handle in the pump body so the seal starts straight into the pump flange. Then drive the seal in until it bottoms.

(c) Place the shorter end of the adaptor J 1508-9 over the pilot and against the shoulder of the installer handle. Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing the adaptor. Then insert the

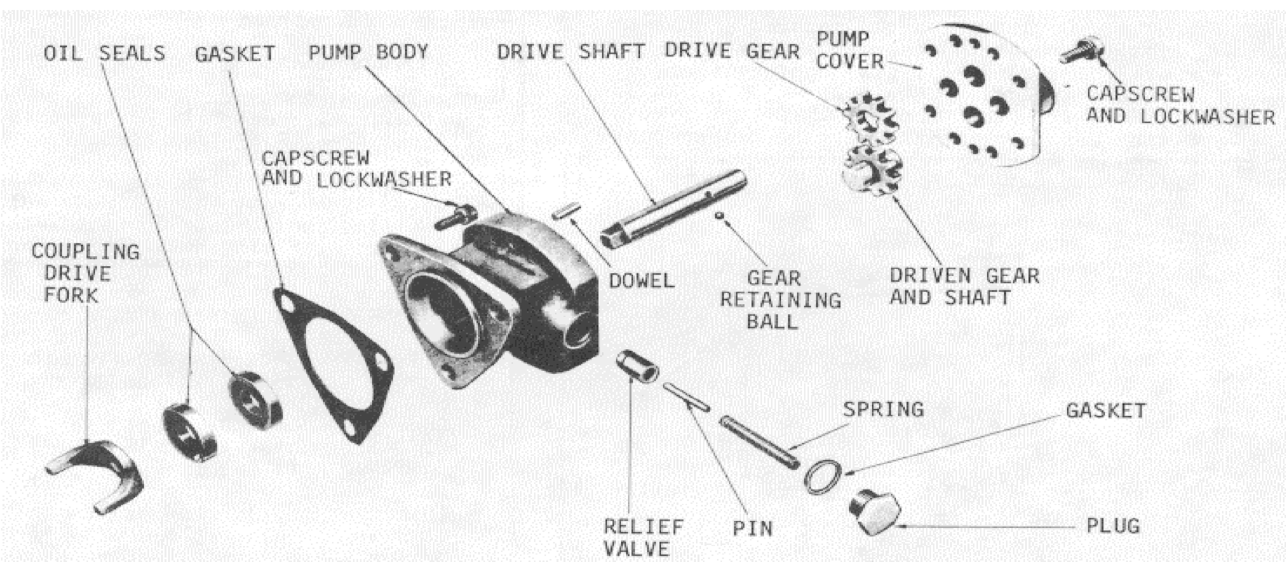



*Fig. 7*
*Fuel Pump Details and Relative Location of Parts*

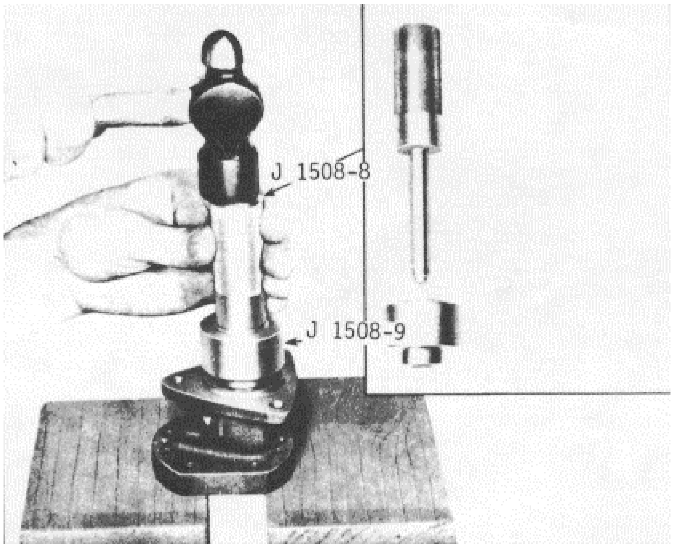



Fig. 9
Installing Outer Oil Seal

pilot of the installer handle into the pump body and drive the seal in (Fig. 9) until the shoulder of the adaptor contacts the pump body. Thus the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

(2) Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring inside of the valve and the pin inside of the spring. With a new gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the 1/2"-20 plug to 18-22 ft-lbs (24-30 Nm) torque.

(3) Install the fuel pump drive gear over the end of the drive shaft which is not squared (so the slot in the gear will face the plain end of the shaft). This operation is very important, otherwise fine score marks caused by pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the gear retaining ball detent. Then place the ball in the detent and press the gear back until the end of the slot contacts the ball.

(4) Lubricate the pump shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals as shown in Fig. 10.

(5) Place the driven shaft and gear assembly in the pump body.

Note: <u>The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear' with a slot is used, the slot must face toward the pump cover</u>.

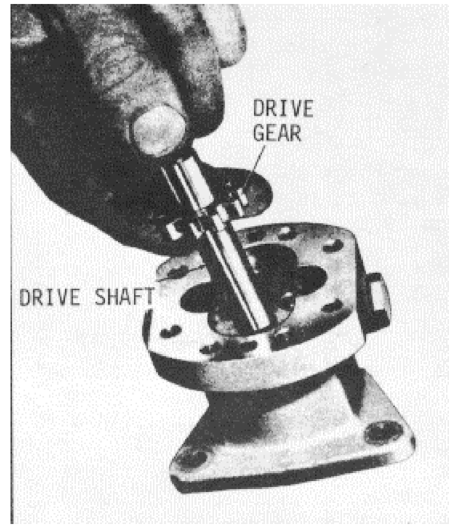



Fig. 10
Installing Drive Shaft and Gear Assembly

(6) Lubricate the gears and shafts with clean engine oil.

(7) Apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area. Then place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

Note: <u>The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too much sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result</u>.

(8) Secure the cover in place with eight bolts and lockwashers, tightening the bolts alternately and evenly.

(9) After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.

(10) Install 1/8" pipe plugs in the upper unused drain holes.

(11) If the pump is not to be installed immediately, place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

35.6 Install Fuel Pump

The pump must always be installed with the inlet opening in the pump cover (marked "RH IN") on the side toward the cylinder block. Note in Fig. 2 that the fuel pump is bolted to the blower. The pump is driven by a drive disc at the rear of the blower lower rotor. Install the pump as fol1ows:

(1) Affix a new gasket to the pump body mounting flange. Then place the drive coupling fork on the square end of the drive shaft.

(2) Place the fuel pump against the blower, being certain that the drive couplings fork registers with the slots in the drive disc on the blower rotor shaft.

(3) Secure the pump to the blower with three nylon patch bolts.

Note: To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

(4) If removed, install the fuel inlet and outlet fittings in the pump cover.

(5) Connect the inlet and outlet fuel lines to the fuel pump.

(6) Connect the fuel pump drain tube, if used, to the pump body.

(7) If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine. This will prevent the possibility of pump seizure upon initial starting.

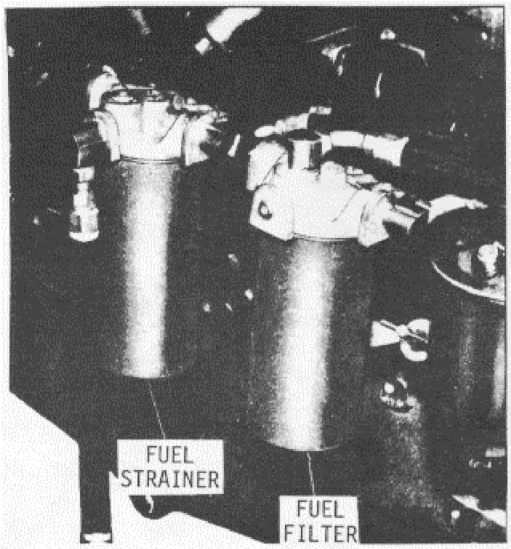



*Fig. 1*
*Typical Spin-On Filter Mounting*

A spin-on type fuel strainer and fuel filter (Fig. 1) is used. The spin-on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly (Fig. 2). No separate springs or seats are required to support the filters.

The filter covers incorporate a threaded sleeve to accept the spin-on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

The fuel strainer and fuel filter are essentially the same in construction and operation, and they will be treated as one in this section.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

No drain cocks are provided on the spin-on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before reinstalling it.

36.1 Operation

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The fuel filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters through the inlet passage in the cover and into the shell surrounding the filter element. Pressure or suction created by the pump causes the fuel to flow through the filter element where dirt particles are removed. Clean fuel flows to the interior of the filter element, up

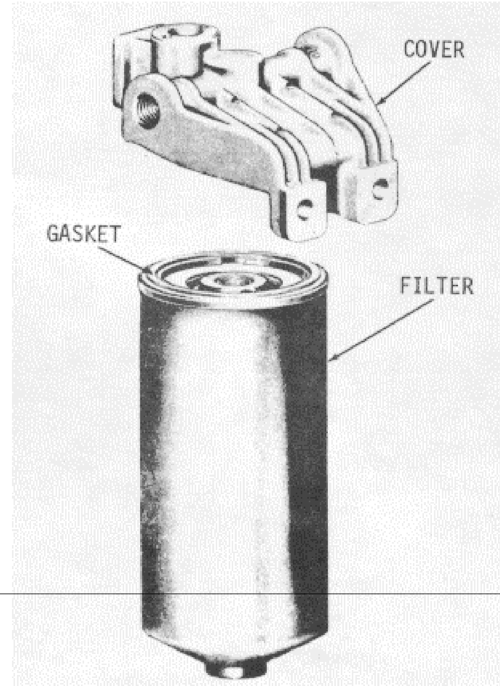



*Fig. 2*
*Spin-On Filter Details*

through the central passage in the cover and in-to the outlet passage, then to the fuel inlet manifold in the cylinder head.

If engine operation is erratic, indicating shortage of fuel or flow obstructions, refer to Trouble Shooting in SM6-5.72.0.

36.2 Filter (or Strainer) Replacement

A 1" diameter twelve-point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

(1) Unscrew the filter (or strainer) and discard it.
(2) Fill a new filter replacement cartridge about two-thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.
(3) Install the new filter assembly and tighten it to two-thirds of a turn beyond gasket contact.
(4) Start the engine and check for leaks.

The fuel injectors are supplied with fuel oil through pipes connected to the fuel inlet manifold. Excess fuel oil is returned to the fuel tank from the fuel injectors through pipes connected to the fuel outlet manifold.

The fuel inlet and outlet manifolds are an integral part of the current heads (Fig. 1).Since there are inlet and outlet passages provided opposite each injector position in the side of the head as well as at each end, greater flexibility is permitted in the installation of the fuel lines to the fuel manifolds.

The fuel passages are identified by the words "IN" (top manifold) and "OUT" (bottom manifold) cast in several places in the side of the cylinder head. The fuel manifold connectors are assemblied to the integral fuel manifold cylinder head, using special steel sealing washers, and tightened to 40-45 ft-lbs (54-61 Nm) torque.

A special fitting with a restricted opening is used in the fuel outlet manifold to maintain the proper pressure within the fuel system. Refer to SM6-5-70.0 for the size of restriction used.

37.1 A service cylinder head includes the shorter fuel connectors and the steel sealing washers. A length of flexible hose and two hose fittings are also provided. Since the fuel inlet can be located at any one of the inlet passages in the side of the head, the flexible hose can be cut to the required length for connecting the fuel filter to the fuel inlet manifold.

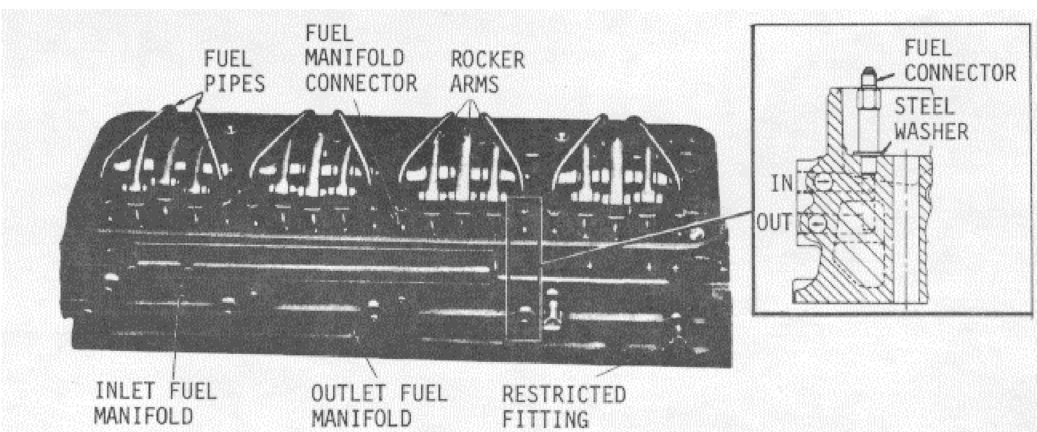



*Fig. 1*
*Cylinder Head with Integral Fuel Manifolds*

Horsepower requirements on an engine may vary due to fluctuating loads; therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control a governor is introduced in the linkage between the throttle control and the fuel injectors. The governor is mounted on the front end of the blower and is driven by the upper blower rotor. The following type of mechanical governor is used:
(1) Variable Speed Mechanical Governor.

The governor has an identification plate located on the control housing, containing the governor assembly number, type, idle speed range and drive ratio. The maximum engine speed, not shown on the identification plate, is stamped on the option plate attached to the valve rocker cover.

38.1 Check Governor Operation

Governor difficulties are usually indicated by speed variations of the engine; however, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations are present, check the engine as follows:

(1) Make sure the speed changes are not the result of excessive load fluctuations.
(2) Check the engine to be sure that all of the cylinders are firing properly (refer to SM6-5-77.O).If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined in SM6-5-33.0.
(3) Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

(1) If an injector rack sticks or moves too hard, it may be due to the injector hold-down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolt to 20-25 ft-lbs (27-34 Nm) torque.
(2) An injector which is not functioning properly may have a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in SM6-5-33.0.
(3) An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in SM6-5-68.0.
(4) The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their no-fuel position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in SM6-5-68.O.
(5) A bent injector control tube return spring may cause friction in the operation of the injector control tube. f the spring has been bent or otherwise distorted, install a new spring.
(6) Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary. If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

The variable speed mechanical governor (Fig. 1) performs three functions:

(1) Controls the engine idle speed.
(2) Limits the maximum no-load speed.
(3) Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The single weight governor is mounted on the front of the blower (Fig. 2) and is driven by the upper blower rotor.

The governor consists of four sub-assemblies:

(1) Control Housing Cover.
(2) Control Housing.
(3) Weight and Housing.
(4) Variable Speed Spring Housing and Shaft.

39.1 Operation

Two manual controls are provided on the variable speed governor; a stop lever (Fig. 1) for starting and stopping, and a speed control lever. For starting, the stop lever is moved to the RUN position, which holds the injector control racks near the full-fuel position. Upon starting, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion, which is transmitted through the riser and operating shaft to the operating shaft lever. One end of the operating lever bears against the variable speed spring plunger, while the other end provides a changing fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving governor weights and tension on the variable speed spring. When the forces reach a balanced condition again, the engine speed will be stabilized for. the new speed setting or new load.

A fuel rod connected to the differential lever and injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

Adjustment of the engine idle speed is accomplished by changing the tension on the variable speed spring by means of the idle speed adjusting screw. Refer to SM6-5-68.0 for idle speed adjustment.

Adjustment of the maximum no-load speed is accomplished by varying the tension on the variable speed spring by the installing or removal of stops and shims, as required. Refer to SM6-5-68.0 for maximum no-load speed adjustment.

39.2 Lubrication

Surplus oil returning from the cylinder head provides lubrication for the parts in the governor control housing, the riser thrust bearings, and the weight shaft end bearing. Oil, picked up from a reservoir in the blower front end plate, by a slinger attached to the lower rotor shaft, provides lubrication for the governor weights and weight carrier.

Pressure lubrication has been provided for the weight housing bearings on current engines. The oil tube is attached between the oil gallery in the cylinder block and the governor weight housing.

39.3 Remove Governor

Governor operation should be checked as outlined -in SM6-5-38.0 before the governor is removed from 6 the engine. If, after performing these checks, the governor fails to control the engine properly_ it should be removed and reconditioned.

(1) Refer to Fig. 2 and disconnect the throttle control rod and booster spring from the speed control lever.
(2) Remove the breather tube.
(3) Remove the four cover screws and lift the governor cover, with the stop lever and retraction spring and cover gasket from the governor housing.
(4) Refer to Figs. 1 and 2 and disconnect the fuel rod from the differential lever and injector control tube lever.
(5) Disconnect the oil tube at the governor weight housing, or cover.
(6) Remove the two governor-to-cylinder head bolts.
(7) Remove the control housing from the cylinder head and weight housing.
(8) Use wrench J 4242 and remove the six governor weight housing-to-blower bolts, then withdraw the housing from the blower.

39.4 Disassemble Governor

With the cover removed from the control housing, disassemble the governor as follows:

(1) Disassemble the governor cover (Fig. 3).
    (a) Loosen the clamping bolt and remove the stop lever from the shaft. Remove the lever torsion retraction spring.
    (b) Remove the control shaft lock ring and seal retainer. Withdraw the control shaft from the cover.

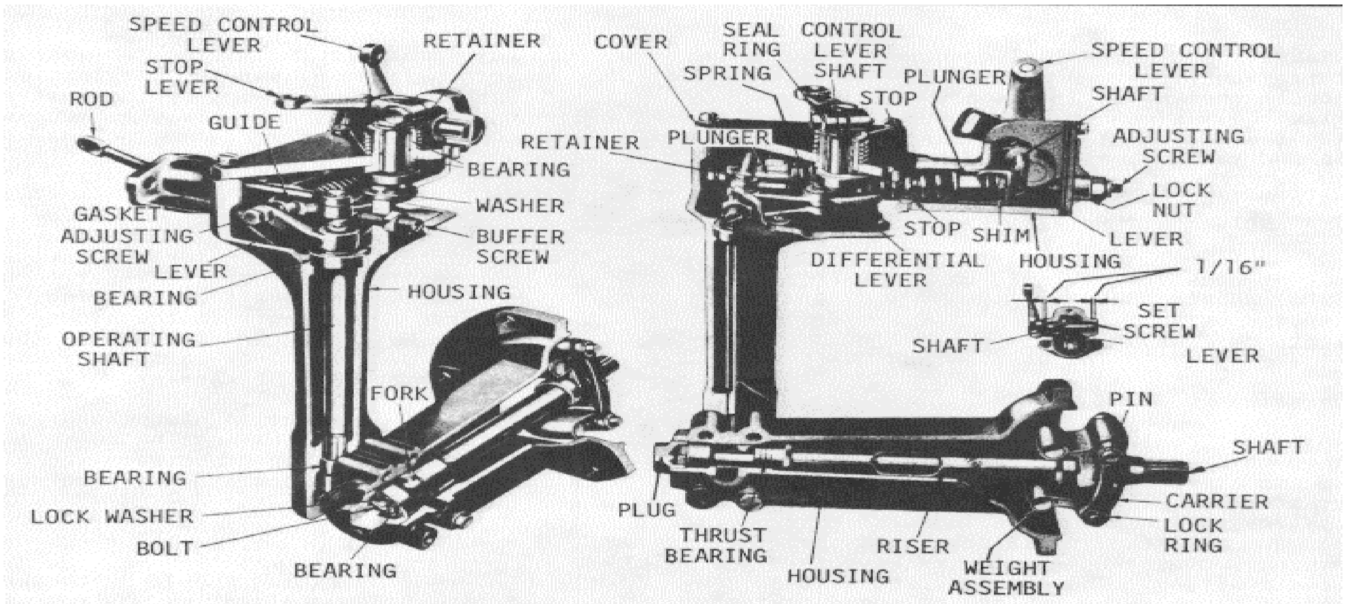



*Fig. 1*
*Variable Speed Mechanical Governor*

(c) Remove the seal ring from the governor cover.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(d) Wash the cover assembly, the cover assembly contains a bushing which is not serviced. When replacement is necessary use needle bearings) thoroughly in clean fuel oil and inspect the bushing for wear or damage.

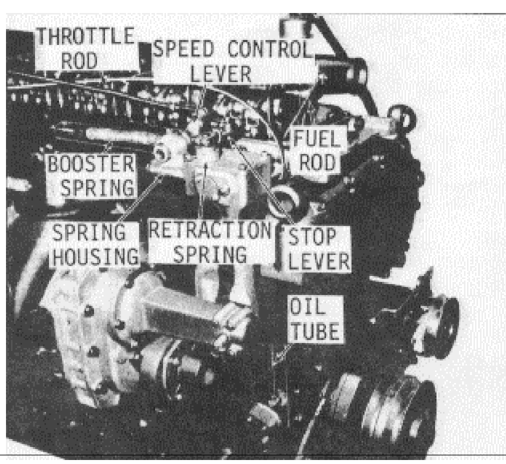



*Fig. 2*
*Variable Speed Governor Mounting*

(e) If bushing removal is necessary, place the inner face of the cover over the opening in the bed of an arbor (Fig. 4). Place remover J 21967 on top of the bushing and under the ram of the press, then press bushing out of the cover.

(2) Disassemble the governor control housing.

(a) Place the control housing (Fig. 5) in the soft jaws of a vise.

(b) Remove two bolts and lockwashers and withdraw the variable speed spring housing, spring plunger, and spring as an assembly. Withdraw the spring plunger from the plunger guide.

c) Remove the spring retainer and washer. Lift the differential lever off the pin of the operating shaft lever.

(d) Refer to Fig. 6 and remove the variable speed spring-plunger guide. Remove the bearing retaining screw, flat washer and lockwasher.

(e) Remove the expansion plug out of the lower end of the control housing.

(f) Support the control housing bottom side up on the bed of the press. Use a brass rod and press the operating shaft from the operating fork (Fig. 7).Withdraw the operating shaft, operating lever and bearing as an assembly from the control housing (Fig. 5).

(g) Support the operating shaft and lever on the bed of the press as shown in Fig. 8. Use a brass rod and press the shaft from the operating lever and bearing.

(3) Disassemble the governor weight housing.

(a) Place the weight housing (Fig. 9) in the

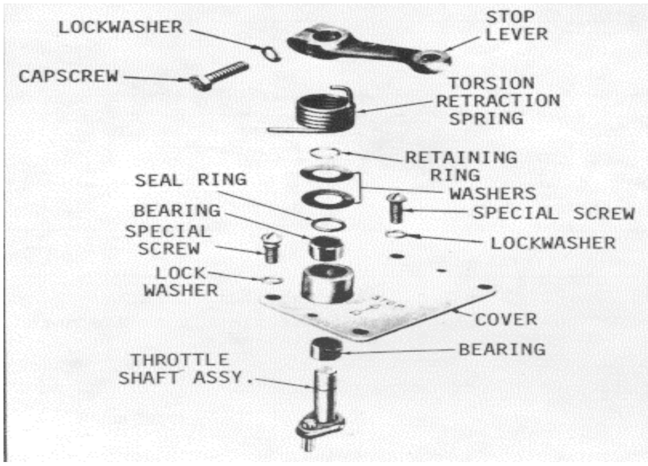



Fig. 3
Governor Cover Details and Relative Location of Parts

soft jaws of a vise. Remove the end plug and gasket.

(b) Straighten the tang of the lockwasher and remove the bearing retaining bolt.

(c) Thread a 5/16"-24 x 3" bolt into the tapped end of the weight shaft. Support the weight housing on the bed of the press as shown in Fig. 10, then press the shaft from the bearing.

(d) Slide the riser thrust bearing and governor riser from the shaft.

This bearing is specially designed to absorb thrust load; therefore, looseness between the mating parts does not indicate excessive wear.

(e) Remove the bearing from the weight housing.

(f) Use tool J 4880 and remove one lock ring from each weight pin. Withdraw the pins, flat washers and governor weights.

(g) If required, the weight carrier (Fig. 9) may be pressed from the governor weight shaft and a new carrier installed.

(4) Disassemble the governor variable speed spring housing.

(a) Refer to Fig. 1 and withdraw the variable speed spring, stops, spring plunger and shims from the spring housing.

(b) Loosen the bolt and withdraw the speed control lever (Fig. 1) from the speed control lever shaft. Remove the Woodruff key (Fig. 14) from the shaft.

(c) Remove the plain washer and seal from the shaft.

(d) On the spring housing, remove one screw and lockwasher and remove the spring housing cover and gasket. Then remove the set screw from the spring lever.

(e) Support the spring housing on the bed of the press with the shaft up. Use a brass rod and press the shaft, plug and bear-

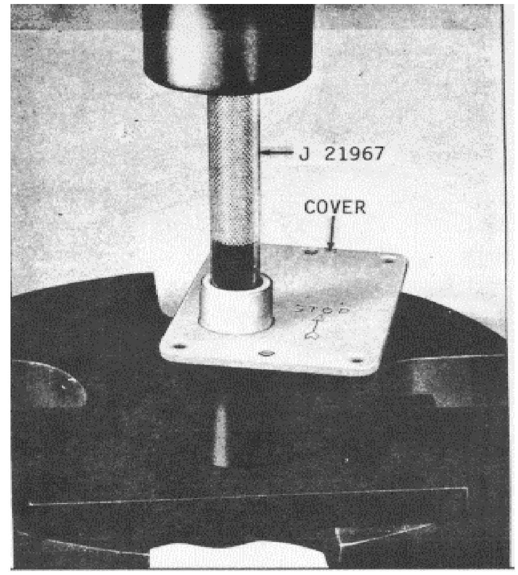



Fig. 4
Removing Bearings from Cover

ing from the housing. Remove the bearing from the shaft and the spring lever from the housing.

(f) If required, the second bearing may be pressed from the housing.

39.5 Inspection

**WARNING|**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Clean all of the parts with fuel oil and dry them with compressed air.

Inspect all of the governor components and replace worn or damaged parts.

Revolve the operating shaft bearing and the governor weight shaft bearing slowly by hand; replace the bearings if rough or tight spots are detected.

Inspect the operating shaft and shaft bushing for excessive wear. If excessive wear is noted, a new bushing and shaft must be installed.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, a new thrust bearing assembly must be installed.

Inspect the bushing and the control lever shaft for excessive wear or flat spots. If one or both conditions exists, new bearings and control shaft must be installed.

The bushing contained in the cover assemblies is not serviced. When replacement is necessary, use needle bearings.

Inspect the spring lever shaft and bearings for excessive wear or flat spots at the bearing surface. If one or both conditions exist, a new shaft and bearings must be installed.

When installing, a new bearing in the spring housing lever assembly, note that the roller type bearing rides on a hardened bearing pin and is a press fit in the spring lever. Also, when installing the roller type bearing, the pressed-in pin must be below the surface of the lever and staked in three places on both sides.

Examine the weight carrier pins and bearings for excessive wear and flat spots. If either of these conditions exist, new parts must be installed.

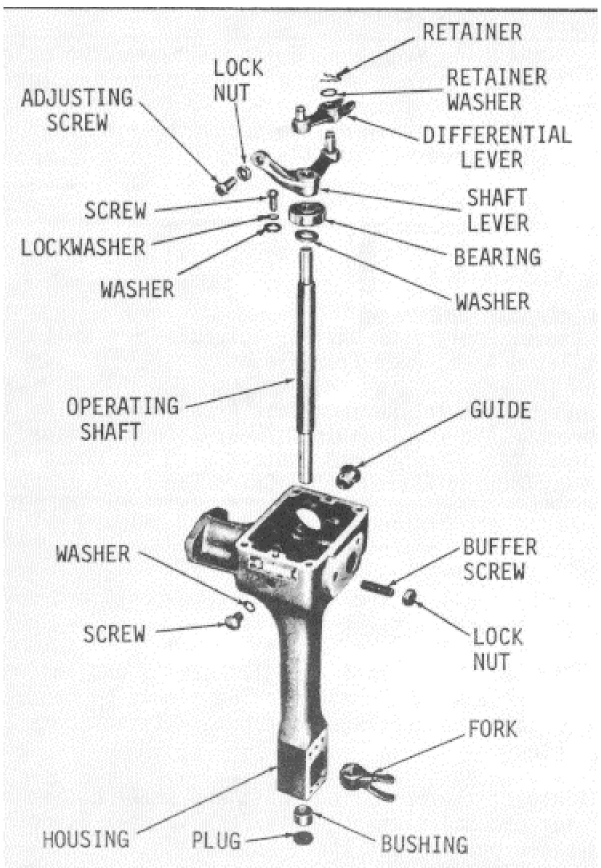



*Fig. 5*
*Governor Control Housing Details and Relative Location of Parts*

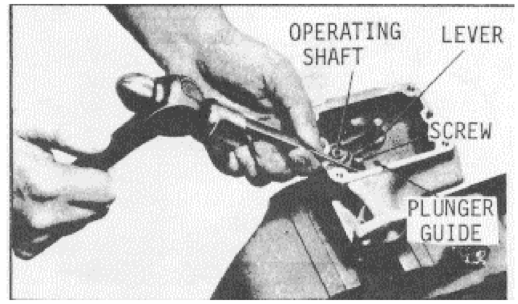



Fig. 6
Removing Variable Speed Spring Plunger Guide

Check the finished surface of the governor weights for flat spots. If flat spots are noted, new weights should be installed.

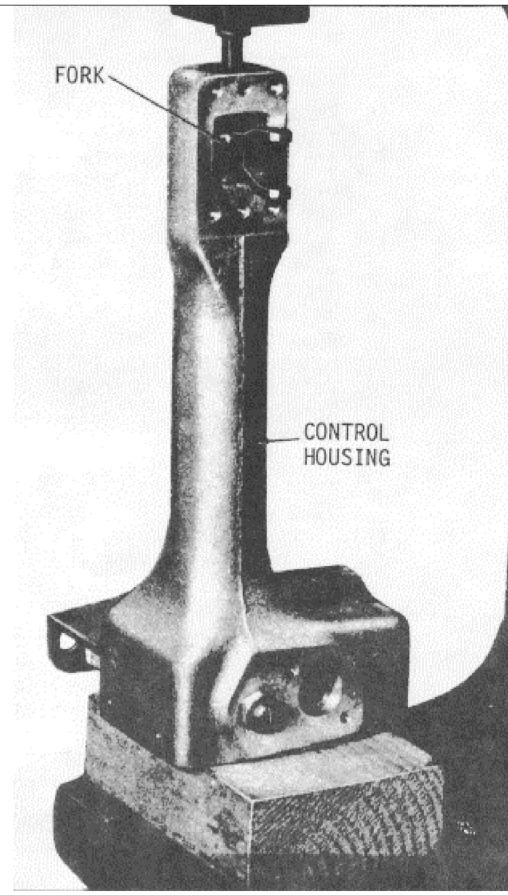



*Fig. 7*
*Removing Operating Shaft from Operating Fork*

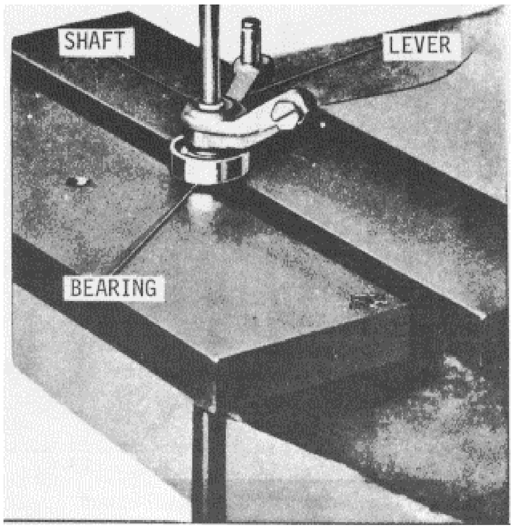



*Fig. 8. Removing Operating Shaft from Operating Lever*

39.6 Assemble Governor Cover

(1) If needle bearings are to be installed in the governor cover, place the governor cover on the bed of an arbor press with the inner face of the cover down. Start a new needle bearing straight into the bearing bore of the cover with number on the bearing up. Then insert bearing installer J 21068 (Fig. 11) in the bearing and press the bearing in until the shoulder on the tool contacts the cover.

(2) Reverse the governor cover on the bed of the press (inner face of cover up). Start the second bearing straight into the bore of the cover with the bearing number up. Press the bearing in flush with the cover with tool J 21068.

Note: Do not use impact tools to install needle bearings.

(3) Pack the needle bearings with grease. If the cover contained a bushing which was not removed, lubricate it with clean engine oil. Insert the throttle shaft through the bearing or bushing.

(4) Insert a seal ring over the throttle shaft and into the counterbore against the upper bearing. Place the retainer over the shaft and against the seal ring.

(5) Locate the lock ring in the groove of the throttle shaft.

(6) Place the torsion retraction spring over the cover hub with the hooked end up (Fig. 2). Then place the stop lever on the shaft and tighten the clamping bolt.

39.7 Assemble Governor Control Housing

(1) Place the bearing washer (Fig. 5) over the short, finished end of the operating shaft. Start the bearing over the end of the shaft. Support the opposite end of the shaft on the bed of the press. Using a sleeve having the same diameter as the bearing inner race, press the bearing on the shaft tight against the washer.

(2) With the pivot pin in the operating lever up, start the lever over the end of the shaft with the flat on the shaft registering with the flat surface in the lever. Press the lever on the shaft tight against the bearing.

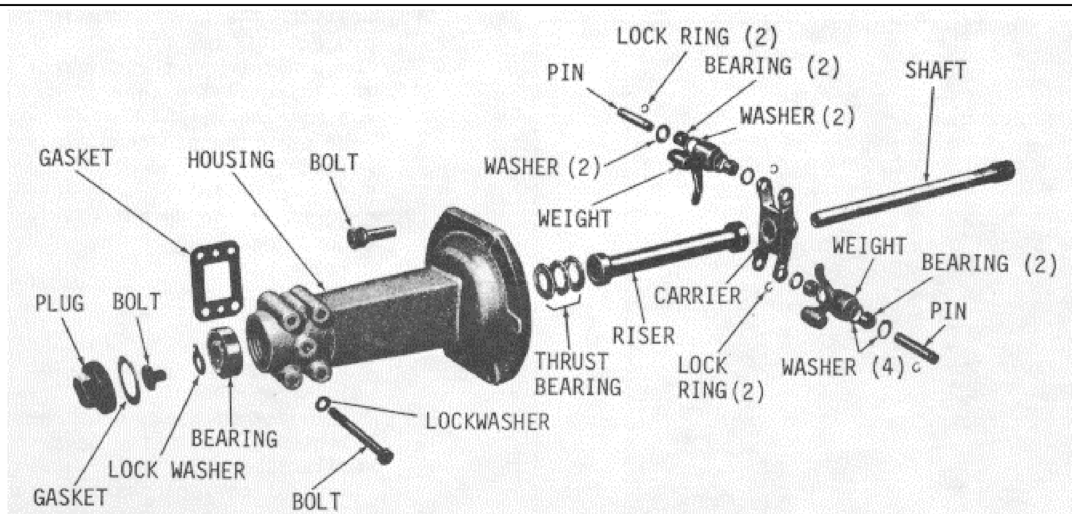



*Fig. 9. Governor Weight Housing Details and Relative Location of Parts*

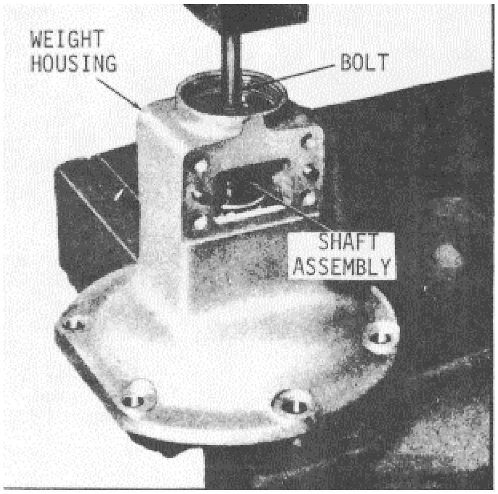



*Fig. 10. Removing Governor Weight and Shaft Assembly*

(3) Lubricate the bearing and operating shaft bushing in the housing with clean engine oil. Insert the lever and operating shaft assembly in the control housing.

(4) Position the operating fork over the lower end of the operating shaft so the finished side of the fork fingers will rest against the thrust bearing as shown in Fig. 1.

(5) Support the operating shaft and control housing on the bed of an arbor press with the upper end of the shaft resting on a steel block. Align the flat in the operating fork with the flat on the shaft, then place the sleeve over the end of the shaft and rest it on the fork. Press the fork straight down tight against the shoulder on the shaft.

(6) Place the differential lever over the pivot pin of the operating lever. Install the plain washer and spring retainer.

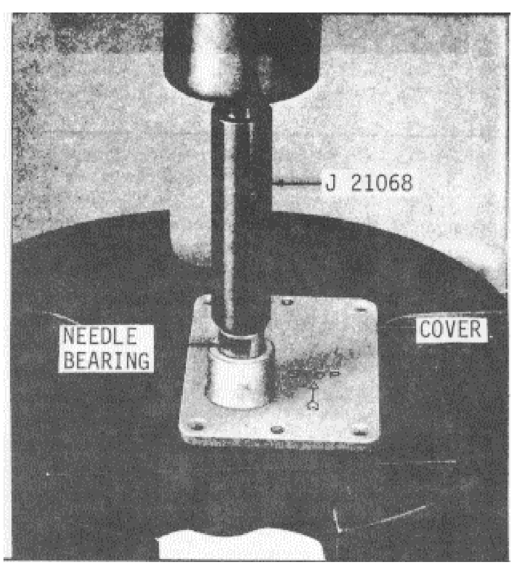



*Fig. 11. Installing Needle Bearing in Governor Cover*

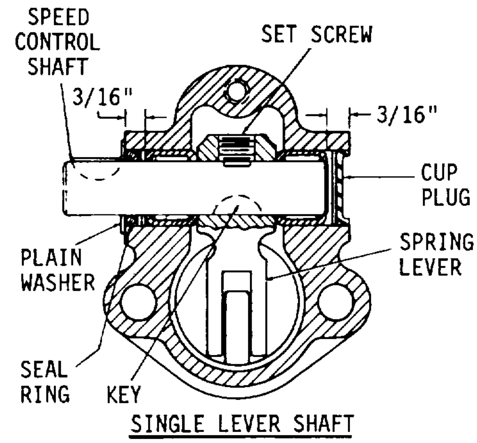



*Fig. 12. Cross Section of Governor Variable Speed Spring Housings*

(7) Place the lockwasher and the flat washer over the bearing retaining screw. Refer to Fig. 1 and thread the screw in the control housing tight to secure the bearing.

(8) Refer to Fig. 6 and insert the variable speed spring plunger guide in the control housing.

(9) Apply a good quality sealant around the outer periphery of the expansion plug and tap the plug into the lower end of the control housing.

39.8 Assemble Governor Weight Housing

(1) Install the lock ring (Fig. 9) in the groove of the weight pin. Place the flat washer over the pin and against the lock ring.

(2) Start the pin through the opening in the weight carrier. Place the second washer over the pin and against the projecting arm of the weight carrier.

(3) Position the governor weight between the projecting arms of the weight carrier. Push the pin through the governor weight. Place the third flat washer over the pin and against the weight.

(4) Then push the pin completely through the weight carrier and place the fourth flat washer over the pin and against the projecting arm of the weight carrier. Install the second lock ring in the groove of the weight carrier pin.

(5) Install the second governor weight as outlined in Steps 1 through 4. (6) Slide the riser over the shaft and against the finished surfaces of the governor weights as shown in Fig. 1.

(7) Assemble the riser thrust bearing on the weight shaft with the bearing race having the smaller inside diameter against the thrust riser. Incorrect installation of the bearing will result in erratic operation of the governor.

(8) Insert the weight carrier and shaft assembly in the weight housing.

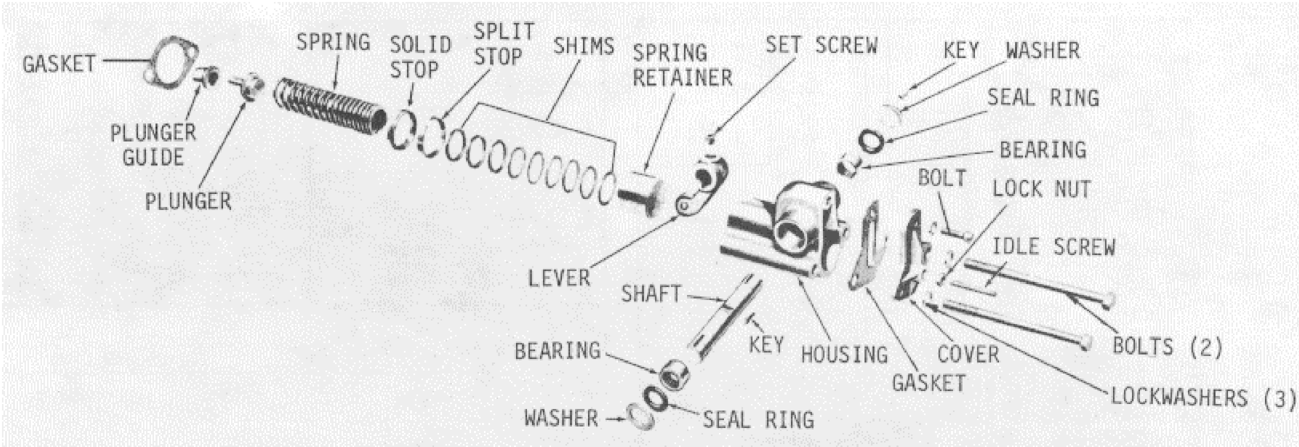



*Fig. 13. Variable Speed Spring Housing and Shaft Details and Relative Location of Parts*

(9) Support the splined end of the shaft on the bed of an arbor press. Start the shaft end bearing in the housing and cover the end of the shaft with the numbered side of the bearing facing away from the shaft. Press the bearing in place with a sleeve that bears against the inner race.

(10) Place a washer (Fig. 9) over the bearing retaining bolt. Thread the bolt into the tapped end of the shaft and tighten it. Bend the tang of the washer against the head of the bolt.

(11) Place a gasket in the housing and against the bearing. Apply a Loctite sealant, grade HV, or equivalent, to the full 3600 circumference of the end plug and thread the plug into the tapped end of the governor weight housing. Tighten the plug to 45ft-lbs (61 Nm) torque with either the flat or the point of the head on a horizontal line.

39.9 Assemble Variable Speed Spring Housing

(1) Refer to Figs. 12 and 13. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then start one of the bearings, numbered end up, straight in the bearing bore in the right-hand side of the spring housing.

(2) Install the needle bearing pilot rod J 9196-2 in the installer body J 9196-1 and secure it in place with the retaining screw.

(3) Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press as shown in Fig. 14, then press the bearing in the housing until the shoulder on the installer contacts the housing.

Note: When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

(4) If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

(5) Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

(6) Insert the correct end of the single or double lever type, speed control lever shaft (Fig. 12) through the bearing bore in the side of the spring housing, opposite the bearing previously installed. Align the key in the shaft with the keyway in the spring lever, and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the set screw hole in the lever.

(7) Thread the set screw into the spring lever, making sure the point of the screw is seated in the flat on the shaft.

(8) Place the second speed control lever shaft needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

(9) Remove the bearing pilot rod J 9196-2 from the installer body J 9196-1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press as shown in Fig. 14, then press the bearing in the housing until the shoulder on the installer contacts the housing.

(10) Apply a thin coat of sealing compound to the outside diameter of the cup plug. Start the cup plug straight in the bearing bore in the housing, then support the spring housing, bearings and shaft assembly on a sleeve on the bed of an arbor press, and press the cup plug in flush with the outside face of the housing (Fig. 12).

(11) Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to 5-7 ft-lbs (7-10 Nm) torque.

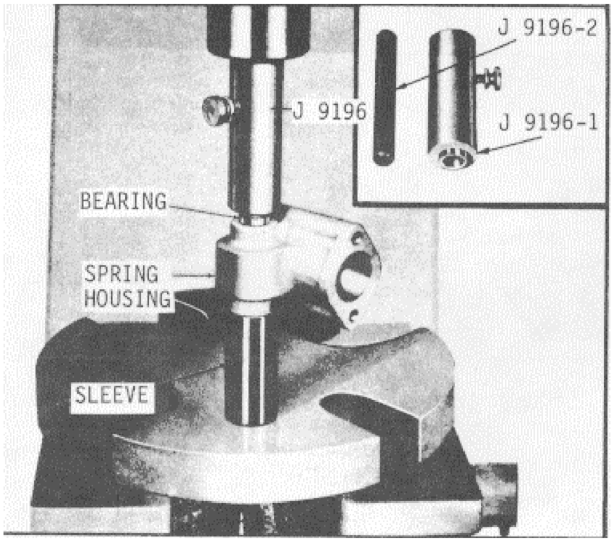



*Fig. 14 Installing Speed Control Shaft Bearings in Spring Housing*

(12) Stake the edge of the spring lever set screw hole with a small center punch and hammer to retain the set screw in the lever.

(13) Place a seal ring over the end of the shaft and push it into the bearing bore and against the bearing. Place the plain washer over the shaft and against the housing, then install the Woodruff key in the keyway in the shaft.

(14) Place the speed control lever(s) on the shaft in its original position. Align the keyway in the lever with the key in the shaft and push the lever in against the plain washer and secure it in place with the retaining bolt and lockwasher.

(15) If removed, thread the locknut on the idle speed adjusting screw. Then, thread the idle speed adjusting screw into the spring housing cover approximately 1.00".

9.10 Assemble Variable Speed Spring Housing to the Control Housing

(1) Refer to Fig. 13 and insert the small end of the spring plunger in the plunger guide. Insert the solid stop in the governor control housing.

(2) Place the spring retainer in the spring housing, with the closed end of the retainer against the spring lever. If shims were used, place them inside of the spring retainer. Insert the split stop in the spring housing and against the spring retainer.

**Note**: Be sure to use shims with an .344" inside diameter. Either spring retainer may be used with shims which have a .750" I.D. However, do not use the .344" I.D. shims with a spring retainer which has only one air bleed hoe.

(3) Insert the variable speed spring in the spring plunger with the tightly wound end of the spring against the shims.

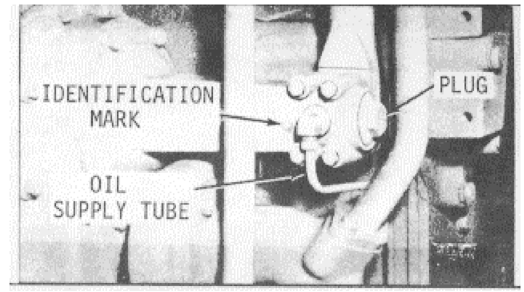



*Fig. 15. Governor Weight Housing*

(4) Insert the bolts through the spring housing. Place a new gasket over the bolts and against the housing.

(5) Place the spring housing in position against the control housing with the spring plunger engaged in the end of the variable speed spring. Thread the bolts in the control housing and tighten them securely.

39.11 Install Governor

(1) Affix a new governor-to-blower gasket to the governor weight housing. Refer to Fig. 2 and start the splined end of the weight shaft into the upper blower rotor and position the housing against the blower end plate.

(2) Place a new copper gasket on each weight housing-to-blower bolt and thread the bolts into the blower end plate, finger tight only.

(3) Place a new gasket (Fig. 9) over the dowels and against the side of the weight housing facing the engine.

(4) Move the thrust bearing assembly and riser toward the weight end of the shaft.

(5) Refer to Fig. 2 and position the lower end of the control housing over the dowel pins of the weight housing.

**Important**: The finished surface of the operating fork must be placed against the outer side of the thrust bearing.

**Note**: For ease in assembling the governor control housing to the interim weight housing (no identification mark, Fig. 15), install a special bolt (3/8"-24 x 3/4" or 7/8"), from which the outer 1/2" of thread down to a diameter of 5/16" to 1/4" has been removed, as a tool in the 1/8" NPTF oil hole to prevent the thrust bearing from moving too far forward in the weight housing. The weight housing has two ribs cast on the inner surface of the housing to prevent any part of the riser thrust bearing from sliding forward to where the operating fork could be inserted on the wrong side of one or more parts of the bearing.

(6) Use a new gasket and attach the governor control housing to the cylinder head with two bolts (Fig. 2). Tighten the bolts.

(7) Tighten the governor-to-blower bolts with tool J 4242.

(8) Place the weight housing cover in position. Install the four weight housing-to-control housing bolts with lockwashers and tighten the bolts.

(9) Connect the oil tube to the restricted fitting on the weight housing or cover.

(10) Refer to Fig. 1 and position the fuel rod over the differential lever pin. Place a flat washer over the pin and secure it with a retainer.

(11) Attach the fuel rod to the injector control tube lever with a pin and cotter pin.

(12) Place a new gasket on the governor control housing and mount the governor cover on the housing with the pin on the lever shaft registering with the machined slot in the differential lever as shown in Fig. 1.

(13) Secure the cover to the governor housing with three regular screws, one special screw and lockwashers.

(14) Hook the torsion retraction spring to the special cover screw and the stop lever (Fig. 2).

(15) Perform an engine tune-up as outlined in SM6-5-68.0

The fuel injector control tube assembly (Fig. 1) is mounted on the cylinder head and consists of a control tube, injector rack control levers, a return spring and injector control tube lever mounted in two bracket and bearing assemblies attached to the cylinder head.

The injector rack control levers connect with the fuel injector control racks and are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no-fuel position. The injector control tube lever is pinned to the end of the control tube and connects with the fuel rod which connects with the engine *governor.* Refer to *SM6-5-68.0* for positioning of the injector rack control levers.

Emergency engine shutdown is accomplished by tripping the air shut-off valve in the air inlet housing. Normal shut down is accomplished by pulling the governor shutdown lever to the no-fuel position. Adjustment of the injector rack control lever can be performed as outlined in SM6-5-68.0.

40.1 Remove Injector Control Tube

(1) Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube control lever.
(2) Remove the two attaching bolts and lockwashers at each bracket. Disengage the rack levers from the injector control racks and lift the control tube assembly from the cylinder head.

40.2 Disassemble Injector Control Tube

The injector control tube, one mounting bracket, a spacer and injector control tube lever are available as a service assembly. When any part of this assembly needs replacing, it is recommended the complete service assembly be replaced. Therefore, the disassembly and assembly procedure for these items is not included in the following:
(1) Remove the bracket from the injector control tube.
(2) Loosen the adjusting screws at each injector rack control lever.
(3) Disconnect the return spring from the bracket and front or rear rack lever.
(4) Then remove the return spring and rack levers from the control tube.

40.3 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wash all of the injector control tube parts in clean fuel oil and dry them with compressed air.

Examine the control tube, control lever, control tube rack control levers and brackets for excessive wear, cracks or damage and replace them if necessary. The bearing in the bracket is not serviced separately. Examine the return spring and replace if worn or fractured.

40.4 Assemble Injector Control Tube
With all of the parts cleaned and inspected and the necessary new parts on hand, refer to Fig. 1 and assemble as follows:
(1) Install the rack control levers on the control tube, with the levers facing the front bracket position. Turn the adjusting screws into the slots in the control tube far enough to position the levers.
(2) On both designs, install the control tube return spring and front bracket on the control tube. Attach the curled end of the re turn spring to the rack control lever and the extended end of the spring behind the front bracket.

40.5 Install Injector Control Tube
(1) Engage the injector rack control levers-with

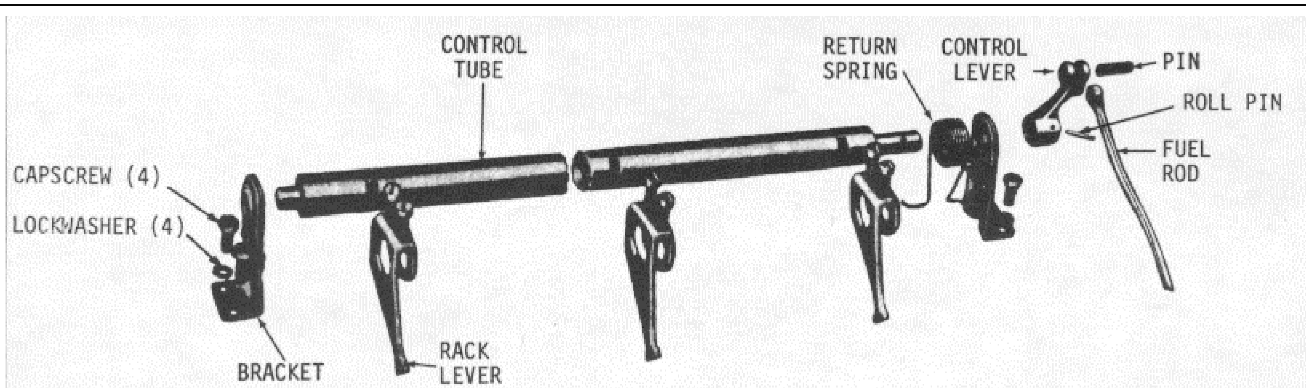



*Fig. 1. Injector Control Tube Assembly (Non-Spring Loaded)*

the injector control racks and place the bracket over the mounting holes on the cylinder head.

(2) Install the two 1/4"-20 x 5/8" bolts and lockwashers at each bracket to attach the injector control tube assembly to the cylinder head. Tighten the bolts to 10-12 ft-lbs (14-16 Nm) torque.

(3) Check the control tube to be sure it is free in the brackets. Tap the control tube lightly to align the bearings in the bracket, if necessary.

(4) Connect the fuel rod to the injector tube control lever with a clevis pin and a new cotter pin.

(5) Refer to SM6-5-68.0 and position the levers can be placed in a no-fuel position injector rack control levers.

**Note**: Be sure the injector rack control before restarting the engine.

**WARNING**

Loss Of Shut Down Control Could Result In A Runaway Engine Which Could Cause Personal Injury.

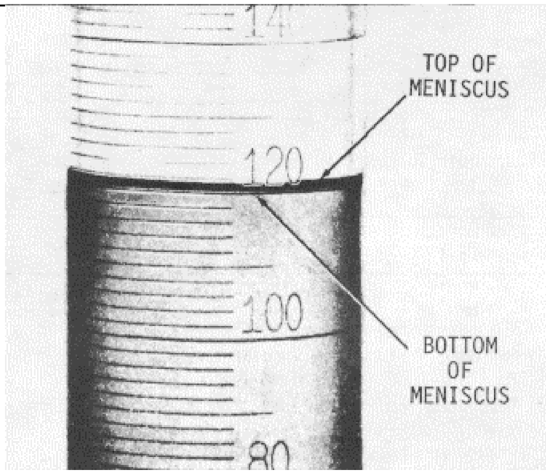



*Fig. 1. Checking Fuel Output*

41.1 Injector Calibrator Readings

Several factors affect the injector calibrator output readings. The four major items are:

(1) Operator Errors: If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of 1 or 2 points will result. Refer to Fig. 1.

(2) Air Lines: This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.

(3) Counter Improperly Set: The counter should be set to divert the injector output at 1,000 strokes.

This should not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 1,000 strokes (if properly set) although the counter may overrun several digits.

(4) Test Oil: A special test oil is supplied with the calibrator and should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts.

The fuel oil introduced into the test oil when the fuel injector is placed in the calibrator for a calibration check contaminates the test oil. Therefore, it is important that the test oil and test oil filter be changed every six months, or sooner if required.

In addition, other malfunctions such as a slipping drive belt, low level of test oil a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell-tale conditions.

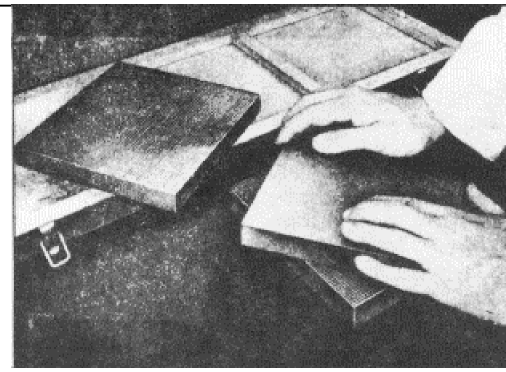


*Fig. 2. Refinishing Lapping Blocks*

41.2 Check Injector Tester J 23010

The injector tester should be checked monthly to be sure that it is operating properly. The following check can be made very quickly using test block J 9787-49.

Fill the supply tank in the injector tester with clean injector test oil J 26400. Open the valve in the fuel supply line. Place the test block on the injector locating plate and secure the block in place with the fuel inlet connector clamp. Operate the pump handle until all of the air is out of the test block, then clamp the fuel outlet connector onto the test block. Break the connection at the gauge and operate the pump handle until all of the air bubbles in the fuel system disappear. Tighten the connection at the gauge. Operate the pump handle to pressurize the tester fuel system to 2400-2500 psi. (16 536-17 225 kPa). Close the valve on the fuel supply line. After a slight initial drop, the pressure should remain steady. This indicates that the injector tester is operating properly. Open the fuel valve and remove the test block.

If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected and the tester rechecked before checking an injector.

Occasionally dirt will get into the pump check valve in the tester, resulting in internal pump valve leakage and the inability to build up pressure in the tester fuel system. Pump valve leakage must be corrected before an injector can be properly tested.

When the above occurs, loosen the fuel inlet connector clamp and operate the tester pump handle in an attempt to purge the dirt from the pump check valve. A few quick strokes of the pump handle will usually correct a dirt condition. The pump check valve must be replaced on tester J 23010.

If an injector tester supply or gauge line is damaged or broken, install a new replacement line (available from the tester manufacturer). Do not shorten the old lines or the volume of test oil will be altered sufficiently to give an inaccurate valve holding pressure test.

If it is suspected that the lines have been altered, i.e., by shortening or replacing with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

41.3 Refinish Lapping Blocks

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from
time to time.

It is good practice, where considerable lapping work is done, to devote some time each day to refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the blocks.

To refinish the blocks, spread some 600 grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together as shown in Fig. 2. Alternate the blocks from time to time. For example, assuming the blocks are numbered 1, 2 and 3, work 1 and 2 together, then 1 and 3, and finish by working 2 and 3 together. Continue this procedure until all of the blocks are perfectly flat and free of imperfections.

Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory when the entire surface is a solid dark gray. Bright or exceptionally dark spots indicate defects and additional lapping is required.

After the surfaces have been finished, remove the powder by rinsing the lapping blocks in trichloroethylene and scrubbing with a bristle brush.

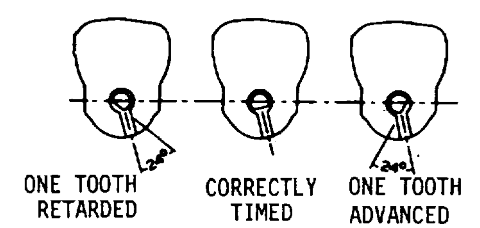



*Fig. 3. Injector Rack-to-Gear Timing*

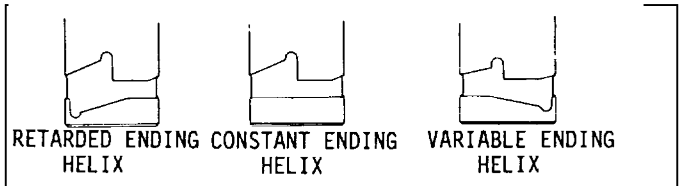



*Fig. 4. Types of Injector Plungers*

When not in use, protect the lapping blocks against damage and dust by storing them in a close fitting wooden container.

41.4 Master Injector Calibrating Kit

Use Master Injector Calibrating Kit J 26298 to determine the accuracy of the injector calibrator.

With the test fluid temperature at 100°F±1° (38°C ± 1°) and each injector warm after several test cycles, run the three injectors contained in the kit. Several readings should be taken with each injector to check for accuracy and repeatability. If the output readings are within 2% of the values assigned to the calibrated masters, the calibrator can be considered accurate.

Injector testing can be carried out not without any adjustment of figures. However, when testing new injectors for output, any difference between the calibrator and the masters should be used to compute new injector calibration. If more than a 2% variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

41.5 Injector Timing

If it is suspected that a fuel injector is "out of time", the injector rack-to-gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector rack and gear are correctly timed. When the rack is all the way in (full-fuel position), the flat side of the plunger will be visible in the hole, indicating that the injector is "in time". If the flat side of the plunger does not come into full view (Fig. 3) and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack-to-gear timing.

41.6 Injector Spray Tips

Due to a slight variation in the size of the small orifices in the end of each spray tip, the fuel output of an injector may be varied by replacing the spray tip.

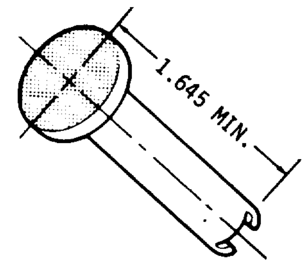



*Fig. 5. Injector Follower*

Flow gauge J 25600 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

41.7 Effect of Pre-Ignition on Fuel Injector

Pre-ignition is due to ignition of fuel or lubricating oil in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures and may eventually cause burning of the injector spray tip and lead to failure of the injectors in other cylinders.

When pre-ignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of pre-ignition to avoid recurrence of the problem. Check for oil pull-over from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

41.8 Injector Plungers

The fuel output and the operating characteristics of an injector are, to a great extent, determined by the type of plunger used. Three types of plungers are illustrated in Fig. 4. The beginning of the injection period is controlled by the upper helix angle. The lower helix angle retards or advances the end of the injection period. Therefore, it is imperative that the correct plunger is installed whenever an injector is overhauled.

If injectors with different type plungers (and spray tips) are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Injector plungers cannot be reworked to change the output or operating characteristics. Grinding will destroy the hardened case and result in chipping at the helices and seizure or scoring of the plunger.

When refinishing the face of an injector follower, it is extremely important that the distance between the follower face and the plunger slot is not less than 1.645" minimum as shown in Fig. 5. If this distance is less than specified, the height of the injector follower in relation to the injector body will be altered and proper injector timing cannot be realized.

**Note**: The maximum amount of metal that can be removed from the injector follower face, and still ensure a sufficiently hardened surface for contact with the rocker arm, is .010".

41.10 Bluing Injector Body and Nut

The appearance of the injector body and nut of a rebuilt injector can be enhanced with an oxide finish obtained through a dipping process known as bluing. Pre-mixed compounds are available commercially for preparing the necessary solutions. Detailed instructions are usually provided with the commercial compounds. An effective bluing solution can be prepared in the service shop by mixing the following materials: 6 lbs. of sodium hydroxide per gallon of water. 3-1/2 lbs. of sodium nitrite per gallon of water and 1 ounce of phosphoric acid per gallon of water.

The procedure usually follows five (5) steps in sequence:

(1) An alkaline solution bath (180-212°F or 82-100°C) to pre-clean.
(2) A hot or cold water rinse.
(3) The bluing solution bath.
4) A cold water rinse.
5) An engine lubricating oil bath (180-2120F or 82-1000C) to rust proof the parts. The bluing tank should be a double walled, 1-1/2" insulated type of 10 gauge steel.

The temperature of the bluing solution should be 295-305°F or 146-152°C. The boiling point of the solution is directly related to its concentration. Therefore, when the boiling point is too high, the solution is too concentrated and the volume of water is probably low. When this occurs, the boiling point can be reduced to 300°F (149°C) by adding water. The parts should be placed in the solution for 15 to 30 minutes.

It is extremely important that the parts be free of oil before placing them in the bluing bath. Oil will produce a varied color part.

**WARNING**

There Are Several Important Safety Precautions To Be Followed For Preparing And Using The Solutions. Protective Clothing Such As Rubber Gloves, Rubber Arm Covers, Rubber Apron And Protective Face Shield Contribute To The Safety Of Personnel Carrying Out The Procedures. When Preparing The Solutions, The Compounds Should Be 4dded To The -Hater And-Not later Added To The Compounds. The Dipping Tanks Should Be Properly Vented And All Fumes Exhausted To The Outside Atmosphere. Since Temperatures Of The Caustic Solutions Exceed The Boiling Point Of Water, Any Splashing Encountered While Adding Make Up Water Can Cause Serious Burns. Always Add Water Slowly And With Extreme Care. When The Parts To Be Dipped Are Cold, Caution Should Be Taken To Avoid Splashing That Might Occur When The Cold Parts Come In Contact With The Hot Solutions. A Heavy Wire Screen Type Basket, Suitable For Holding A Quantity Of Injector Bodies, Is Recommended For Dipping The Parts In The Solutions.

41.11 Fuel Lines

Flexible fuel lines are used to facilitate connection of lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

Be sure a restricted fitting of the proper size is used to connect the fuel return line to the fuel return manifold. Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, run the engine long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also check the filter cover bolts for tightness.

41.12 Locating Air Leaks in Fuel Lines

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or a loss of power. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return line in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observing the fuel filter contents after, the filter is bled and the engine is operated for 15 to 20 minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

41.13 Pressurize Fuel System - Check for Leaks

Always check the fuel system for leaks after injector or fuel pipe replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a serious fuel leak in this area can lead to dilution of the lube oil and bearing and/or cylinder kit damage.

41.14 Prime and Purge

Prime and/or purge the engine fuel system before starting the fuel leak check. Prime the system by blocking or disconnecting the line from the fuel pump, then apply fuel under pressure (60-80 psi or 413-552 kPa) to the inlet of the secondary filter. If the system is to be purged of air as well, allow the fuel to flow freely from the fuel return line until a solid stream without air bubbles is observed.

41.15 Check for Leaks

Use one of the following methods to check for leaks.

Method 1. Use when the engine has been operating 20-30 minutes.

After operating the engine, shut if off and remove the rocker covers. Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel pipes join the fuel pipe nuts.

If there is any leakage at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking. Disassemble, inspect and correct or replace the suspect parts (connector washer, connector, injector or jumper line). Test and reinspect.

Method 2. Use when the engine is not operating such as during or after repairs.

Remove the rocker covers. Pour lube oil over all fuel pipes and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as mentioned in Method 1.

Block off the fuel return line and disconnect the fuel pump supply line at the secondary filter. Install a pressure gauge in the filter adapter, then apply 60-80 psi (413-552 kPa) fuel to the outlet side of the secondary filter with the inlets plugged. Severe leaks will show up immediately. Minor leaks caused by nicks or burrs on sealing surfaces will take longer to appear. After maintaining 40-80 psi (276-552 kPa) for 20 to 30 minutes, a careful puddle inspection should reveal any suspect connectors.

Inspect and repair or replace connectors as necessary. Test and reinspect (see note).

Method 3. Use while the engine is operating at 400-600 rpm.

Apply an outside fuel source capable of 60-80 psi (413-552 kPa) to the outlet side of the secondary filter. Pour lube oil over jumper lines and connectors so that oil puddles form where lines and connectors meet. Install a valve and a pressure gauge in the fuel return line. With the engine idling, close the valve enough to raise the engine fuel pressure to 70 psi (483 kPa). After 10 to 20 minutes inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on. Repair and retest.

**Note**: With the engine at rest, as in Method 2 all injectors will leak to some extent when pressurized. The leakage occurs because there is no place else for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off.

Slightly worn plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exists.

If injectors are suspected of leaking and contributing to dilution of the lube oil, they should not be tested by pressurizing the fuel system as in Method 2. Injectors should be removed from the engine and tested for pressure-holding capability (see Fuel Injector Section).

41.16 Points to Remember

Lube oil puddle inspection is the key to pressure testing the fuel system for internal leaks. This test can be performed any time the rocker covers are removed, after the fuel pipes and connectors have been splashed with oil and there is normal fuel pressure in the system. The weak or missing puddles show where the leaks are.

All leakage or spillage of fuel during leak detection testing further dilutes the lube oil, so the final step in maintenance of this type should include lube oil and lube oil filter changes.

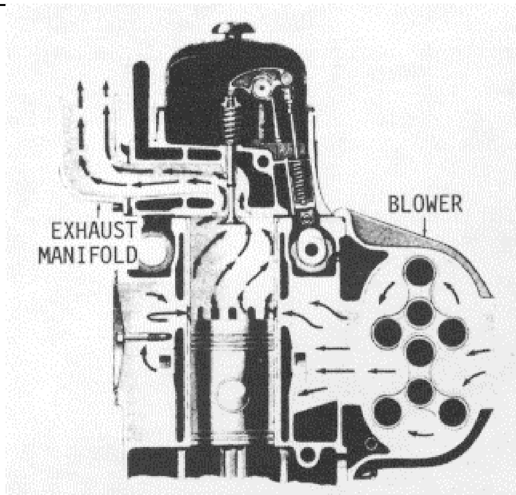



*Fig. 1. Air Flow Through Blower and Engine*

In the scavenging process employed in the 71 In-Line engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, therefore, each cylinder is filled with fresh clean air which provides for efficient combustion.

The air, entering the blower from the air cleaner or air silencer, is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows in Fig. 1. The continuous discharge of fresh air from the blower creates an air pressure of approximately 7 psi (48 kPa) in the air chamber of the cylinder block at maximum engine speed. This air sweeps through the intake ports, which start to open as the piston approaches the end of its downward travel and close after the compression stroke begins.

The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

The air shutdown housing, mounted on the side of the blower, serves as a mounting for the air cleaner or for air cleaner ducting. The air shutdown housing contains an air shutdown valve(s) that shuts off the air supply and stops the engine-whenever abnormal operating conditions require an emergency shut down (SM6-5-66.0).

43.1 Remove Air Shutdown Housing

(1) Remove the air cleaner or air cleaner ducts.
(2) Disconnect the Bowden wire or cable assembly from the air shut-off cam pin handle.
(3) Remove the bolts and washers that retain the housing to the blower and remove the housing from the blower. Remove the air shutdown housing gasket from the blower.

43.2 Disassemble Air Shutdown Housing

If necessary, the air shut-off valve assembly may be disassembled after the air shutdown housing has been removed from the blower.

Refer to Fig. 1 and disassemble the air shut-off valve assembly as follows:

(1) Use a small punch to remove the pin from the air shut-off valve shaft. Remove the washer from the shaft. Remove and discard the seal ring from the housing.
(2) Remove the pins that secure the air shut-off valve(s) to the shaft.
(3) Note the position of the air shut-off valve spring and the valve. Then withdraw the shaft from the housing to release the valve (s) and spring in the housing. Remove and discard the seal ring from the housing.
(4) Remove the bolt, lockwasher and plain washer from the housing and remove the latch, latch spring and spacer.

43.3 Inspection

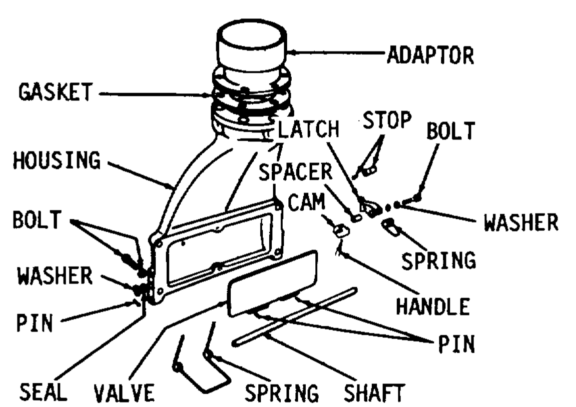



*Fig. 1. Typical Current Cam and Latch Type Air Shutdown Housing Details and Relative Location of Parts*

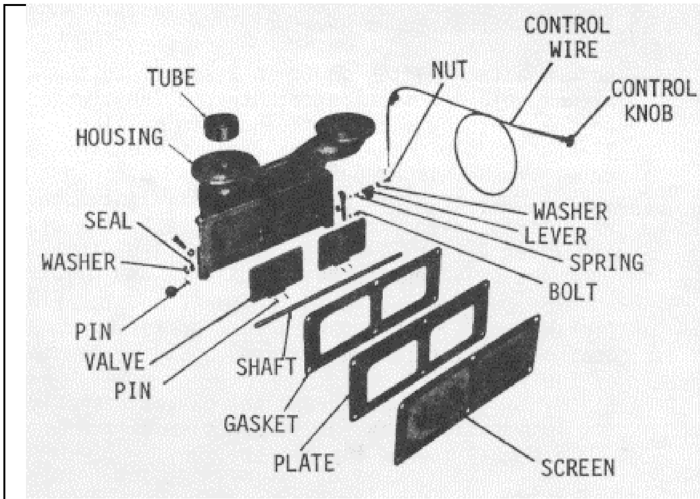



*Fig. 2. Air Shutdown Housing Mounting and Bolt Location*

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean all of the parts thoroughly, including the blower screen, with fuel oil and dry them with compressed air. Inspect the parts for wear or damage. The face of the air shut-off valve(s) must be perfectly flat to assure a tight seal when it is in the shutdown position.

43.4 Assemble Air Shutdown Assembly

The holes for the cam pin handle and the retaining pins must be drilled at the time a new service shaft or air shut-off valve(s) are assembled. Refer to Fig. 1 and proceed as follows:

(1) Place the valve(s) and spring in position in the housing and slip the shaft in place. The shaft must extend .760" from the side of the housing where the shutdown latch is assembled. Then install the pins which retain the valve(s) to the shaft.
(2) Lubricate with engine oil and install a new seal ring at each end of the shaft.
(3) Install the cam and cam pin handle on the shaft.
(4) Install a washer and retaining pin at the other end of the shaft.
(5) Assemble the spacer and spring on the latch. Then slip the attaching bolt through the lockwasher, plain washer, latch and spacer. Attach the latch assembly to the housing and tighten the bolt.
(6) After assembly, check for .015" to .040" shaft end play.

43.5 Install Air Shutdown Housing

Before attaching the shutdown assembly to the blower, place a steel straight-edge lengthwise on the finished face of the housing bolting flange and close the valves against the straight edge. The finished pads at each end of both valves must be flush against the straight-edge when it is moved from the top to the bottom of the inlet housing flange. Now turn the straight-edge crosswise on the housing flange and draw it from end-to-end. Both the upper and lower finished pads of the valves must be flush against the straight-edge throughout the length of the valves.

(1) Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

**Important**: The blower screen gasket consists of wire mesh secured between two sheets of gasket material.

(2) Refer to Fig. 2 and mount the air shutdown housing together with the striker plate gasket and striker plate on the blower with bolts and lockwashers and tighten the bolts to 16-20 ft-lbs (22-27 Nm) torque.

**Note**: The 3/8"-16 x 3-1/4" bolt and the 3/8"-16 x 2" bolt must be installed as shown in Fig. 2. The four 1-5/8" bolts are installed in the four corner bosses of the housing.

(3) Connect the Bowden wire or cable assembly to the air shut-off cam handle pin.

(4) Start and run the engine at idle speed and no-load. Trip the air shutdown. If the engine does not stop, check it for air leakage between the valve(s) and the striker plate. If necessary, reposition the valve (s).

(5) Install the air cleaner or air cleaner ducts.

## Service Manual

The blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow three-lobe rotors revolve with very close clearances in a housing bolted to the cylinder block. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form, (Fig. 1).

Two timing gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance; therefore, as the lobes of the upper and lower rotors do not touch at any time, no lubrication is required.

Oil seals located in the blower end plates prevent air leakage and also keep the oil used for lubricating the timing gears and rotor shaft bearings from entering the rotor compartment.

Lip type oil seals or metal ring type oil seals are installed in the blower end plates. Each ring type oil seal consists of a carrier pressed into the rotor shaft, a collar pressed into the end plate, and a seal ring contained in a groove of the carrier. The outside diameter of the seal ring seals against the collar to prevent leakage of air or oil.

Each *rotor* is supported in the doweled end plates of the blower housing by a roller bearing at the front end and two row pre-loaded radial and thrust ball bearing at the gear end.

The blower upper rotor is driven by the blower drive shaft which is coupled to the upper rotor timing gear by means of a flexible drive hub (20), (Fig. 1).

A flexible coupling, formed by an elliptical cam driven by two bundles of leaf springs which ride on four semi-cylindrical supports and spring seats is attached to the blower drive gear (42) (Fig. 1), and prevents the transfer of torque fluctuations to the blower.

A small diameter rotor blower is used on In-line 71 engines. The small diameter rotor blower with a 2.00:1 blower-to-engine speed ratio is employed in the 71N engines. When higher pressures are required, such as for bulk unloading, a large bearing 2.00:1 ratio (P) blower with metal ring type oil seals is used.

The ratio between the blower speed and the engine speed, and the number of teeth in the blower drive gears and reduction gears is given in the following chart.

| Engine Type | Blower Type | Ratio Blower-to Engine Speed | No. Teeth (Blower Drive Gear) | No. Teeth (Reduction Gear) |
|---|---|---|---|---|
| 71N | Small Dia. Rotor | 2.00:1 | 39 | No Reduction Gears |

Since the lower rotor (timing) gear (14) is also splined to the lower rotor shaft, it drives the upper rotor (timing) gear (13).

The blower rotors are timed by the two rotor (timing) gears (13) and (14) at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance between the rotor lobes will not be maintained.

Normal gear wear causes a decrease in the rotor-to-rotor clearance between the leading edge of the upper rotor lobes and the trailing edge of the lower rotor lobes of the standard blower and the small diameter rotor blower. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While the rotor lobe clearance may be adjusted by the use of shims behind the gears, gear backlash cannot be corrected. When gears have worn to the point where the backlash exceeds .004", the gears must be replaced.

44.1 Lubrication

Oil drains from the valve operating mechanism on the cylinder head into the camshaft pocket in the cylinder block; then, when it reaches a certain level, the oil flows from the pocket into cavities at the upper corners of the blower and through passages in the blower and end plates to lubricate the bearings, governor and water pump drives at the front end, and bearings and gears at the rear end of the blower. A slinger attached to the front end of the lower rotor shaft throws oil onto the front roller bearings and governor weights. A dam in the blower end plates maintains oil at a level adequate to submerge the lower portion of the slinger and the driven gear.

Surplus oil overflows the dams in the end plates and returns through two drilled holes in the cylinder block to the engine crankcase.

44.2 Inspection of Blower

The blower may be inspected for any of the following conditions without being removed from the engine. However, the air shut-down housing must be removed.

**WARNING**

When Inspecting A Blower On An Engine With The Engine Running, Keep Fingers And Clothing Away From The Moving Parts Of The Blower And Run The Engine At Low Speeds Only.

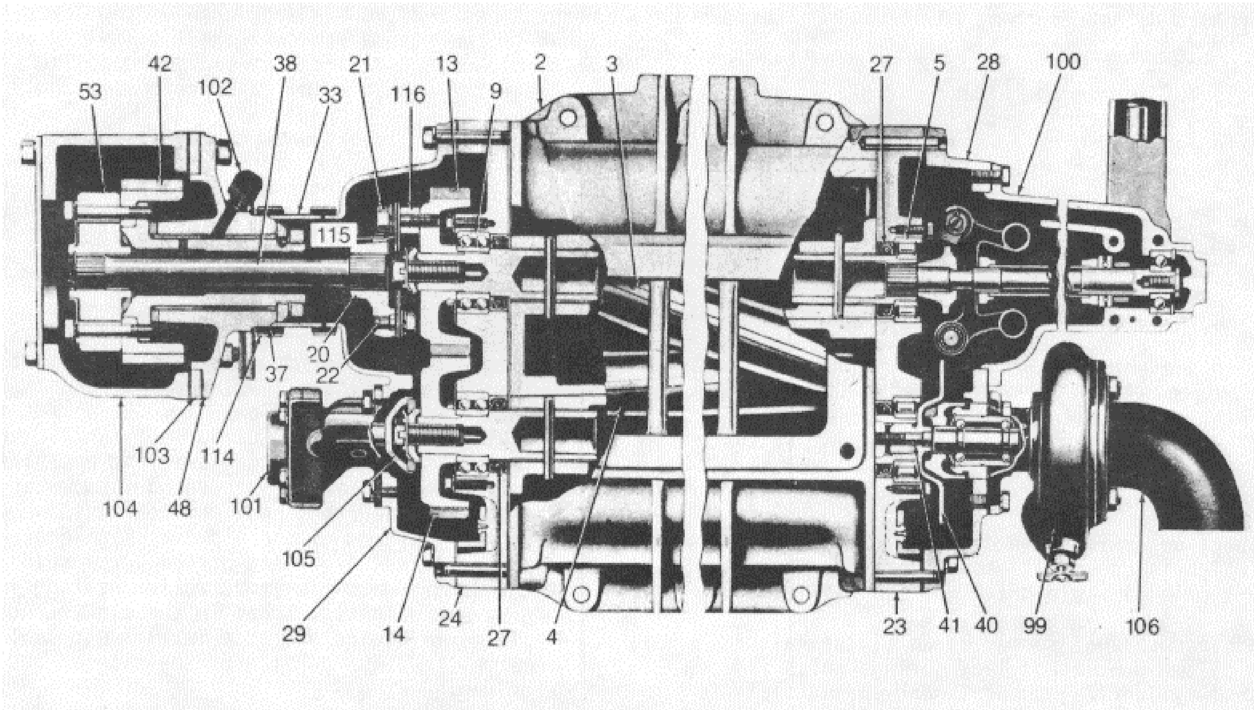



*Fig. 1. Blower and Drive Assembly and Accessories Including Mechanical Governor Attached to Standard Blower or Small Diameter Rotor Blower (71 Engines)*

Fig. 1 - Blower and Drive Assembly and Accessories Including Mechanical Governor Attached to Standard Blower or Small Diameter Rotor Blower (71 Engines)

2. Housing--Blower
3. Rotor--Blower--Upper R.H. Helix
4. Rotor--Blower--Lower L.H. Helix
5. Bearing (Roller)--Front
9. Bearing (Ball)--Rear--Double Row Thrust
13. Gear--Rotor—Upper R.H. Helix
14. Gear--Rotor—Lower L.H. Helix
20. Hub--Rotor Drive Gear
21. Bolt--Plate to Gear
22. Bolt--Plate to Hub
23. End Plate—Front
24. End Plate--Rear
27. Oil Seal--End Plate
28. Cover--End Plate—Front
29. Cover--End Plate—Rear
33. Cover--Blower Drive Shaft
37. Seal--Drive Shaft Cover
38. Shaft--Blower Drive
40. Coupling Assy. Water Pump Drive
41. Bolt--Allen Head Coupling
42. Gear--Blower Drive
48. Support--Blower Drive Gear Hub
53. Coupling Assy. Blower Drive
99. Pump--Fresh Water
100. Governor
101. Pump—Fuel
102. Elbow (90°)--Oil Line to Blower Drive
103. End Plate--Cylinder Block--Rear
104. Housing--Flywheel
105. Fork--Fuel Pump Drive
106. Cover--Water Pump Inlet
114. Clamp--Drive Cover Seal
115. Plate--Blower Rotor Drive Hub
116. Spacer--Plate to Gear

Dirt or chips drawn through the blower will make deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine and dress the parts down to eliminate the interference, or replace the rotors if they are too badly scored.

Leaky oil seals are usually manifested by the presence of oil on the blower end plates and rotors or the inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals is indicative of an oil leak.

A worn blower drive, resulting in a rattling noise inside the blower, may be detected by grasping the top rotor firmly and attempting to rotate it. Rotors may move from 3/8" to 5/8", measured at the lobe crown, with a springing action. When released, the rotors should move back at least 1/4". If the rotors cannot be moved as directed above, or if the rotors move too freely, inspect the flexible blower drive coupling and replace it if necessary.

If the drive coupling is worn, the blower drive gear assembly may be removed from the cylinder block end plate after the blower has been removed from the engine and the drive gear hub bearing support to cylinder block end plate bolts are removed (refer to SM6-5-29.0).

Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates, or between the rotors and the housing. Generally, a combination of these conditions exists. A loose shaft usually causes rubbing between the rotors and the end plates. Worn or damaged bearings will cause rubbing between the mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing. This condition will usually show up at the end where the bearings have failed.

Excessive backlash in between the blower timing gears usually results in the rotor lobes rubbing throughout their entire length.

To correct any of the above conditions, remove the blower from the engine and either repair or replace it.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Inspect the blower inlet screen periodically, as noted in Operator's Manual, for an accumulation of dirt which, after prolonged operation, may affect the air flow. Servicing of the screen consists of thoroughly washing it in fuel oil and cleaning with a stiff brush until the screen is free of all the dirt deposits.

44.3 Remove Blower

In most cases, removal of the blower, together with the governor drive, fresh water pump, fuel oil pump, and the blower drive shaft cover, will be found most advantageous. For removal of this assembly, refer to Fig. 2 and proceed as follows

(1) Drain the cooling system.
(2) Remove the governor control housing assembly as outlined under "Remove Governor" in SM 6-5-39.0.
(3) Disconnect the fuel lines at the fuel pump.
(4) Loosen the water pump connections at the pump cover (inlet) and the cylinder block.
(5) If the engine is equipped with a manually operated shut-down, disconnect the control wire from the air shut-down valve shaft lever, then remove the bolt securing the control wire clip to the air shut-down housing.

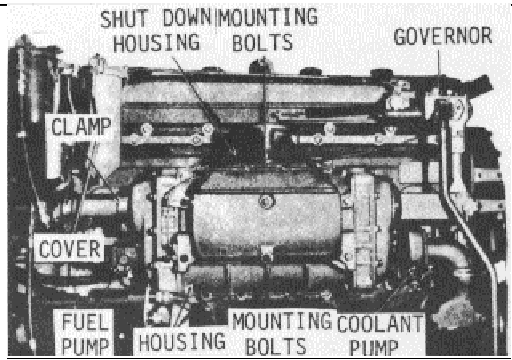



*Fig. 2. Typical Blower Mounting (71 Engine)*

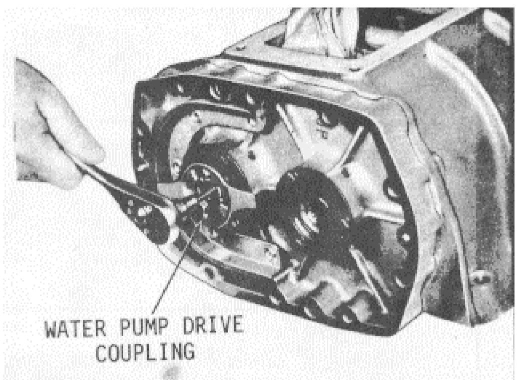



*Fig. 3. Removing Water Pump Drive Coupling Bolt from Blower Rotor Shaft*

(6) Remove the air cleaner, then remove the air inlet housing, gasket, striker plate and air inlet screen from the blower.

(7) Remove the blower drive shaft as outlined in SM6-5-29. 0.

(8) Loosen the blower drive shaft cover seal clamp at the blower drive gear hub support.

(9) Remove the bolts and plain washers securing the blower to the cylinder block. Slide the blower slightly forward, withdraw the blower drive shaft cover from the seal, then lift the blower away from the cylinder block.

44.4 Remove Accessories from Blower

(1) Remove the three bolts and seal washer assemblies securing the fuel pump to the blower rear end plate cover, then remove the fuel pump, gasket and drive coupling fork.

(2) On the blower, loosen the seal clamp securing the blower drive shaft cover to the blower end plate cover, then remove cover, seal and clamp from the end plate cover.

(3) Remove the three bolts and seal washer assemblies securing the fresh water pump to the blower front end plate cover, then remove the water pump and gasket. If necessary, tap the pump with a plastic hammer to loosen it.

(4) Remove the six bolt and seal washer assemblies securing the governor weight housing to the blower front end plate cover, then remove the weight housing and gasket.

Refer to Figs. 1 and 9 and disassemble the blower as follows:

(1) Remove the ten bolts and lockwashers securing the end plate covers (28) and (29) to the blower front and rear end plates. Tap the ends of the end plate covers with a plastic hammer to loosen the covers from the gaskets and dowel pins in the end plates. Then, remove the covers and gaskets from the end plates.

(2) Place a clean folded shop towel between the rotors and a towel between the rotor and the housing to prevent the rotors from turning. Then, remove the bolt securing the water pump drive coupling to the blower rotor shaft as shown in Fig. 5.

(3) Thread adapter J 6471-4 (1/2"-20 threads) or adapter J 6471-10 (9/16"-18) into the water pump drive coupling, then attach side hammer and shaft J 2619-5 to the adapter and pull the drive coupling from the blower rotor shaft.

(4) Refer to Figs. 11 and 12 and remove the bolts (21), lockwashers and plain washers securing the blower rotor drive hub (20) and drive hub plates (115) to the blower rotor timing gear (13) or drive gear (14), then remove the drive hub plates and spacers (116) from the gear. If necessary, remove the three bolts (22), lockwashers and plain washers securing the drive plates to the drive hub.

(5) Remove the blower rotor timing gear as follows:

(a) Remove bolt, lockwasher and retainer securing the timing gear to the right-hand helix rotor shaft. Then remove the bolt, lockwasher and fuel pump coupling disc (18) securing the other timing gear to the left-hand helix rotor shaft.

(b) Back out the center screw of both pullers J 6270-1 and secure the pullers to the gears with 5/16"-24 x 1-1/2" bolts.

**Note**: Both gears must be pulled from the rotor shafts at the same tine.

(c) With the shop towels between the blower rotors and housing to prevent them from turning, turn the puller screws uniformly clockwise and pull the gears from the rotor shafts (Fig. 4).

(d) Remove the shims from the rotor shafts or the inner face of the gears, and note the number and thickness of the shims used with each gear.

(6) Remove the bolts and lockwashers securing the rotor shaft bearing retainers (6) to both the front and rear end plates. Remove the retainers.

(7) Remove the blower rear end plate and bearing assembly from the blower housing and rotors with the two pullers J 6270-1 as follows:

(a) Remove the two fillister head screws (26) securing the rear end plate (24) to the blower housing, and loosen the two fillister head screws securing the front end plate (23) to the housing approximately three turns.

(b) Back out the center screws of the puller far enough to permit the flange of each puller to lay flat on the face of the end plate.

(c) Secure the pullers to the end plate with six 1/4"-20 x 1-114" bolts.

**Note**: Be sure that the 1/4"-20 bolts are threaded all the way into the tapped holes in the end plate to eliminate possible damage to the end plate.

(d) Turn the two puller screws uniformly clockwise and withdraw the end plate and bearings from the blower housing and rotors as shown in Fig. 5.

(8) Remove the blower front endsplate in the same manner as described under Step 7.

(9) Withdraw the blower rotors from the housing.

(10) Remove the bearings and the lip type oil seals from the blower end plates as follows:

(a) When performing a major overhaul, discard the oil seals, otherwise inspect the oil seals. If the seals are scored or hard, new seals must be installed. If necessary, remove the seals from the end plates at the same time the individual bearings are removed.

(b) Support the outer face of the end plate on wood blocks on the bed of an arbor press.

(c) Place the long end of the oil seal removed and installer J 6270-3 down through the oil seal and into the bearing, with the opposite end of the remover under the ram of the press (Fig. 8). Then, press the bearing and oil seal out of the end plate.

(d) Remove the remaining bearings and oil seals from the end plates in the same manner.

(11) Remove the bearings and ring type oil seals (if used), carriers and collars from the blower rotor shafts and end plates as follows:

(a) Clamp one lobe of the rotor in a bench vise equipped with soft jaws (Fig. 6). Tighten the vise just enough to hold the rotor stationary.

(b) If used remove .005" shims (spacer) on the 71P blower.

(c) Remove the oil seal ring from the seal ring carrier on each blower rotor shaft with a pair of snap ring pliers J 4880 as shown in Fig. 6.

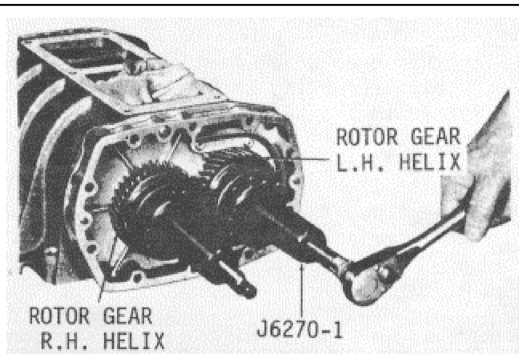



*Fig. 4. Removing Blower Rotor Gears from Blower Rotor Shafts*

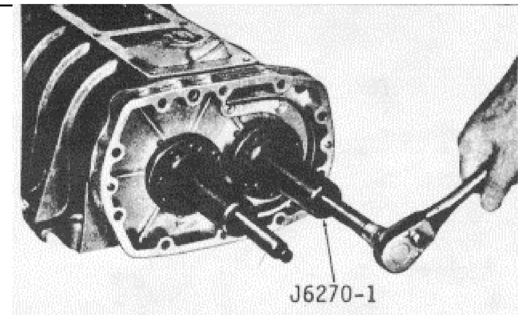



*Fig. 5. Removing Blower End Plate*

(d) Refer to Fig. 7 and place the seal ring carrier remover adapter J 6270-2 over the carrier. Make sure the adapter is seated in the groove of the carrier.

(e) Back out the center screw of puller J 6270-1 far enough to permit the puller flange to lay flat against the adapter J 6270-2.

(f) Place the puller over the end of the rotor shaft and against the adapter on the oil seal ring carrier. Then, secure the puller to the adapter with two bolts.

(g) Turn the puller screw clockwise and pull 6 the oil seal ring carrier from the rotor shaft (Fig. 7).

(h) Remove the remaining oil seal ring carriers from the rotor shafts in the same manner.

(i) Refer to Fig. 8 and support the outer face of the blower end plate on wood blocks on the bed of an arbor press.

(j) Place the long end of the oil seal remover and installer J 6270-3 down through the oil seal ring collar and into the bearing, with the opposite end of the remover under the ram of the press (Fig. 8). Then, press the bearing and oil seal ring collar out of the end plate.

(k) Remove the remaining bearings and oil seal ring collars from the end plates in the same manner.

44.6 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Wash all of the blower parts in clean fuel oil and dry them with compressed air.

Examine the bearings for any indications of corrosion or pitting. Lubricate each bearing with light engine oil; then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough

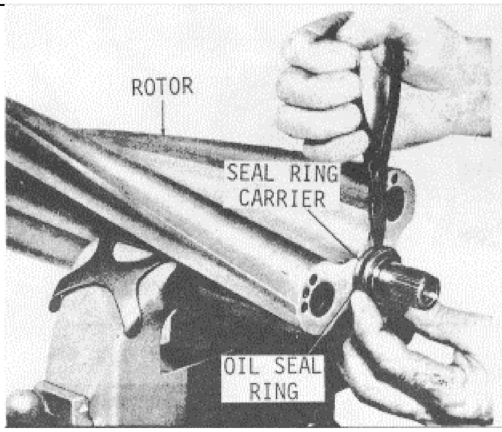



*Fig. 6. Removing Oil Seal Ring from Carrier*

The double-row ball bearings are pre-loaded and have no end play. A new double-row bearing will seem to have considerable resistance to motion when revolved by hand.

Check the oil seal rings, carriers and collars for wear and scoring. If worn excessively, they must be replaced. The oil seal rings are chrome flashed and the carriers are liquid nitrided. When replacement of an oil seal ring or carrier is necessary, both parts must be replaced together. Inspection of the lip type oil seal is covered in item "a" under Step 10.

**Note**: <u>When a blower with lip type oil seals is being reconditioned, the installation of new seals is recommended. Oversize oil seals and oil seal spacers are available in the blower kit to replace the standard oil seals where the blower rotor shafts are grooved.</u>

Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring. Rotors must be smooth for efficient operation of the blower. If the rotors are slightly scored or burred, they may be cleaned up with emery cloth.

Examine the rotor shaft serrations for wear, burrs, or peening. Also, inspect the bearing and oil seal contact surfaces of the shafts for wear and scoring.

Inspect the inside surface of the blower housing for burrs and scoring. The inside surface must be smooth for efficient operation of the blower.

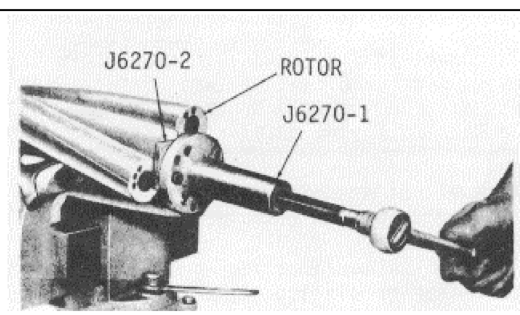



*Fig. 7. Removing Oil Seal Ring Carrier from Blower Rotor Shaft*

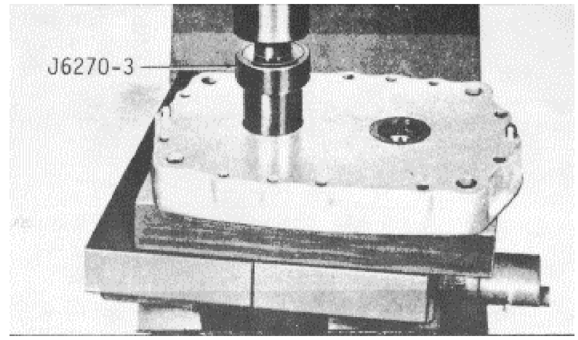



*Fig. 8. Removing Oil Seal Ring Carrier (or Seal Ring Collar) and Bearing from End Plate*

If the inside surface of the housing is slightly scored or burred, it may be cleaned up with emery cloth.

Check the finished ends of the blower housing, for flatness and burrs. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

Examine the serrations in the blower timing gears for wear and peening; also check the teeth for wear, chipping or damage. If the gears are worn to the point where the backlash between the gear teeth exceeds .004", or damaged sufficiently to require replacement, both gears must be replaced as a set.

Check the blower drive shaft serrations for wear or peening. Replace the shaft if it is bent.

Inspect the blower drive coupling springs (pack) and the cam for wear. Replace all worn or excessively damaged blower parts.

44.7 Assemble Blower

The lobes on the upper blower rotor and the teeth on its gear form a right-hand helix while the lobes and teeth of the lower rotor and gear form a left-hand helix. Therefore, a rotor with right-hand helix lobes must be used with a gear having right-hand helix teeth and vice versa.

With this precaution in mind, proceed with blower assembly, referring to Figs. 9 through 20 as directed in the text.

(1) Install the lip type oil seals (Fig. 11) as follows:
   (a) Support the blower end plate, finished surface facing up, on wood blocks on the bed of an arbor press (Fig. 10).

   **Note**: <u>If oversize oil seals are being used in the blower end plates, use installer J 6270-28 to install the oversize oil seal spacers on the rotor shafts.</u>

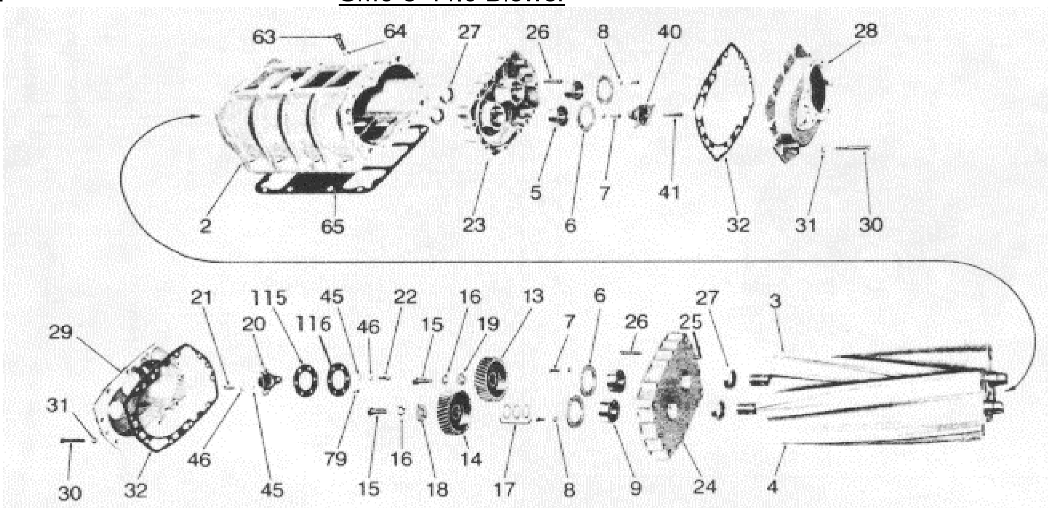



*Fig. 9*

*Typical Details and Relative Location of Parts - Standard and Small Diameter Rotor Six Cylinder 71 Blowers*

2. Housing—Blower Water
3. Rotor--Blower--Upper--R.H. Helix
4. Rotor--Blower--Lower--L.H. Helix
5. Bearing(Roller)—Front
6. Retainer—Bearing
7. Bolt--Bearing—Retainer
8. Lockwasher Housing
9. Bearing (Ball)—Rear Double Row Thrust
13. Gear--Rotor--Upper--R.H. Helix
14. Gear--Rotor--Lower--L.H. Helix
15. Bolt--Rotor Gear
16. Lockwasher--Bolt to Rotor Gear
17. Shim--Gear to Bearing (For Timing Rotors)
18. Disc--Fuel Pump Coupling
19. Washer--Rotor Gear Retaining
20. Hub--Rotor Drive
21. Bolt--Plate to Gear
22. Bolt--Plate to Hub
23. End Plate—Front
24. End Plate--Rear
25. Pin (Dowel)--Housing to End Plate
26. Bolt--End Plate
27. Oil Seal--End Plate
28. Cover--End Plate—Front
29. Cover--End Plate--Rear
30. Bolt--End Plate Cover
31. *Lockwasher*
32. Gasket--End Plate Cover
40. Coupling Assy.—Pump Drive
41. Bolt--Allen Head
45. Plain Washer
46. Lockwasher
63. Bolt--Blower Mounting
64. Plain Washer--Blower Mounting
65. Gasket--Blower
115. Plate--Blower Rotor Drive Hub
116. Spacer--Plate to Gear

(b) Start the oil seal straight Into the bore in the end plate with the sealing edge facing down (toward the bearing bore).

(c) Place the short end of oil seal remover and installer J 6270-3 in the oil seal and under the ram of the press (Fig. 10) Then, press the oil seal into the end plate until the shoulder on the installer contacts the end plate.

Note: <u>A step under the shoulder of the installer will position the oil seal approximately .005" below the finished face of the end plate. This is within the .002" to .008" specified.</u>

(d) Install the remaining oil seals in the end plates in the same manner.

(2) If used, install the ring type oil seal, carriers, and collars on the rotor shafts and in the end plates as follows:

(a) Support one of the rotor assemblies on wood blocks on the bed of an arbor press as shown in Fig. 12.

(b) Lubricate the inside diameter of the oil seal ring carrier with engine oil; then start the carrier straight over the end of the rotor shaft with the chamfered inside diameter end facing the rotor.

(c) Place the oil seal ring carrier installer J 6270-4 over the end of the rotor shaft and against the carrier with the end of the installer under the ram of the press. Then, press the carrier down tight against the rotor.

(d) Install the *remaining* oil *seal ring* carriers on the rotor shafts in the same manner.

(e) Install an oil seal ring in the ring groove of each carrier with a pair of snap ring pliers J 4880 in the same manner as shown in Fig. 6.

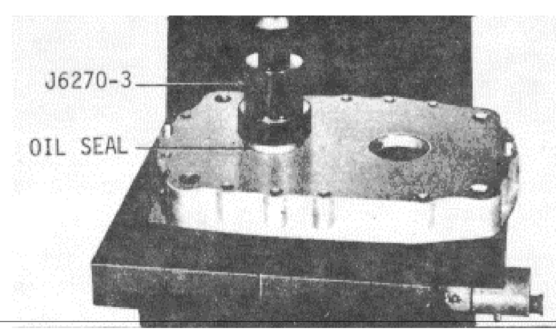



*Fig. 10*
*Installing Oil Seal (or Seal Ring Collar) in Blower End Plate*

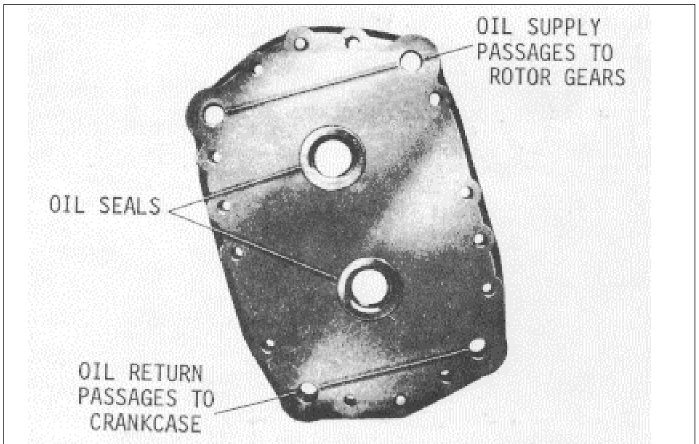



*Fig. 11*
*Blower End Plate and Lip Type Oil Seal Location*

**CAUTION**
To Avoid Breaking The Oil Seal Rings, Do Not Spread Them Any More Than Necessary To Place Them Over The End Of The Carrier.

(f) Support one of the blower end plates, inner face up, on wood blocks on the bed of an arbor press as shown in Fig. 10.

(g) Lubricate the outside diameter of a seal ring collar with engine oil; then start the chamfered outside diameter end of the collar straight into the bore in the end plate.

(h) Place the oil seal ring collar installer J 6270-4 on top of the seal ring collar and under the ram of the press in the same manner as shown in Fig. 10. Then, press the collar into the end plate until the shoulder on the installer contacts the end plate.

Note: A step under the shoulder of the installer will position the collar approximately .005" below the finished face of the end plate. This is within the .002" to .008" specified.

(i) Install the remaining oil seal ring collars in the end plates in the same manner.

44.8 Assemble Rotors and End Plates (With Lip Type Oil Seals)

Note that no gaskets are used between the end plates and the housing, therefore the mating surfaces must be perfectly flat and smooth.

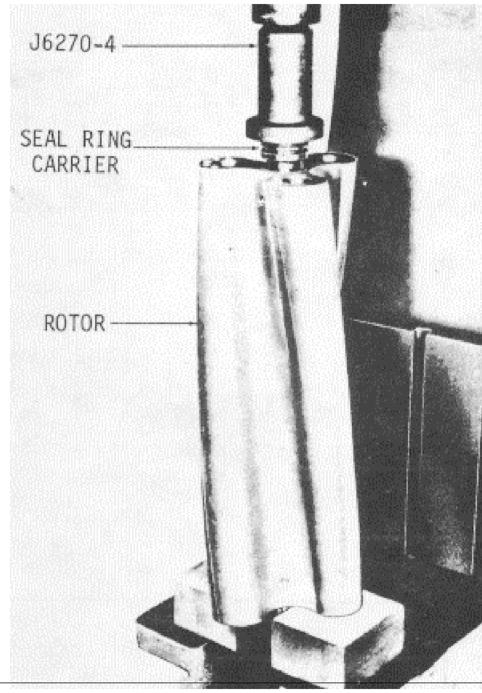



*Fig. 12*
*Installing Oil Seal Ring Carrier on Blower Rotor Shaft*

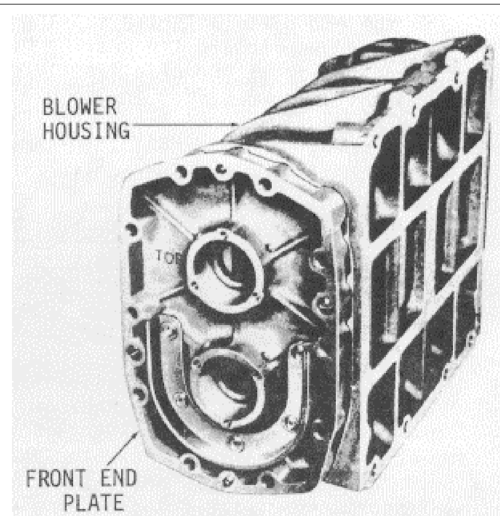



*Fig. 13*
*Position of Blower Front End Plate on Housing*

(1) For naturally aspirated engines apply a rubber base sealant as required to avoid leakage between the end plates and the blower housing.

(2) For turbocharged engines apply a rubber base sealant between the entire joint face of both ends of blower housing to end plates interfaces, especially around the bolt holes and dowels.

Note: Be sure no sealant protrudes into the blower housing. Also the sealant must not prevent the end plates from laying against the housing.

(1) Install the blower front end plate, making sure the mark TOP on the outer ribbed side is at the top of the blower housing, identified by the flange which supports the housing on the top edge of the cylinder block (Fig. 13).

The front and rear end plates of the blower are interchangeable.

One end plate should be assembled to the front end of the blower housing first and the other plate should be assembled to the rear of the blower housing after the rotors are in place. Attach an end plate to the front of the blower housing as follows:

(a) Check the dowel pins. The dowel pins must project .380" from the flat inner face, and .270" from the outer face of the front end plate to assure proper alignment of the end plate to the hous- ing and the cover to the end plate.

(b) Place the blower housing on a bench with the top of the housing up, and the front end of the housing facing the outside of the bench.

(c) Position the end plate in front of the blower housing with the flat finished face of the end plate facing the housing and the end marked TOP facing the flanged side of the housing. Then, start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing.

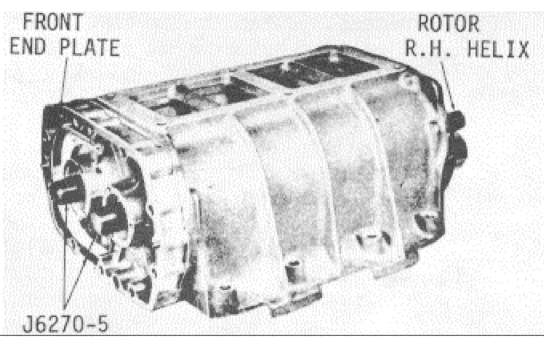



*Fig. 14*
*Assembling Blower Rotors into Housing and Front End Plate (Lip Type Oil Seals)*

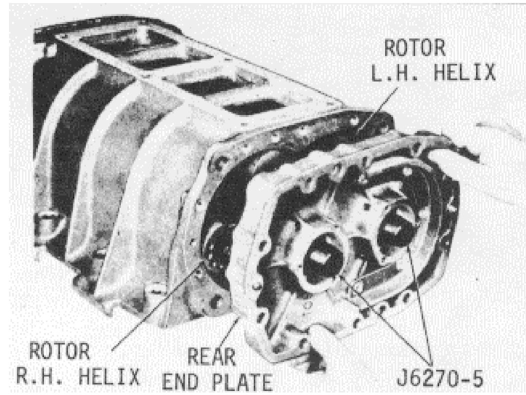



*Fig. 15*
*Installing Blower Rear End Plate (Lip Type Oil Seals)*

Note that gaskets are not used between the end plates and the housing; therefore, the mating surfaces must be flat and smooth. 6

(d) Insert the two fillister head screws through the end plate and thread them into the housing. Tighten the screws to 5-10 ft-lbs (7-14 Nm) torque. Do not use lockwashers on these screws

(2) Assemble the blower rotors in the blower housing and front end plate as follows: T

The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig. 23.

Note: The housing used in E, T and P blower assemblies are stamped for identification with the letters "E", "T" or "P" near the top of the housing. The "N" engines are also stamped "E".

(a) Place an oil seal pilot J 6270-5 on the short (non-splined) end of each rotor shaft. Then, place the rotors in mesh with the omitted serrations in the shafts in alignment as shown in Fig. 23

Note: <u>When oversize oil seals are used in the blower end plate, use oil seal spacer installers J 6270-28 for the oil seal pilots in place of J 6270-5.</u>

(c) Insert the blower rotors with oil seal pilots straight into the blower housing with the right-hand helix rotor at the top, flange, side of the housing. Then, push the rotor shafts and oil seal pilots on through the oil seal in the front end plate as shown in Fig. 16.

(3) Attach the blower rear end plate to the blower housing as follows:

(a) Reverse the blower housing on the bench (rear end of housing facing the outside of the bench).

(b) Place an oil seal pilot J 6270-5 on the serrated end of each rotor shaft.

Note: <u>When oversize oil seals are used in the blower end plate, use oil seal spacer installers J 6270-28 for the oil seal pilots in place of 6270-5.</u>

(c) Check the dowel pins. The dowel pins must project .380" from the flat inner face, and .270" from the outer face of the rear end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.
(d) Place the rear end plate in position in front of the oil seal pilots with the flat finished face of the end plate facing the blower housing and the mark TOP on the end plate at the top flange side of the housing.
(e) Place the rear end plate over the oil seal pilots (Fig. 15) and start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing.
(f) Insert the two fillister head screws through the end plate and thread them into the housing. Tighten the screws to 5-10 ft-lbs (7-14 Nm) torque. Do not use lockwashers on these screws.
(g) Remove the oil seal pilots from the rotor shafts.

44.9 Assemble Rotors and End Plates (With Ring Type Oil Seals)

Note that no gaskets are used between the end plates and the housing, therefore, the mating surfaces must be perfectly flat and smooth.

(1) For naturally aspirated engines apply a rubber base sealant as required to avoid leakage between the end plates and the blower housing.
(2) For turbocharged engines apply a rubber base sealant between the entire joint face of both ends of blower housing to end plates interfaces, especially around the bolt holes and dowels.

Note: <u>Be sure no sealant protrudes into the blower housing. Also the sealant must not prevent the end plates from laying against the housing.</u>

(1) Install the blower rotors in the blower rear end plate as outlined below:

The front and rear blower end plates are interchangeable. Note that gaskets are not used between the end plates and the housing; therefore, mating surfaces must be flat and smooth.

(a) Check the dowel pins. The dowel pins must project .380" from the flat inner face, and .270" from the outer face of the rear end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.
(b) Support the rear end plate on two wood blocks, approximately 4" high, with the inner face of the end plate facing up and the TOP end of the end plate facing to the right (Fig. 16).
(c) Lubricate the oil seal ring in the carrier on the rear (splined) end of the right-hand helix rotor shaft with engine oil.
(d) Hold the right-hand helix rotor in a vertical position (gear end up) and position the seal ring in the carrier so the ring protrudes from its groove the same amount on each side and the gap is facing away from the serviceman.
(e) With the omitted serration in the splines of the shaft facing toward the top side of the end plate, start the end of the rotor shaft into the right-hand shaft opening in the end plate so that the gap portion of the seal ring is started into the ring collar (Fig. 16). Continue to lower the rotor and very carefully apply pressure to the seal ring approximately 180° from the gap while gently working the seal ring into the collar until the rotor contacts the end plate.
(f) Perform Steps "c" and "d" above on the left-hand helix rotor.
(g) Position the two rotors together so the lobes are in mesh and the omitted serration in splines of both shafts face toward the top of the end plate; then, start the splined end of the shaft straight into the left-hand shaft opening in the end plate. Continue to lower the rotor in place as outlined in Step "e".

(2) Determine the rotation of the blower being assembled, then install the blower housing over the rotors as follows:
(a) Position the blower housing above the rotors with its mounting flange facing toward the right-hand helix rotor. Lower the housing over the rotors until it contacts the dowel pins in the end plate.
(b) Align the dowel pin holes in the blower housing with the pins and push the housing tight against the end plate. If necessary, tap the housing lightly with a plastic hammer.

(3) Install the blower front end plate on the rotors and housing as outlined below:
(a) Check the dowel pins. The dowel pins must project .380" from the flat inner face, and .270" from the outer face of the front end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.
(b) Lubricate the oil seal rings in the carriers on the rotor shaft with engine oil.

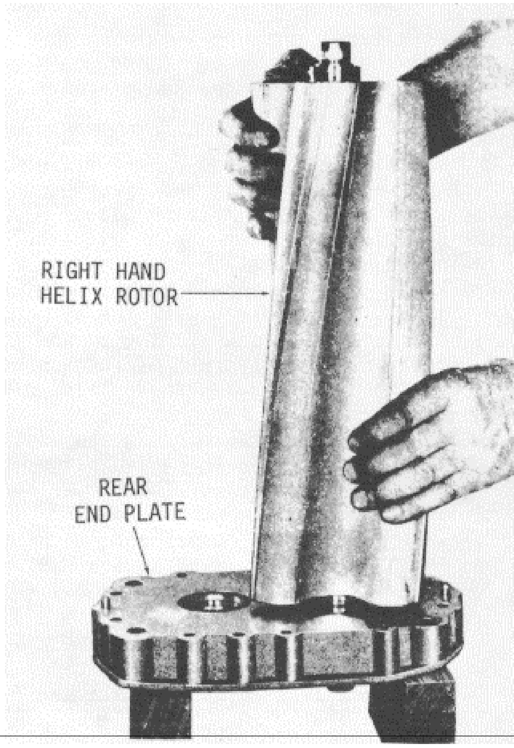



*Fig. 16*
*Installing Blower Rotor in Rear End Plate (Ring Type Oil Seals)*

(c) Position the oil seal rings in the carriers so the ring protrudes from its groove the same amount on each side.

(d) Position the front end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors and the mark "TOP" on the end plate at the flange side of the housing as shown in Fig. 17.

(e) Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing (Fig. 17); then, carefully work the dowel pins into the dowel pin holes in the housing and the oil seal rings into .the collars. Push the end plate tight against the housing. If necessary, tap the end plate lightly with a plastic hammer.

(f) Insert the two fillister head screws through the front end plate and thread them into the housing. Tighten the screws to 5-10 ft-lbs (7-14 Nm) torque. Do not use lockwashers on these screws.

44.10 Install Blower Rotor Shaft Bearings and Gears

(1) With the blower housing, rotors and end plates supported in a vertical position on the two wood blocks, install the roller bear ings on the rotor shafts and in the front end plate as follows:

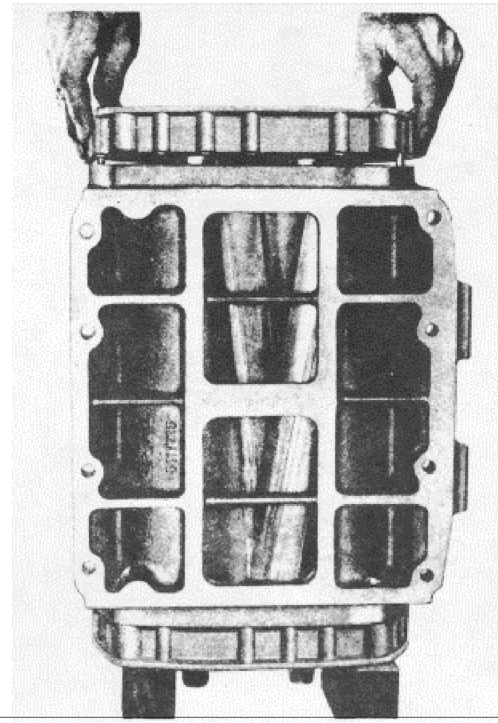


*Fig. 17*
*Installing Front End Plate on Blower Rotors and Housing (Ring Type Oil Seals)*

(a) Lubricate one of the roller bearings with engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

(b) Place installer J 6270-4 on top of the bearing and tap the bearing on the shaft and into the front end plate as shown in Fig. 18.

(c) Install the second roller bearing on the remaining rotor shaft in the same manner.

(d) Place the bearing retainers on top of the bearings and the end plate; then, install the retainer bolts and lockwashers. Tighten the bolts to 7-9 ft-lbs (9-12 Nm) torque.

(2) Start the end of the water pump drive coupling straight into the left-hand helix rotor shaft. Then, place a clean shop towel between the blower rotors to prevent them from turning. Install the drive coupling retaining bolt and draw the coupling and slinger tight against the end of the shaft, then tighten the bolt to 18 ft-lbs (24 Nm) torque.

(3) Affix a new gasket (32) to the blower front end plate cover (29).

Note: <u>The former blower end plate cover is not interchangeable with the current blower end plate cover.</u>

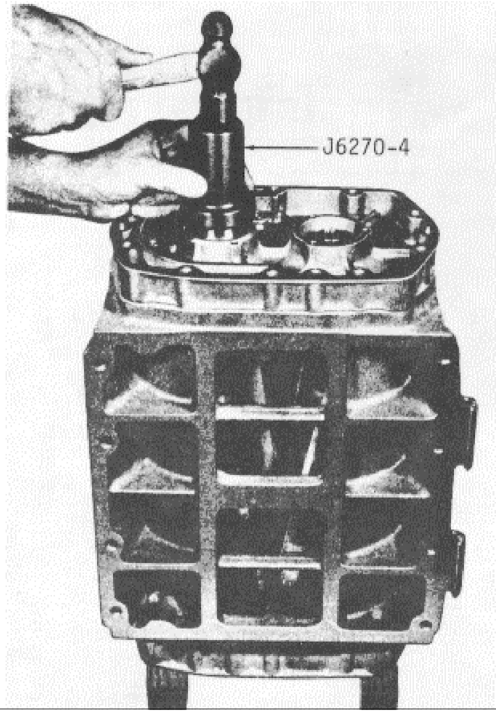



*Fig. 18*
*Installing Roller Bearing on Rotor Shaft and in Front End Plate*

(4) Position the end plate cover over the end plate dowel pins, with the large hole in the cover toward the top of the end plate, then push the cover against the end plate. Install the ten bolts and lockwashers. Tighten the bolts to 13-17 ft-lbs (18-23 Nm) torque.

(5) Install the ball bearings on the rotor shafts and in the rear end plate as follows:

(a) Reverse the position of the blower housing on the two wood blocks (Fig. 19).

(b) On a blower with ring type oil seals, insert the two fillister head screws through the rear end plate and thread them into the housing. Tighten the screws to 5-10 ft-lbs (7-14 Nm) torque. Do not use lockwashers on these screws.

(c) Lubricate one of the ball bearings with engine oil. Start the bearing numbered end up, straight on one of the rotor shafts.

(d) Place installer J 6270-7 on top of the bearing and tap the bearing straight on he shaft and into the rear end plate as shown in Fig. 23.

(e) Install the second ball bearing on the remaining rotor shaft in the same manner.

(f) lace the bearing retainers on top of the bearing and the end plate; then, install the retainer bolts and lockwashers. Tighten the bolts to 7-9 ft- lbs (9-12 Nm) torque.

(6) Make a preliminary check of the rotor-to-end plate and rotor-to-housing clearances at this time with a feeler gauge as shown in blower clearances.

(7) Install the blower rotor timing gears on a standard blower or a smaller diameter rotor blower as follows:

One serration is omitted on the drive end of each blower rotor shaft and a corresponding serration is omitted in each gear. Assemble the gears on the rotor shafts with the serrations in alignment.

(a) Place the blower housing and rotor assembly on the bench with the air inlet side of the housing facing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench.

(b) Rotate the rotors to bring the omitted serrations on the shafts in alignment and facing the top of the blower housing (Fig. 23).

(c) Install the same number and thickness of shims on the rotor shafts that were removed at the time of disassembly.

Note: <u>When rebuilding a blower with new rotors or new gears, first install the gears on the rotor shafts without the shims, then check the clearances between the rotors to determine the location and thickness of shims to be used; refer to Fig. 23.</u>

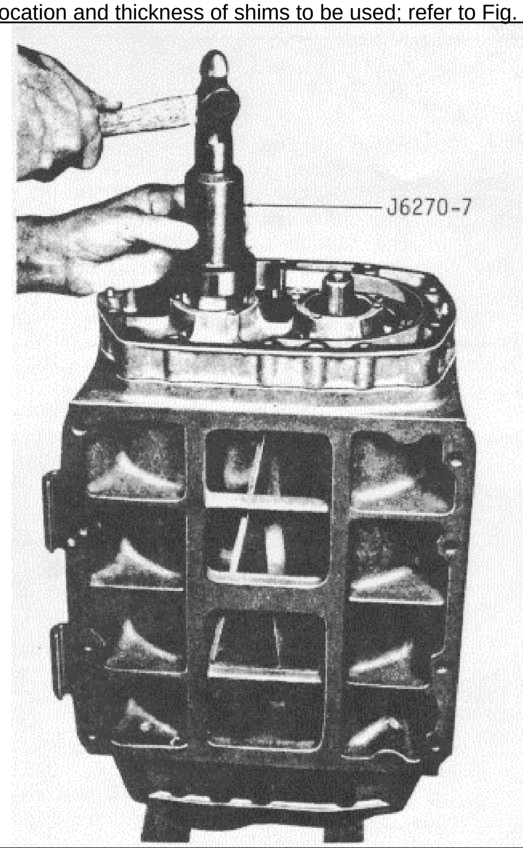



*Fig. 19*
*Installing Ball Bearing on Rotor Shaft and in Rear End Plate*

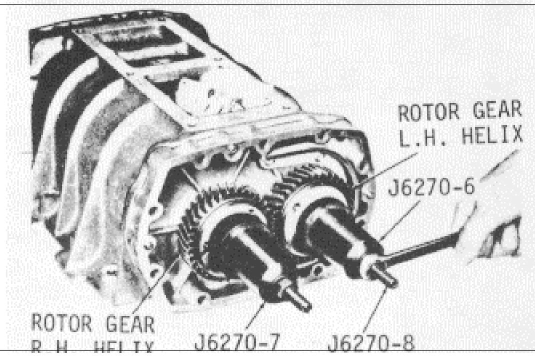



*Fig. 20*
*Installing Rotor Gears on Rotor Shafts for Preliminary Check of Clearances*

(d) Lubricate the serrations of the rotor shafts with engine oil.

(e) Place the teeth of the rotor gears in mesh so that the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts.

Note: A center punch mark placed in the end of each rotor shaft at the omitted serrations will assist in aligning the gears on the shafts.

(f) Start both rotor gears straight on the rotor shafts with the right-hand helix gear on the right-hand helix rotor and the left-hand helix gear on the left-hand helix rotor, and the omitted serrations in the gears in line with the omitted serrations on the rotor shafts.

(g) Thread an installer screw J 6270-8 in the end of each rotor shaft until it bottoms. Place gear installer J 6270-7 over the installer screw and against the right-hand helix gear, and gear installer J 6270-6 over the installer screw and against the left-hand helix gear; then, thread a nut on each installer screw (Fig. 20).

(h) Place a clean shop towel between the rotors, and another one between the rotor and the housing to prevent the rotors from turning. Then, turn the nuts on the installer screws clockwise as shown in Fig. 20 and force the gears into position tight against the shims and bearing inner races.

Note: Both gears must be pressed on the rotor shafts at the same time.

(i) Remove the rotor timing gear installers from the rotor shafts.

(j) Place a lockwasher (16) and the gear retaining washer (19) on one of the gear retaining bolts (15). Thread the bolt into the right-hand helix rotor shaft and guide the lugs on the retaining washer in the slots in the gear hub, then bend one of the tangs on the lock-washer over into the slot of the retaining washer. Tighten the gear retaining bolt to 55-65 ft-lbs (75-88 Nm) torque.

(k) Place a lockwasher (16) and the fuel pump drive coupling disc (18) on the remaining gear retaining bolt. Thread the bolt into the left-hand helix rotor shaft and guide the lugs on the disc in the slots in the gear hub, then bend one of the tangs on the lockwasher over into the slot in the disc. Tighten the gear retaining bolt to 55-65 ft-lbs (75-88 Nm) torque.

(1) Bend one of the tangs of each lockwasher over against the head of the gear retain ing bolt. Remove the cloth from the blower rotors.

44.11 Timing Blower Rotors

After the blower rotors and timing gears are installed, the blower rotors must be timed.

The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

If the right-hand helix gear is moved out, the right-hand helix rotor will turn counterclockwise when viewed from the gear end. If the left-hand helix gear is moved out, the left hand helix rotor will turn clockwise when viewed

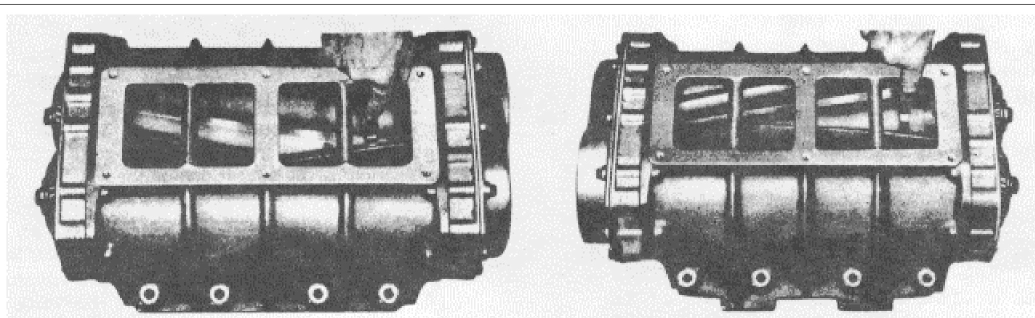
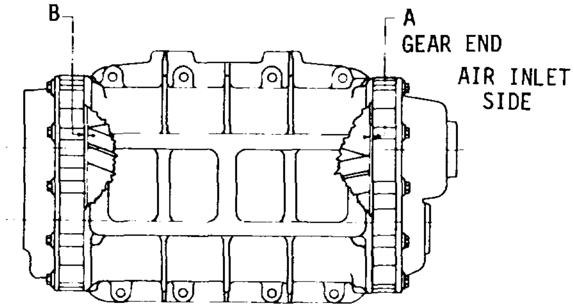
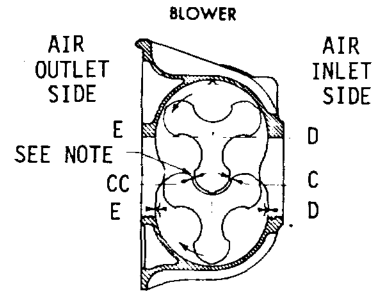


*Fig. 21*
*Measuring "CC" and "C" Clearances Between Blower Rotor Lobes*

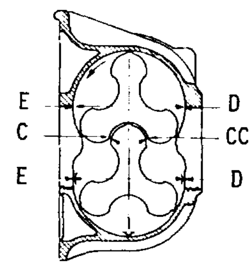



NOTE: TIME ROTORS TO DIMENSION ON CHART FOR CLEARANCE BETWEEN TRAILING SIDE OF UPPER ROTOR AND LEADING SIDE OF LOWER ROTOR (CC) FROM BOTH OUTLET AND INLET SIDE OF BLOWER

| | | A | B | C | CC | D | E |
|---|---|---|---|---|---|---|---|
| 6-71 | MIN. | .007 | .014 | .012 | .002 | .015 | .004 |
| | MAX. | | | | .006 | | |

TIME ROTORS TO DIMENSIONS ABOVE




ALL VIEWS FROM REAR OF ENGINE

*Fig. 22*

*Chart of Minimum Clearances for Standard Blowers, Smaller Diameter Rotor Blowers and Large Bearing (P) Blowers*

from the gear end. This positioning of the gear, to obtain the proper clearance between the rotor lobes, is known as blower timing.

Moving the gears OUT or IN on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

The clearance between the rotor lobes should be checked with 1/2" feeler gauges in the manner shown in Fig. 21. When measuring clearances of more than .005", laminated feeler gauges that are made up of .002", .003" or .005" feeler stock are more practical and suitable than a single feeler gauge. Clearances should be measured from both the inlet and outlet sides of the blower.

A specially designed feeler gauge set J 1698-02 for the blower clearance operation is available. Time the rotor as follows:

(1) 71 Blower--Time the rotors to have .002" to .006" clearance between the TRAILING edge of the UPPER rotor and LEADING edge of the LOWER rotor ("cc" clearance) measured from both the inlet and outlet sides as shown in Figs. 21 and 22. If possible, keep this clearance between the LEADING edge of the UPPER and the TRAILING edge of the LOWER rotors ("c" clearance) for the minimum clear ance shown in Fig. 22. Rotor-to-rotor measurements should be taken 1" from the governor end, at the center, and 1" from the drive end.

(2) After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear as shown in Fig. 23 to produce the desired result. When more or less shims are required, both gears must be removed from the rotors. Placing a .003" shim in back of a rotor gear will revolve the rotor .001".

(3) Install the required thickness of shims back of the proper gear and next to the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.

(4) Determine the minimum clearances at points "A" and "B" shown in Fig. 24. Insert the

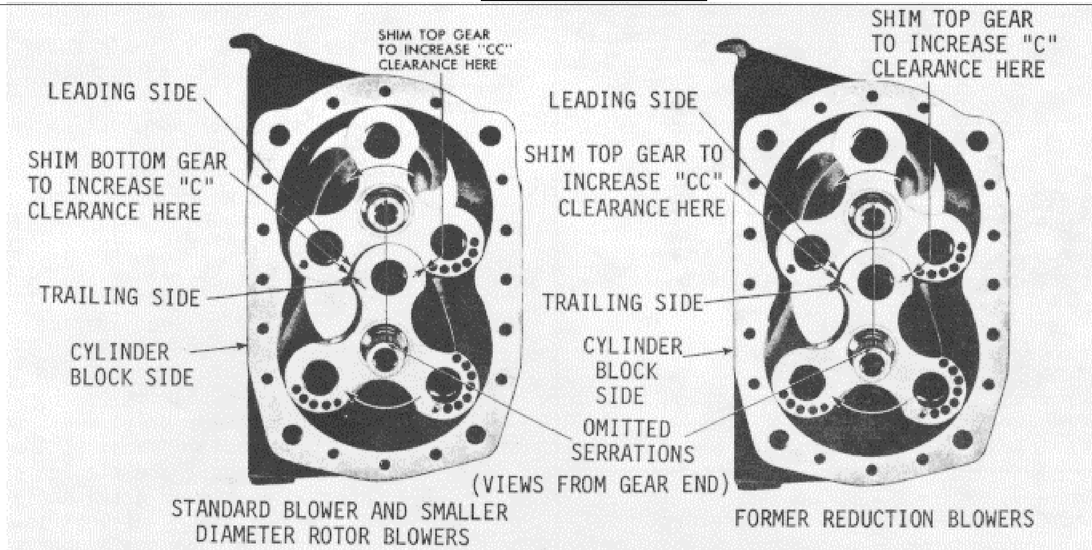



Fig. 23
Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances

feeler gauges, as shown in Fig. 24, between the end plates and the ends of the rotors. This operation must be performed at the ends of each lobe, making twelve measure- ments in all. See Fig. 24 for the minimum clearances.

(5) Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side--twelve measurements in all. See Fig. 26 for the minimum clearances.

After the blower rotors are timed, complete the assembly of the blower as outlined below:

(1) On the former reduction blowers, install the rotor drive and driven gears on the rotor shafts as follows:

(a) Place the blower housing and rotor assembly, air inlet side of housing facing up, on the bench with the timing gear end of the blower facing the outside of the bench.

(b) Start the left-hand helix driven gear on the shaft of the left-hand helix rotor with the omitted serrations in the gear and the shaft in alignment. Then, tap the gear on the shaft and against the timing gear with a plastic hammer, or install the gear with the gear installers J 6270-6, 7 and 8.

(c) If removed, install the drive gear bearing in the right-hand helix drive gear with the number on the race of the bearing facing the outside face of the gear.

(d) Lubricate the bearing in the drive gear with engine oil, then place the drive gear on the rotor shaft with the numbered side of the bearing facing out.

(e) Place the lockwasher and the bearing retainer (117) on the 7/16-20 x 1/4" drive-gear retaining bolt (143). Thread the bolt into the right-hand helix rotor shaft and guide the lug on the rear face of the retainer in the slot in the end of the rotor shaft, then bend one of the tangs on the lockwasher over into the slot in the retainer. Tighten the bolt to 55-65 ft-lbs (75-88 Nm) torque.

(f) Place the lockwasher (147) and the fuel pump drive coupling disc (18) on the 1/2"-20 x 1-1/4" driven gear retaining bolt (146). Thread the bolt into the left-hand helix rotor shaft, and guide the lugs on the disc in the slots in the gear hub, then bend one of the tangs on the lockwasher over into the slot in the disc. Tighten. the bolt to 55-65 ft-lbs (75-88 Nm) torque. 6

(g) end one of the tangs of each lockwasher over against the head of each gear retaining bolt.

(2) Refer to Fig. 9 and attach the blower rotor drive hub (20) and drive hub plates (115) to the blower gear as follows:

(a) If removed, attach the rotor drive hub plates (115) to the drive hub (20) with three bolts (22), lockwashers and plain washers. Tighten the bolts to 25-30 ft-lbs (34-41 Nm) torque.

(b) Attach the rotor drive hub and drive plates to the right-hand helix rotor timing gear with three bolts (21), lockwashers, plain washers and three spacers (116) on the standard blower and smaller diameter rotor blower, or drive gear ( 14 ) on the former reduction blowers, along with three spacers (116) and bearing retainer (117) between the plates and the face of the gear. Tighten the bolts to 25-30 ft-lbs (34-41 Nm) torque.

(c) Check the runout of the splines in the rotor drive hub with an indicator. The spline runout must not exceed .020" total indicator reading.

(3) Affix a new gasket (32) to the blower rear end plate cover (29).

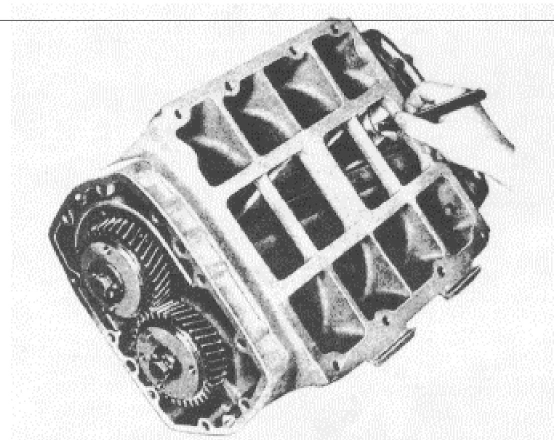


*Fig. 24*
*Measuring End Clearance Between Blower Rotors and End Plate*

Note: The former blower end plate cover is not interchangeable with the current blower end plate cover.

(4) Position the end plate cover over the end plate dowel pins, then push the cover against the end plate. Install the ten bolts and lockwashers. Tighten the bolts to 13-17 ft-lbs (18-23 Nm) torque.

44.12 Attach Accessories to Blower

Refer to Fig. 1 and attach the fuel pump, water pump, blower drive shaft cover and governor weight housing assembly to the blower as follows:

(1) Attach the fuel pump to the blower as out-lined under "Attach Fuel Pump to Blower" in SM6-5-35.0.
(2) Attach the water pump to the blower as out-lined under "Install Fresh Water Pump" in SM6-5-54.O.
(3) Attach the governor weight housing or drive housing assembly to the blower as outlined under "Install Governor" in SM6-5-39.0.
(4) On the current blower, attach the blower drive shaft cover (33) to the blower rear end plate cover (29) with cover seal (37) and seal clamp (114) as shown in Fig. 1.

14.13 Attach Blower to Engine

Refer to Fig. 2 and attach the blower assembly to the engine as follows:

Before attaching the blower assembly to the engine, check the inside of the blower for any foreign material and revolve the rotors by hand to be sure they turn freely.

(1) Affix a new blower to block gasket to the cylinder block with Scotch Grip Rubber Adhesive No. 4300, or equivalent, to prevent the gasket from shifting when placing the blower against the block.
(2) Place a new drive shaft cover seal (37) and seal clamp (114) over the end of the drive shaft cover (33).
(3) Place the water pump outlet packing flange, flat face toward pump body, and slide a new packing ring over the pump outlet. Then, place a new water pump cover seal and clamp on top of the oil cooler housing outlet opening.
(4) Place the blower assembly into position against the cylinder block, being careful not to dislodge the blower gasket.
(5) Install the eight blower to cylinder block bolts and plain washers, and tighten the bolts to 55-60 ft-lbs (75-81 Nm) torque.
(6) Slide the blower drive shaft cover seal (37) into position against the blower drive gear hub support and tighten the seal clamp.
(7) Install the blower drive shaft (38) by pushing the plain end, without squared hole, of the shaft through the blower drive coupling from the rear of the engine, then into the blower drive gear hub. If necessary, rotate the blower rotors slightly to align the splines of the drive shaft with those in the gear hub (20). Then, install the lock ring in the blower drive cam.
(8) Install the flywheel housing small hole cover.
(9) Connect the water pump outlet packing flange to the cylinder block. Also, tighten the seal clamp connecting the water pump cover to the oil cooler housing.
(10) Place the blower air shutdown housing, together with the striker plate gasket, striker plate and screen and gasket assembly against the blower, the screen side of the gasket assembly toward the blower and secure them in place with bolts and lockwashers. Tighten the bolts to 16-20 ft-lbs (22-27 Nm) torque.
(11) Connect the control wire to the air shutdown valve shaft lever and attach the control wire clip under the head of the air inlet housing attaching bolt.
(12) Install the governor control housing assembly as outlined under "Install Governor" in SM6-5-39.0.
(13) Install the air cleaners.
(14) Connect the fuel lines to the fuel pump.
(15) Fill the cooling system with clean fresh water plus rust inhibitor (or sufficient quantity of high boiling point antifreeze) and check the system for leaks.

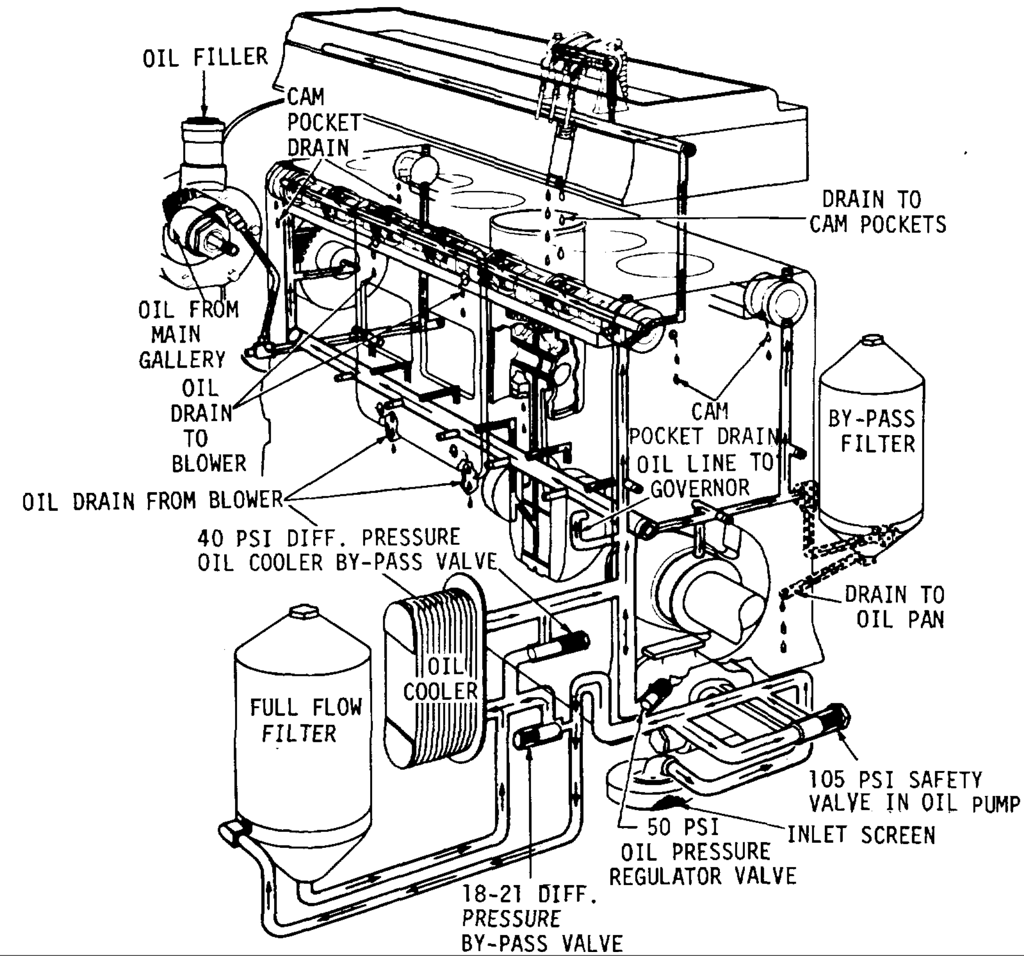



*Fig. 1*
*Schematic Diagram of Typical Lubrication System*

6

Figure 1 schematically illustrates the flow of oil through a typical Series 71 lubricating system including the various components such as the oil pump, oil cooler, by-pass and full-flow filters, the pressure regulator valve and by-pass valve.

The lubricating oil is circulated by a gear-type pressure pump mounted on the No. 1 and No. 2 main bearing caps and gear driven from the crankshaft.

All the oil leaving the pump is forced through the full-flow oil filter to the cooler and then into the oil gallery in the cylinder block from where it is distributed to the various engine bearings. The drain from the cylinder head and other engine parts leads back to the oil pan.

A spring-loaded integral plunger-type relief valve, located in the oil pump body, by-passes excess oil from the discharge to the intake side of the pump when the pressure in the engine oil gallery exceeds approximately 105 psi (724 kPa).

If the oil cooler should become clogged, the oil will flow from the pump through a spring-loaded by-pass valve directly into the oil gallery.

Clean engine oil is assured at all times by the use of a replaceable element type full-flow oil filter incorporated in the engine lubrication system. With this type filter, which is installed in the lubricating system between the pump and the cooler, all of the oil is filtered before entering the engine.

Stabilized oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve located between the pump outlet and the inlet to the cylinder block. When the oil pressure at the valve exceeds 50 psi (345 kPa), the regulator valve opens and remains open until the pressure is less than the opening pressure.

45.1 Oil Distribution

Oil from the cooler is conducted by a vertical passage to a longitudinal main oil gallery on the blower side of the cylinder block. As shown in Fig. 1, this gallery distributes the oil, under pressure, to the main bearings and to a horizontal, transverse passage at each end of the cylinder block. From each of these two horizontal passages, oil flows through two vertical bores (one at each end of the cylinder

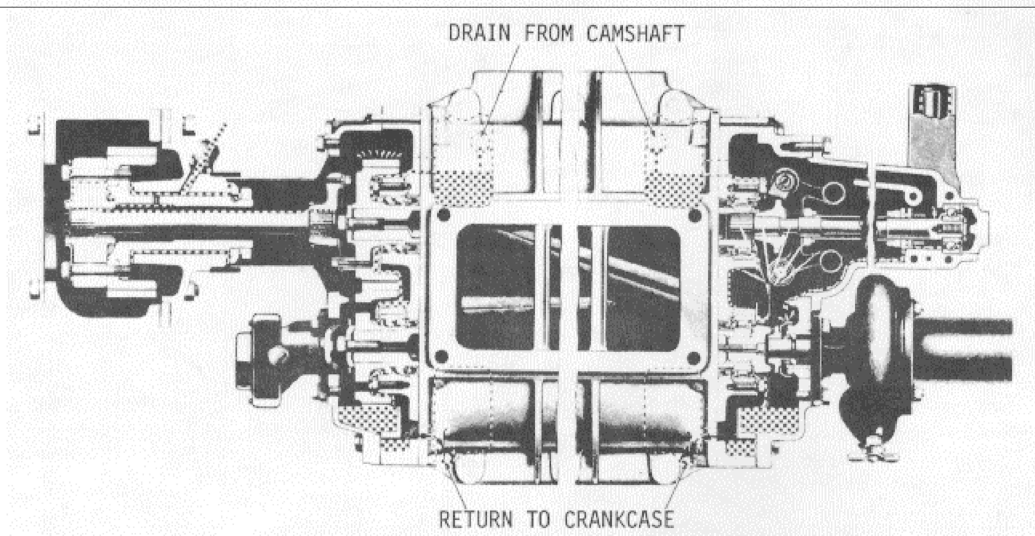



*Fig. 2*
*Blower Lubrication*

block) to the end bearings of the camshaft and balance shaft. In addition, oil is forced through an oil passage in the camshaft which lubricates the camshaft intermediate bearings. Oil for lubricating the connecting rod bearings, piston pins and for cooling the piston head is provided through the drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pocket through a communicating passage into the flywheel housing. Some oil spills into the flywheel housing from the bearings of the camshaft, balance shaft and idler gear.

The blower drive gear bearing is lubricated through an external pipe from the rear horizontal oil passage of the cylinder block.

A longitudinal oil gallery on the camshaft side of the cylinder head is supplied with oil from one of the vertical bores located at each end of the cylinder block. Oil from this gallery enters the drilled rocker arm shafts through the rocker shaft brackets at the lower ends of the drilled bolts and lubricates the rocker arm bearings and push rod clevis bearings.

Excess oil from the rocker arms lubricates the ends of the valve push rods, injector push rods and the cam followers and then drains to cam pockets in ,the top of cylinder block from which the cams are lubricated. When these pockets are filled, the oil overflows through two holes, one at each end of the blower housing, as shown in Figs. 1 and 2, and thus provides lubrication for the blower drive gears at the rear end and for the governor mechanism at the front end. A dam in the blower rear end plate cover maintains an oil level in which the teeth of the lower blower rotor timing gear run. A slinger at the forward end of lower rotor throws oil from the dam onto the governor weight assembly. Surplus oil overflows the dam in the two end plate covers and passes through drilled holes in the cylinder block to the oil pan.

45.2 Lubrication System Maintenance

Use the proper viscosity grade and type of heavy duty oil as outlined in the Lubricating Oil Specifications in Operator's Manual. Change the oil and replace the oil filter elements at the periods recommended by the oil supplier (based on his analysis of the drained engine oil) to ensure trouble-free lubrication and longer engine life.

The oil level should never be allowed to drop below the low mark on the dipstick. Overfilling the crankcase may contribute to abnormal oil consumption, high oil temperature, and also result in oil leaking past the crankshaft rear oil seal.

To obtain the true oil level, the engine should be stopped and sufficient time (approximately twenty minutes') allowed for the oil to drain back from the various parts of the engine. If more oil is required, add only enough to bring the level to the full mark on the dipstick.

45.3 Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by ethylene glycol antifreeze solution or other soluble material, refer to SM6-5-53.0 for the recommended cleaning procedure.

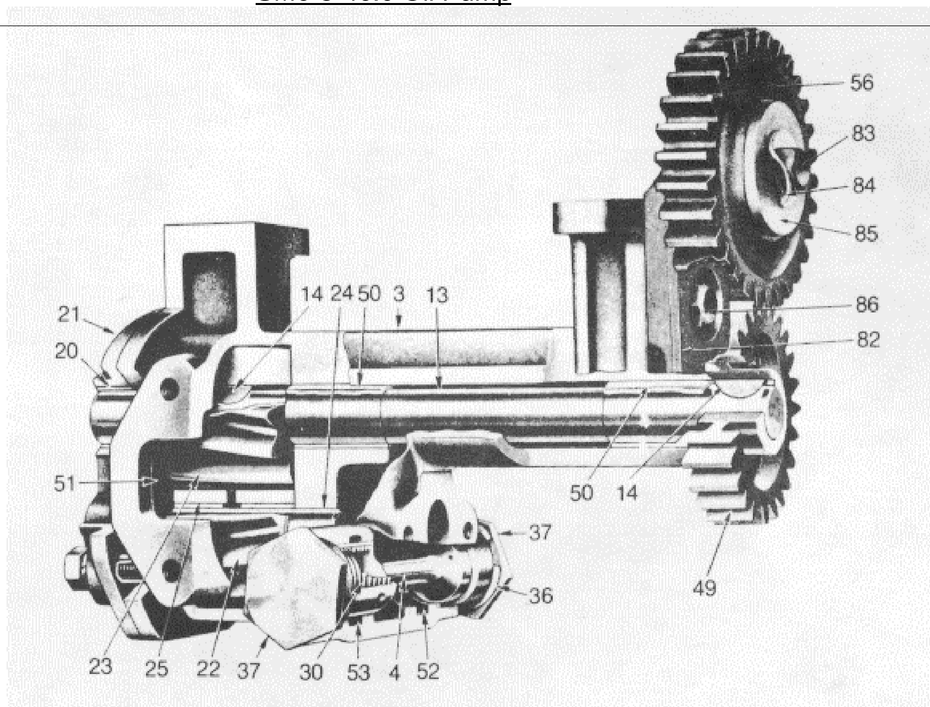



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Fig. 1
Oil Pump Assembly

3. Body--Oil Pump
4. Valve--Oil Pressure Relief
13. Shaft--Drive
14. Woodruff Key
20. Bushing--Drive Shaft (Short)
21. Cover--Pump
22. Gear—Driven
23. Gear—Drive
24. Shaft--Driven Gear
25. Bushing
30. Spring--Relief Valve
36. Gasket--Copper
37. Plug--Relief Valve
49. Gear--Drive-Driven
50. Bushing--Drive Shaft (Long)
51. Gear Cavity (Intake Side)
52. Oil Passage (Gear Cavity to Pump Outlet)
53. Oil Passage (By-pass to Intake Side of Gear Cavity)
56. Gear--Idler
82. Support--Idler Gear
83. Bolt--Idler Gear-to-Support
84. Lockwasher
85. Thrust Washer--Idler Gear-to-Support Bolt
86. Bolt--Support-to-Pump

The gear type oil pump shown in Figs. 1 and 2 is mounted on the first and second main bearing caps and is gear driven from the front end of the crankshaft.

The oil pump helical gears rotate inside a housing (Fig. 1). The drive gear (23) is keyed to the drive shaft which is supported inside the housing on two bushings with a drive-driven gear keyed to the outer end of the shaft. The driven gear (24) is supported on the driven gear shaft which is pressed into the pump body.

An integral plunger-type relief valve (4) by-passes excess oil to the inlet side of the pump when the pressure in the oil lines exceeds 105 pounds per square inch.

An inlet pipe (19) attached to the inlet opening in the pump body, leads to the inlet screen (2) which is mounted with brackets to a main bearing cap.

The inlet screen is located below the oil in the pan and serves to strain out any foreign material which might damage the pump.

The oil pump inlet screen should be removed and cleaned periodically in addition to the cleaning it receives each time the engine is reconditioned.

An idler gear (56) is mounted on a support bracket which is attached to the pump body (Fig. 1). Pressure lubrication of the idler gear bushing is provided by means of a drilled passage in the pump body and a connecting passage in the idler gear support bracket.

46.1 Remove Oil Pump

(1) Remove the drain plug from the oil pan and drain the oil.
(2) Remove the oil pan bolts and remove the oil pan.
(3) Remove the bolts and lockwashers securing the oil pump, regulator body and oil outlet tube and oil inlet tube support from the main bearing caps, and cylinder block (Fig. 2).

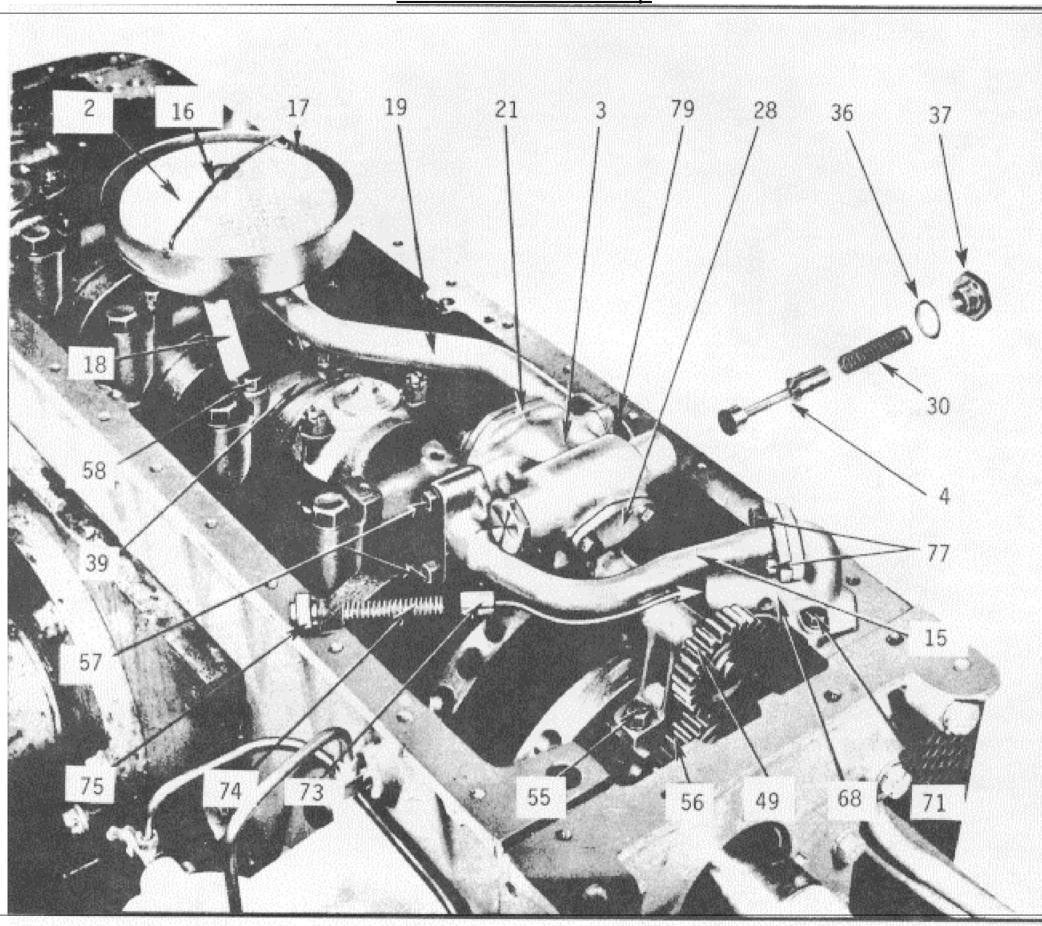


*Fig. 2*
*Typical Oil Pump Mounting*

2. Screen--Oil Pump Intake
3. Body--Oil Pump
4. Valve—Oil Pressure Relief
15. Pipe—Pump Outlet
16. Retainer--Screen
17. Cover--Screen
18. Bracket—Scren
19. Pipe--Pump Inlet
21. Cover--Pump
28. Cover—Pump Inlet Pad
30. Spring--Relief Valve
36. Gasket—Copper
37. Plug--Relief Valve
39. Cap—Main Bearing
49. Gear--Drive-Driven
55. Bolt--Pump to Bearing Cap
56. Gear--Idler
57. Bolt--Outlet Pipe to Pump
58. Bolt--Screen Bracket to Bearing Cap
68. Oil Pressure Regulator Assy.
71. Bolt--Regulator to Cylinder Block
73. Valve--Regulator
74. Spring--Regulator
75. Plug--Regulator
77. Bolt--Outlet Pipe to Regulator
79. Bolt--Inlet Pipe to Pump

Note: Remove and save the shims, if used between the oil pump mounting feet and the bearing caps.

46.2 Disassemble Oil Pump

Observe carefully the position of all parts including the oil inlet and outlet pipes during disassembly to facilitate reassembly of the puma

(1) Remove the oil pump inlet pipe (19) with the screen cover and mounting brackets.

(2) Remove the oil pressure regulator and the oil pump outlet pipe (15) as an assembly from the pump body (3).

(3) Remove the valve plugs (37) and copper gaskets (36) from each side of the pump body, and jar the relief valve parts from the bode (Fig. 3).

(4) Remove the pump driven gear (22) from the driven gear shaft (24).

(5) Straighten the lip of the lockwasher (84) and unscrew the bolt (83) thus freeing the idler gear (56).

(6) Clamp the pump body, drive shaft and gear assembly in a bench vise. Pull the drive- driven gear from the outer end of the pump drive shaft as shown in Fig. 4.

(7) Remove the Woodruff key (14) from the drive shaft and withdraw the shaft and driven gear (22) from the pump body.

(8) Unscrew the bolt (86) and remove the idler gear support (82) from the pump body.

(9) If the drive gear (23) is to be replaced, position the gear and shaft assembly on bed of arbor press with long end of shaft extending down through slot in bed plate and with

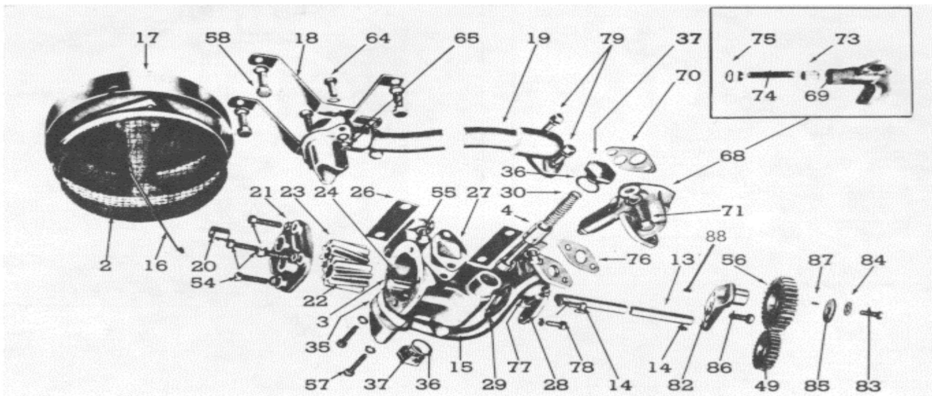


Fig. 3
Oil Pump Details and Relative Location of Parts

2. Screen—Pump
3. Body--Oil Pump
4. Valve--Oil Pressure Relief
13. Shaft—
14. Woodruff Key
15. Pipe--Pump Outlet
16. Retainer--Screen
17. Cover--Screen
18. Bracket--Screen
19. Pipe--Pump Inlet
20. Bushing--Drive Shaft (Short)
21. Cover--Pump
22. Gear--Driven
23. Gear—Drive
24. Shaft--Driven Gear
26. Shim
27. Gasket--Inlet Pipe to Pump
28. Cover--Pump Inlet Pad
29. Gasket--Pad Cover
30. Spring--Relief Drive Valve
35. Gasket—Outlet Pipe to Pump
36. Gasket--Copper
37. Plug--Relief Valve to
49. Gear--Drive-Driven
54. Bolt--Pump Cover
55. Bolt--Pump to Bearing Cap
56. Gear--Idler
57. Bolt--Outlet Pipe to Pump
58. Bolt--Screen Bracket to Bearing Cap
64. Bolt--Inlet Pipe and Cover to Bracket
65. Nut
68. Regulator Assy.—Oil Pressure
69. Regulator Body
70. Gasket—Regulator Cylinder Block
71. Bolt--Regulator to Cylinder Block
73. Valve--Regulator
74. Spring--Regulator
75. Plug—Regulator
76. Gasket--Outlet Pipe to Pressure Regulator
77. Bolt--Outlet Pipe to Pressure Regulator
78. Bolt--Inlet Pad Cover
79. Bolt--Inlet Pipe to Pump
82. Support--Idler Gear
83. Bolt--Idler Gear to Support
84. Lockwasher--Idler Gear-to-Support Bolt
85. Washer--Idler Gear-to-Support 86 Bolt
86. Bolt--Idler Gear Support-to-Pump
87. Locating Pin--Idler Gear Washer
88. Dowel--Idler Gear Support

the face of the gear resting on the plate as shown in Fig. 5. Place a short 1/2" round steel rod on the end of the shaft, and press the shaft from the gear.

46.3 Inspect Oil Pump Parts

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Wash all parts in clean fuel oil and dry them with compressed air.

Examine the gear cavity in the pump body and the drive shaft bushings. If the driven gear bushings are worn, replace the bushings. Service replacement bushings in the driven gears must be reamed after assembly. Bushings used with the .499" diameter driven gear shaft must be reamed to .500" ± .0005" and bushings used with the .623" diameter shaft must be reamed to .625"* .0005".

Inspect the bushings in the pump body and cover. If the bushings are worn excessively, replace the pump and cover unless suitable boring equipment is available for finishing the new bushings. When installing new bushings, replace all of the bushings. The bushings must be located and positioned as shown in Fig. 6. Also, the gear bore and the bushing bore in both the pump body and cover must be concentric within .001". The

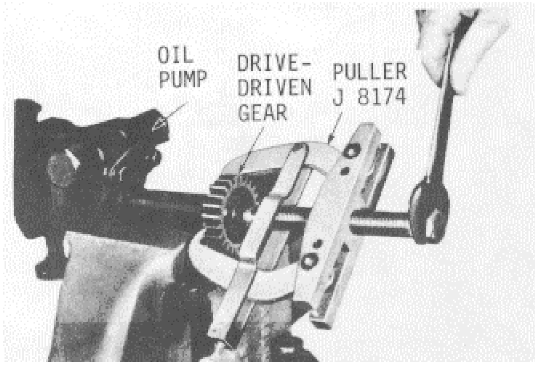


*Fig. 4*
*Removing Oil Pump Drive-Driven Gear from Shaft*

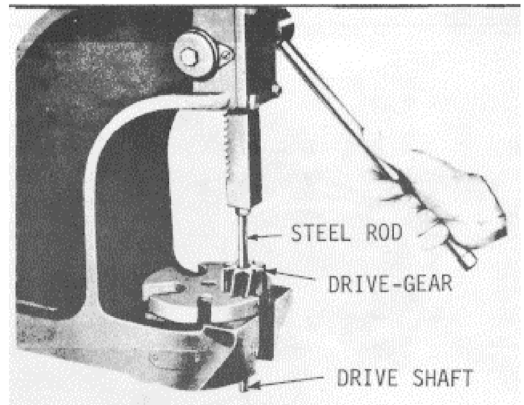


*Fig. 5*
*Removing Oil Pump Drive Gear from Shaft*

shaft-to-pump body-bushing clearance with new parts is .0008" to .0025". The shaft-to-pump cover bushing clearance with new parts is .0010" to .0027".

In an efficient oil pump, the gears should have a free-running fit (with no perceptible looseness) in the pump housing. If the gear teeth are scored or worn, install new gears. The use of excessively worn gears will result in low engine oil pressure which in turn, may lead to serious damage throughout the engine.

Inspect the pressure relief valve and its seat in the pump body. If necessary, install new parts.

46.4 Assemble Oil Pump

Refer to Fig. 3, and assemble the oil pump as follows:

(1) If the drive gear (23) was removed from the drive shaft (13), insert the Woodruff key (14) in the keyway and apply a light coat of engine oil on the shaft. Start the shaft squarely into the bore of the gear and, as shown in Fig. 5, press the shaft into the gear.

The gear must be 6-15/32" from the keyway end of the drive shaft (Fig. 7).

(2) Press the dowel (88) into the pump body, if removed.

(3) Place the idler gear support (82) in position against the forward end of the pump body (fig. 3) and secure the support to the body with bolt (86).

(4) Install the drive gear and shaft assembly in the pump body and slide the driven gear (22) onto the shaft (24).

(5) Insert two Woodruff keys in the keyway and slide the drive gear (gear with keyway) (23) against the spacer.

(6) Slide the driven gear (22) on the driven shaft against the spacer.

(7) Support the drive gear end of the drive shaft (13) on the bed of an arbor press and insert

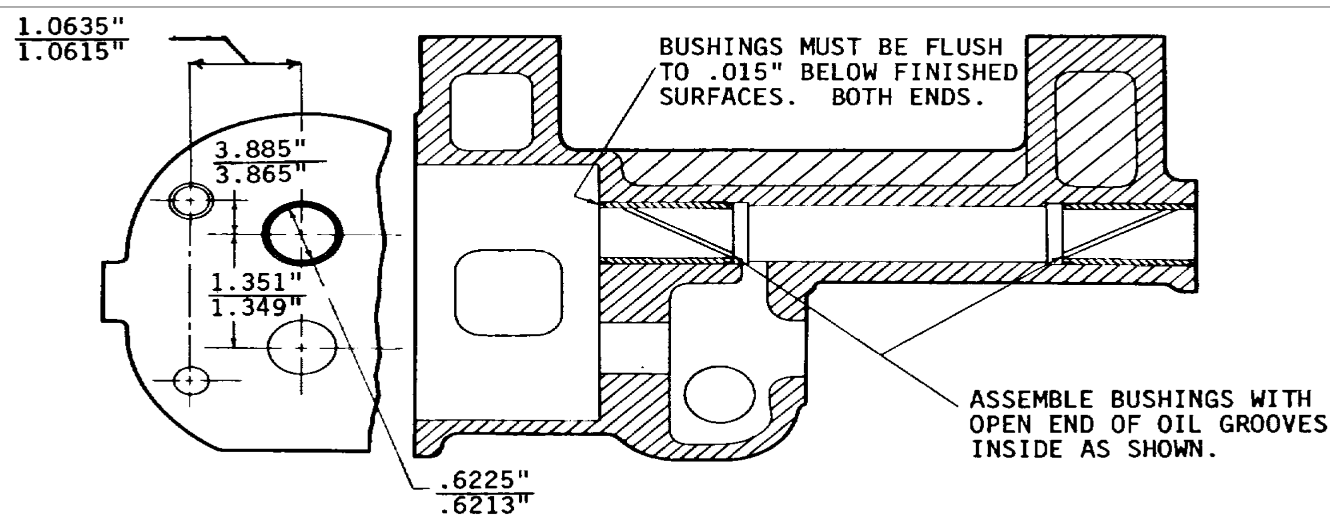


*Fig. 6*
*Diameter and Location of Bushing in Oil Pump*

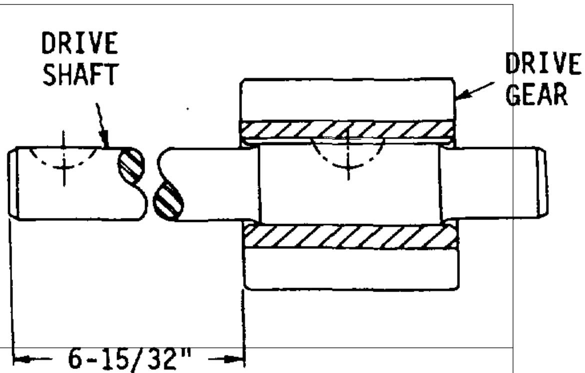


*Fig. 7*
*Oil Pump Drive Shaft and Gear Assembly*

the Woodruff key (14) in the keyway of the shaft. Position the drive-driven gear (49) on the end of the drive shaft with the extended hub side up away from the pump body. Insert a .005" feeler ribbon between the driven gear and the pump body and press the gear on the shaft until the clearance between the gear and the body is .005".

(8) If the locating pin (87) was removed, install it in the idler gear support (82), then lubricate the bearing surface with engine oil and place the gear (56) in position on the support (82) with the flat side of gear facing the support.

(9) Place the lockwasher (84) on the bolt (83) and the special washer (85) next to the lockwasher and start the bolt into the idler gear support. Then rotate the special washer and lockwasher so that the slot in each washer engages the locating pin (87).

(10) Tighten the idler gear bolt so the bolt head is over the end of the locating pin (87). Then bend the lockwasher against one flat of the bolt head.

(11) Screw the relief valve plug (37), with copper gasket (36), into place in the side of the pump body opposite the inlet opening. Then place the valve (4) and spring (30) in the bore at the inlet side of the pump body as shown in Fig. 2, and while compressing the spring, start the second relief valve

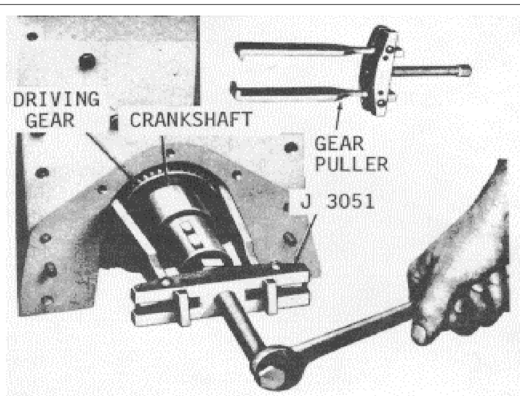


*Fig. 8*
*Removing Oil Pump Driving Gear from Crankshaft*

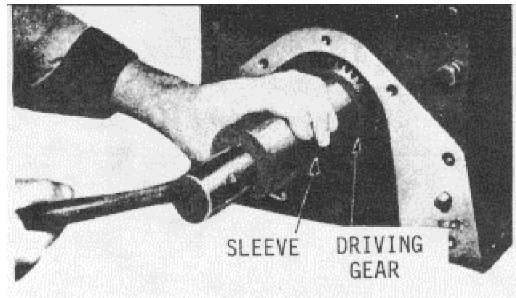


*Fig. 9*
*Installing Oil Pump Driving Gear on Crankshaft*

plug (37), with gasket (36), into the body. Tighten the plugs.

(12) If the cover (28) and gasket (29) were removed from the pump body, reinstall and secure them with the two bolts (78) and lock washers.

The oil pump must turn freely after assembly. Any bind in the pump must be removed before it is installed on the engine.

46.5 Remove Oil Pump Driving Gear from Crankshaft

With the oil pan and lubricating oil pump removed, the oil pump driving gear may be removed from the crankshaft as follows:

(1) Support the front end of the engine and remove the crankshaft front cover (SM6-5-13.0).
(2) Remove the oil slinger.
(3) If required use puller J 3051 (Fig. 8) to pull the pump driving gear from the front end of the crankshaft as follows:
    (a) Screw the crankshaft pulley or cap retaining bolt into the end of the crankshaft.
    (b) Place the jaws of the puller behind the gear and locate the point of the puller screw in the center of the retaining bolt.
    (c) Turn the puller screw clockwise and draw the gear from the crankshaft.
(4) Remove the Woodruff key from the crankshaft.

46.6 Install Oil Pump Driving Gear on Crankshaft

(1) Install the Woodruff key in the crankshaft.
(2) Position the gear (80) so the chamfer on the gear hub is toward the main bearing cap and start the gear on the shaft and over the key.
(3) Slide the gear on the crankshaft or use a sleeve if required, as illustrated in Fig. 9, and drive the gear tight against the shoulder on the crankshaft.
(4) Install the oil slinger with the dished side away from the gear as illustrated in Fig. 1 in SM6-5-14.0.
(5) Install the crankshaft front cover as outlined in SM6-5-13.O.

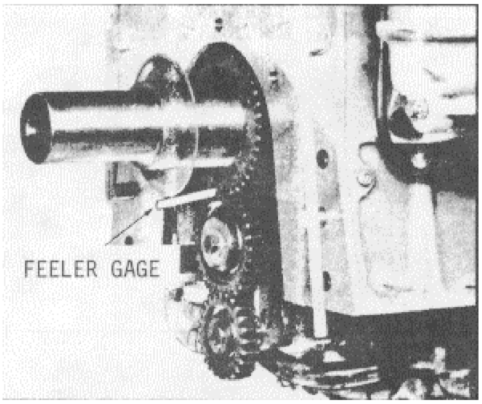


*Fig. 10*
*Measuring the Clearance Between the Teeth of the Oil Pump Driven Gears*

46.7 Install Oil Pump

Refer to Fig. 2 and install the oil pump on the main bearing caps as follows:

(1) Hold the pump assembly against the main bearing caps so the idler gear (56) meshes with the driving gear on the crankshaft.

(2) Insert the four bolts (55) with lockwashers through the mounting feet of the pump and into the bearing caps (39). Align the pump so that the teeth of crankshaft gear and the idler gear are parallel; then tighten the bolts to 35-39 ft-lbs and check clearance between the gear teeth with a feeler gauge. Proper clearance between the crankshaft gear and idler gear is .005" minimum, .012" maximum (Fig. 10).

**CAUTION**

Always Check The Clearance Between The Crankshaft Gear And The Oil Pump Idler Gear With The Engine In The Upright Or Running Position.

change the If shims were used between the pump mounting feet and the bearing caps and new gears are not installed, the same shims (cleaned) or the same number of new (identical) shims should be installed and the number then adjusted to obtain the proper clearance between gear teeth. However, if new gears have been installed, a larger number of shims will be required under the mounting feet. In either event, the pump must be tightened on the bearing cap before the clearance between the gear teeth is measured.

Note: When adjusting for gear tooth clearance by installing or removing shims, the same number of shims must be changed under each foot so that the pump will always be level on the main bearing caps. The insertion or removal of one .005 shim will gear tooth clearance by .0034".

(3) Place a new gasket (76) between the outlet pipe and the pressure regulator and bolt the two parts together loosely. Use a new gasket (35) and secure the outlet pipe (15) to the oil pump body (3) with the bolts not over 7/8" long. Attach the pressure regulator (68) to the cylinder block using a new gasket (70).

When attaching the pump outlet and the pressure regulator, none of the bolts should be tightened until all the bolts have been started. After all bolts are started, the outlet pipe bolts (57) should be tightened alternately, then the pressure regulator bolts (71) should be tightened, and finally the pipe-to-regulator bolts (77) should be secured. This procedure prevents twisting the outlet pipe.

(4) Attach the pump screen brackets (18) to the main bearing caps with lockwashers and bolts (58). Do not tighten the bolts.

(5) Affix a new gasket (27) to the pump end of the inlet pipe (19), then attach the pipe to the oil pump.

(6) Set the screen cover (17) over the outer end of the oil inlet pipe (19) and secure it to the pipe and brackets (18) with bolts (64) washer, lockwashers, and nuts (65).Tighten the bracket bolts (58) to the bearing caps.

(7) Place the screen (2) on the cover (17) and lock it in place with retainer (16).

(8) Recheck all bolts for tightness to assure there will be no leaks in the oil pump and pipe mounting connections.

(9) Place a new gasket on the oil pan and install the oil pan on the cylinder block. All the oil pan bolts should be started before any are tightened. Bolts should be tightened snugly but not excessively, starting with the center bolts and working toward each end of the oil pan. Excessive tightening of the bolts will crush the oil pan gasket unnecessarily.

(10) Fill the crankcase to the proper level with the oil recommended in the Lubricating Oil Specifications in Operator's Manual.

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator Installed between the oil pump outlet pipe and the cylinder block.

The regulator assembly consists of a regulator body, a hollow piston-type valve, a spring and a plug to retain the valve and spring (Fig. 1).

The valve is held on its seat by the spring, which is compressed by the plug threaded into the valve opening in the regulator body. The entire assembly is bolted to the lower flange of the cylinder block and sealed against oil leaks by a gasket between the two members. When the oil pressure at the valve exceeds 50 psi (345 kPa), the valve is forced from its seat and oil from the engine oil gallery is by-passed to the oil pan.

Under normal conditions, the pressure regulator should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

**WARNING|**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

47.1 Remove Oil Pressure Regulator

(1) Remove the two oil pump outlet pipe to regulator attaching bolts and lockwashers.
(2) Remove the two regulator body-to-cylinder block bolts and lockwashers.
(3) Tap the lower end of the regulator body lightly to loosen the body from the gasket and cylinder block. Remove the gasket.

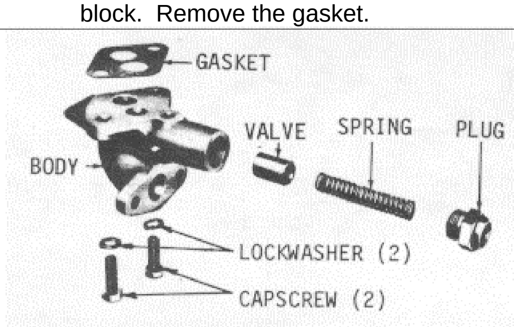


*Fig. 1*
*Lubricating Oil Pressure Regulator Details and Relative Location of Parts*

47.2 Disassemble Oil Pressure Regulator

(1) Clamp the flange of the regulator body in a bench vise with soft jaws and remove the plug from the body.
(2) Remove the spring and valve from the regulator body.

47.3 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

Clean all of the regulator components in fuel oil and dry them with compressed air. Then inspect the parts for wear or damage.

The regulator valve must move freely in the valve body. If the valve or regulator body is scored and cannot be cleaned up with crocus cloth, they 6 must be replaced.

Replace a fractured or pitted spring.

47.4 Assemble Oil Pressure Regulator

Refer to Fig. 1 and assemble the regulator as follows:

(1) Apply clean engine oil to the outer surface of the valve and slide it into the regulator body, closed end first.
(2) Insert the spring in the valve and, while compressing the spring, start the plug into the regulator body. Tighten the plug.

47.5 Install Oil Pressure Regulator

(1) Remove all traces of the old gasket from the regulator body, cylinder block and pump outlet pipe flange.
(2) Affix a new gasket to the regulator body with the oil passage holes in the gasket in alignment with the oil passages in the body and secure the regulator to the cylinder block with two bolts.
(3) Place a new gasket between the regulator and the pump outlet pipe and connect these parts together with two bolts.

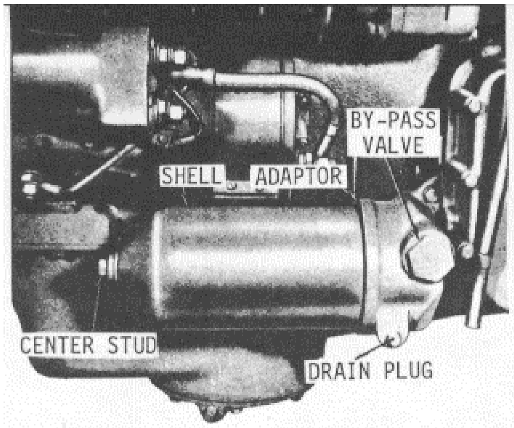


Fig. 1
Typical Full-Flow Oil Filter Mounting

Series 71 engines are equipped with a full-flow type lubricating oil filter.

48.1 Full-Flow Oil Filter

The full-flow type lubricating oil filter is installed ahead of the oil cooler in the lubrication system. The filter may be remotely mounted or mounted on the engine as shown in Fig. 1.

The filter assembly consists of a replaceable element enclosed within a shell which is mounted on an adaptor or base. When the filter shell is in place, the element is restrained from movement by a coil spring.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adaptor to the space surrounding the filter element. Impurities are filtered out as the oil is forced through the element to a central passage surrounding the center stud and out through another passage in the filter adaptor and then to the oil cooler.

A valve which opens at approximately 18-21 psi (124-145 kPa), is located in the filter adaptor or base and will bypass the oil directly to the oil cooler should the filter become clogged.

48.2 Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action. Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found on the filter elements at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles and carbon must be ensured by replacement of the oil filter elements at the time the engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations and proper filter maintenance will ensure trouble-free lubrication and longer engine life.

48.3 Replace Oil Filter Element

Replace the element in either the full-flow or bypass type oil filter assembly (Fig. 2) as follows:

(1) Remove the drain plug from the filter shell or the filter adaptor or base and drain the oil.
(2) Back out the center stud and withdraw the shell, element and stud as an assembly. Discard the element *and* the shell gasket.
(3) Remove the center stud and gasket. Retain the gasket unless it is damaged and oil leaks occurred.

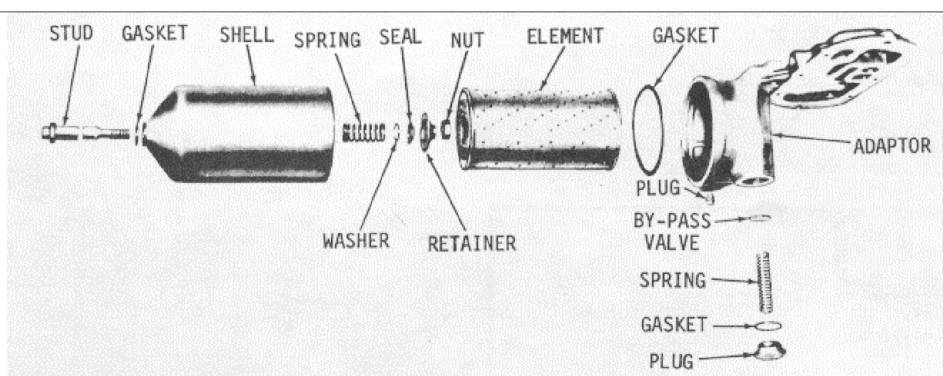


*Fig. 2*
*Full-Flow Oil Filter Details and Relative Locations of Parts*

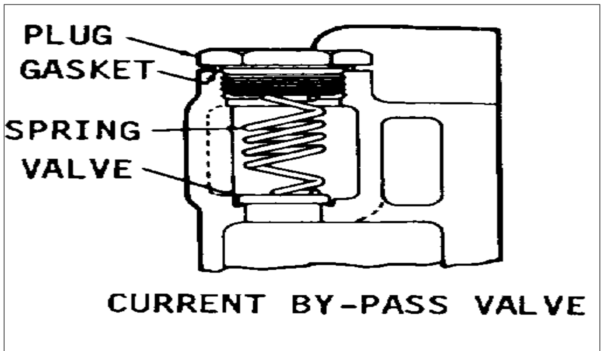


*Fig. 3 Bypass Valve*

(4) Remove the nut or snap ring on the full-flow filter center stud.

(5) Remove and discard the element retainer seal (Fig. 2). Install a new seal.

(6) Clean the filter shell and the adaptor or base.

(7) Install the center stud gasket and slide the stud (with the spring, washer, seal and retainer installed on the full-flow filter stud) through the filter shell.

(8) Install a new shell gasket in the filter adaptor or base.

Note: Before installing the filter shell gasket, be sure all of the old gasket material is removed from the filter shell and the adaptor or base. Also make sure the gasket surfaces of the shell and the adaptor or base have no nicks, burrs or other damage.

(9) Position the new filter element carefully over the center stud and within the shell. Then place the shell, element and stud assembly in position on the filter adaptor or base and tighten the stud to 50-60 ft-lbs (68-81 Nm) torque.

(10) Install the drain plug.

(11) Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough (approximately twenty minutes) for the oil from various parts of the engine to drain back to the crankcase, add sufficient oil to bring it to the proper level on the dipstick.

48.4 Remove and Install Bypass Valve

(1) If necessary, remove the filter adaptor from the engine.

(2) Remove the plug and gasket and withdraw the spring and bypass valve (Fig. 2).

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Inury.

(3) Wash all of the parts in clean fuel oil and dry them with compressed air.

(4) Inspect the parts for wear. If necessary, install new parts.

(5) Reassemble and install the bypass valve (Fig. 3).The bypass pressure is 18-21 psi (124-145 kPa). Tighten the 1-1/4"-16 bypass valve plug to 95-105 ft-lbs (129-130 Nm) torque.

(6) Use a new gasket and install the filter adaptor.

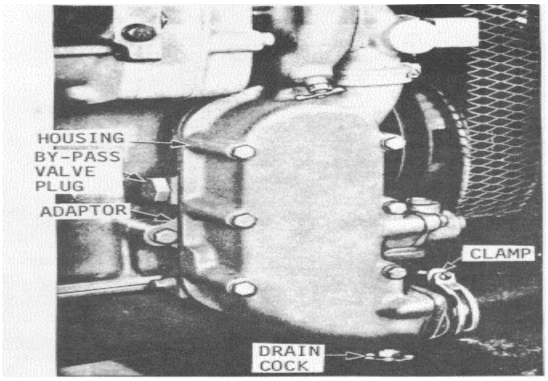


*Fig. 1*
*Typical Lubricating Oil Cooler Mounting - Radiator Cooled Engine*

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

In order to perform its functions satisfactorily, the lubricating oil must be kept within the proper temperature limits. If the oil is too cold, it will not flow freely. If the oil is too hot, it cannot support the bearing loads, it cannot carry away enough heat, and it may result in too great an oil flow. As a consequence, oil pressure may drop below acceptable limits and oil consumption may become excessive.

In performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat and this heat must be dissipated by an oil cooler.

On fan and radiator cooler engines, the lubricating oil cooler is usually located on the side of the engine just below the water pump (Fig. 1).

To assure engine lubrication if the oil cooler becomes clogged, a bypass valve located at the oil inlet to the cooler bypasses oil around the cooler directly to the oil gallery in the cylinder block.

The core through which the oil passes while being cooled is sealed to prevent a coolant from getting into the oil. Whenever an oil cooler is assembled, special care must be taken to have the proper gaskets in place and the retaining bolts tight.

49.1 Remove Lubricating Oil Cooler

(1) Drain the cooling system by opening the drain valve (Fig. 1) at the bottom of the oil cooler housing.
(2) Remove the bolts and lockwashers that attach the water inlet connector to the oil cooler housing.
(3) Loosen the clamp on the water pump inlet seal.
(4) Remove the bolts attaching the oil cooler housing to the adaptor, and remove the housing and core as an assembly. Be careful when withdrawing the assembly not to drop or damage the oil cooler core.
(5) Remove all traces of gasket material from the oil cooler components.
(6) If the core openings are not marked IN and OUT, mark the openings.
(7) If the adaptor is to be removed, remove the bolts that hold the adaptor to the cylinder block and remove the adaptor and gaskets.
(8) Clean the oil cooler core as outlined under 49.2 "Clean Oil Cooler Core".
(9) Pressure check the oil cooler core as outlined under 49.3 "Pressure Check Oil Cooler Core" .

49.2 Clean Oil Cooler Core

(1) Clean Oil Slide of Core - Circulate solution of' trichloroethylene through the core passages with a force pump to remove carbon and sludge.

**WARNING**

This Operation Should Be Done In The Open Or In A Well Ventilated Room When Trichloroethylene Or Other Toxic Chemicals Are Used For Cleaning.

Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate an Oakite or alkaline solution through the core and flush thoroughly with clean hot water.

(2) Clean Water Side of Core - After cleaning oil side of the core, immerse it in the following solution: add one-half (1/2) pound of oxalic acid to each two and one- half (2-1/2) gallons of solution composed

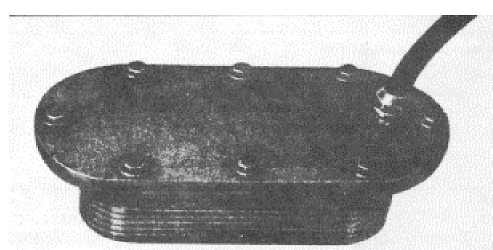

Fig. 2
Oil Cooler Core Prepared for Pressure Check

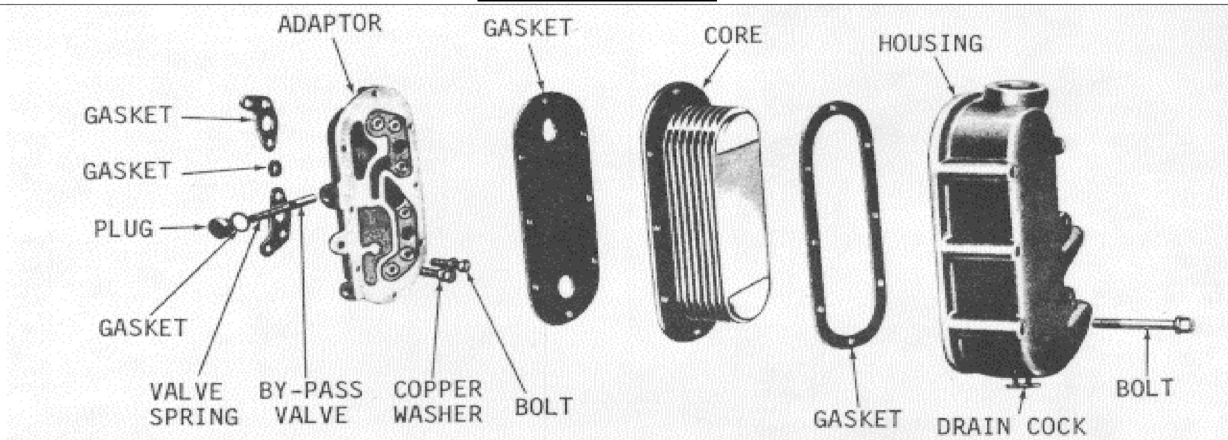


*Fig. 3*
*Lubricating Oil Cooler and Bypass Valve Details and Relative Location of Parts*

of one-third (1/3) muriatic acid and two-thirds (2/3) water. The cleaning action is evidenced by bubbling and foaming. The process must be carefully watched and, when bubbling stops (this usually takes from 30 to 60 seconds), the core should be removed from the cleaning solution and thoroughly flushed with clean hot water. After cleaning dip the core in light oil.

Note: Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. In this instance, replacement of the oil cooler core is strongly recommended.

49.3 Pressure Check Oil Cooler Core

(1) Make a suitable plate and attach it to the flanged side of the oil cooler core. Use a gasket made from rubber to ensure a tight seal. Drill and tap the plate to permit an air hose fitting to be attached at the inlet side of the oil cooler core (Fig. 2).

(2) Attach an air hose and apply 75-150 psi air pressure. Then, submerge the oil cooler core and plate assembly in a tank of heated water (1800F). Any leaks will be indicated by air bubbles in the water.

**CAUTION**

When Making This Pressure Test Be Sure That Personnel Are Adequately Protected Against Any Stream Of Pressurized Water From A Leak Or Rupture Of A Fitting, Hose Or The Oil Cooler Core.

(3) After the pressure check is completed, remove the plate and air hose and dry the oil cooler core with compressed air. Replace the oil cooler core if leaks were indicated.

Note: <u>In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be flushed immediately to prevent serious damage(refer to SM6-5-53.0).</u>

49.4 Install Lubricating Oil Cooler

Refer to Fig. 3 and install the lubricating oil cooler as follows:

(1) If the oil cooler adaptor was removed from the cylinder block, remove the old gaskets from the bosses where the adaptor sets against the block. Affix new adaptor to cylinder block gaskets; then secure the adaptor to the cylinder block with bolts, lockwashers and copper washer.

Note: <u>The copper washer must be installed on the lower right-hand adaptor-to-block bolt to prevent leakage of oil from the adaptor</u>.

(2) Affix new gaskets and to each side of the core, and position the element inside the housing.

Note: The inlet and outlet openings in the oil cooler core are marked "IN" and "OUT". Make sure the oil cooler core is reinstalled in its original position, otherwise the oil flow will be reversed and could result in foreign_ articles that may not have been removed to be loosened and circulated through_ the <u>engine.</u>

(3) Set the housing with the cooler core against the adaptor and secure with bolts and lockwashers, at the same time locating the seal and clamp. Tighten the clamp (Fig. 1). (4) Affix a new gasket to the oil cooler water inlet connector and secure with bolts and 1ockwashers.

49.5 Lubricating Oil Cooler Bypass Valve

To assure proper lubrication if the oil cooler core becomes clogged, a valve, located between the oil inlet and the core, bypasses the oil around the cooler directly to the oil gallery in the cylinder block.

The bypass valve, spring, plug and gasket are housed in the oil cooler adaptor, see Fig. 1. The bypass valve should be removed, cleaned, and reassembled whenever the cooler core is cleaned or replaced. However, if occasion requires, the bypass valve can be removed without removing the oil cooler.

49.6 Remove Bypass Valve

The bypass valve may be removed by removing the plug and lifting the gasket, valve and spring from the adaptor, see Fig. 1.

49.7 Inspection

Clean the bypass valve components with fuel oil and dry them with compressed air.

Inspect the valve parts for wear and replace the parts if necessary.

49.8 Install Bypass Valve

(1) Apply clean engine oil to the outside surface of the bypass valve and place the valve in the adaptor, closed end first.
(2) Slide the valve spring into the valve and screw the plug with the gasket, into the adaptor.

A steel ribbon-type oil level dipstick is used to check the quantity of oil in the engine oil pan. The dipstick is located in an adaptor attached by means of a guide, to an opening in the cylinder block.

Maintain the oil level between the full and low marks on the dipstick and never allow it to drop below the low mark. No advantage is gained by having the oil level above the full mark. Overfilling will cause the oil to be churned by the crankshaft throws causing foaming or aereation of the oil. Operation below the low mark will expose the pump pick-up causing aereation and/or loss of pressure.

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various parts of the engine to drain back into the oil pan.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade.

Fill the crankcase with oil as follows:

(1) Fill the oil pan to the full mark on the dipstick.

(2) Start and run the engine for approximately ten minutes.

(3) Stop the engine and wait a minimum of twenty minutes. Then add the required amount of oil to reach the full mark on the dipstick.

A shallow type oil pan (Fig. 1) is used.

51.1 Remove and Install Oil Pan

(1) Remove the drain plug and drain the oil.
(2) Remove the bolt and washer assemblies. Then remove the oil pan and gasket.
(3) Clean all of the old gasket material from the cylinder block and the oil pan. Then clean the oil pan with fuel oil and dry it with compressed air.
(4) Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.
(5) When installing the oil pan, use a new gasket and, starting with the center bolt on each side and working alternately toward each end of the pan, tighten the bolts to 10-20 ft-lbs (17-27 Nm) torque. Do not overtighten the bolts. Once the bolts are tightened to the specified torque, do not retighten them as it could be detrimental to the oil pan gasket. If a leak should develop at the oil pan, check if the lockwasher is compressed. If not, the bolt may be tightened. However, if the lockwasher is compressed and leaking occurs, remove the oil pan and determine the cause of the leakage.

Note: Oil pan bolts are coated with a locking material. To reactivate the locking ability of the bolts, apply a drop or two of Loctite J 26588-242, or equivalent to the threads of the bolts at reassembly.

(6) Install and tighten the drain plug to 25-35 ft-lbs (34-47 Nm) (refer to SM6-5-71.0).
(7) Fill the oil pan with new oil (refer to SM 6-5-50.0 and Operator's Manual) to the full mark on the dipstick. Then start and run the engine for a short period to check for oil leaks.
(8) Stop the engine and, after approximately twenty minutes, check the oil level. Add oil, if necessary.

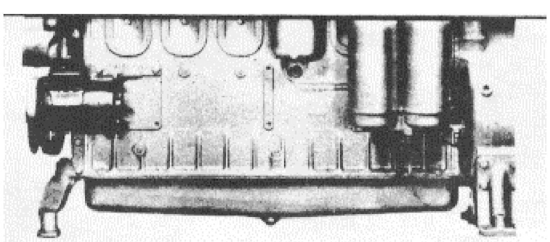

*Fig. 1*
*Typical Shallow-Type Oil Pan*

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartments by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air from the air box past the piston rings. This air sweeps up through the flywheel housing and is admitted to the valve compartment through cavities in the lifter brackets and vent castings. Ventilating air in the valve compartment is drawn off through a vent attached to the valve cover.

52.1 Service

Inspect and clean the breather tube and breather and baffle if necessary to eliminate the possibility of clogging.

The steel mesh pad should be removed and cleaned periodically (refer to Operator's Manual).

To clean the breather assembly:

(1) Loosen the breather tube hose clamp adjacent to the breather cover and pull the hose off of the cover.
(2) Remove the body and breather as an assembly from the oil pan. Remove the body gasket.
(3) Then remove the breather and gasket from the body.

**WARNING**

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(4) Wash the breather assembly and cover thoroughly in clean fuel oil and dry them with compressed air.
(5) Reinstall the breather assembly.

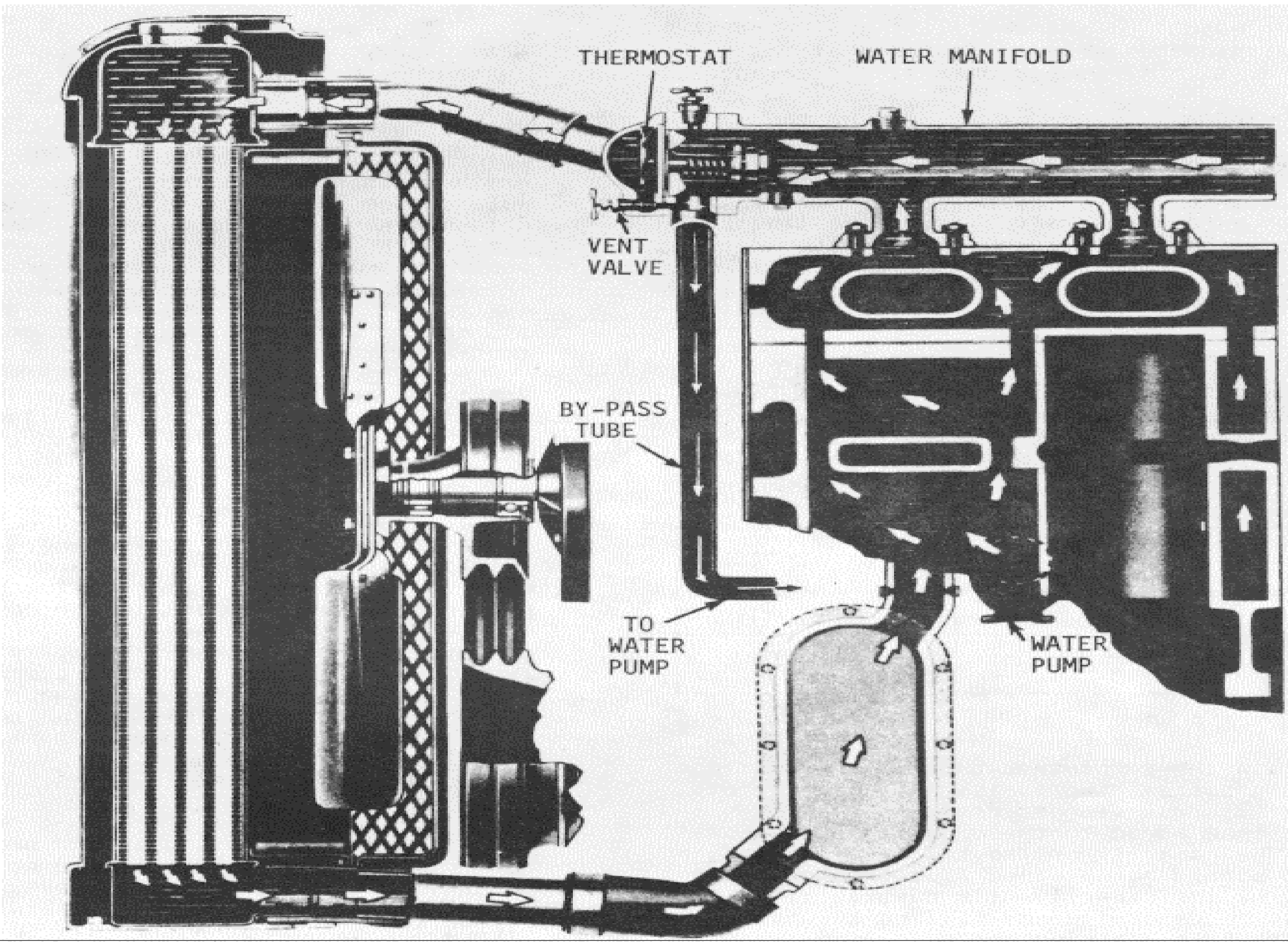



*Fig. 1*
*Typical Cooling System with Radiator and Fan*

To effectively dissipate the heat generated by the engine, the following cooling system is used: radiator and fan. A centrifugal type water pump attached to and driven by the blower, circulates the engine coolant in the system. A thermostat is utilized to maintain a normal engine operating temperature (refer to SM6-5-70.0).

53.1 Radiator and Cooling Fan

The engine coolant is circulated through the radiator (Fig. 1) where the heat is absorbed in the air stream developed by the blower. The water pump draws the coolant through the oil cooler and discharges it into the lower part of the cylinder block. Openings in the water jacket around the cylinder bores connect with corresponding openings in the cylinder head through which the liquid rises to circulate around the valves and fuel injectors. Then the coolant passes through a water manifold, bolted to the cylinder head, past the thermostat and into the radiator.

Upon starting a cold engine or when the coolant is below operating temperature (thermostat closed) the coolant is bypassed from the water manifold directly to the pump, thus providing water circulation within the engine during the warm-up period.

53.2 Engine Cooling System Maintenance

A properly maintained and clean cooling system will reduce engine wear and increase the satisfactory engine operating time between engine overhauls. This is accomplished by the elimination of hot spots within the engine. Thus, when operating within the proper engine temperature range and when not exceeding the recommended horsepower output of the unit, all engine parts will be within their operating temperature ranges and at their proper operating clearances.

53.3 Engine Coolant

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from component parts such as exhaust valves, cylinder liners and pistons which are surrounded by water jackets In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil-to-water oil cooler. Refer to Operator's Manual for coolant recommendations.

53.4 Cooling System Capacity

The capacity of the basic engine cooling system (cylinder block, head, thermostat housings and oil cooler housing) is shown in the following chart.

| COOLING SYSTEM CAPACITY (Basic Engine) | | |
|---|---|---|
| Engine | Gallons | Litres |
| 6-71 | 5.5 | 20.8 |

*Raw Water Intercooled

To ascertain the complete amount of coolant in the cooling system, the additional capacity of the radiator, hoses and accessories such as a heater must be added to the capacity of the basic engine. The capacity of the radiator and related equipment should be obtained from the equipment supplier, or the capacity of a particular cooling system may be determined by filling the system with water, then draining and measuring the amount required.

53.5 Drain Cooling System

Drain the coolant by opening the drain cocks in the water outlet elbow, oil cooler housing, the fresh water pump, the radiator and, on certain engines the water hole cover located on the blower side toward the rear of the cylinder block. Components of the cooling system that do not have a drain cock, are drained through the oil cooler housing drain cock. Remove the cooling system filler cap to permit the coolant to drain completely from the system. To ensure that all of the coolant is drained completely from an engine, all cooling system drains should be opened. Should any water that may be trapped in the cylinder block or radiator freeze, it will expand and may cause damage. When freezing weather is expected, drain a unit not adequately protected by antifreeze. Leave all drain cocks open until refilling the cooling system.

53.6 Fill Cooling System

Before starting the engine, close all of the drain cocks and fill the cooling system with water. The use of clean, soft water will eliminate the need for descaling solutions to clean the cooling system. A hard, mineral-laden water should be made soft by using water softener chemicals before it is poured into the cooling system. These water softeners modify the minerals in the water and greatly reduce or eliminate the formation of scale.

Start the engine and, after normal operating temperature has been reached, allowing the coolant to expand to its maximum, check the coolant level. The coolant level should be within 2" of the top of the filler neck.

Should a daily loss of coolant be observed, and there are no apparent leaks, there is a possibility of gases leaking past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube from the overflow pipe to a water container. Bubbles in the water in the container during engine operation will indicate this leakage. Another method for-observing trapped air in the cooling system is by inserting a transparent tube in the water outlet line.

53.7 Flush Cooling System

If a coolant filter is used and properly maintained, the cooling system need not be flushed. Otherwise, the cooling system should be flushed each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor In the fall, preparing the cooling system for a new solution. The flushing operation should be performed as follows:

(1) Drain the previous season's solution from the unit.
(2) Refill the cooling system with soft, clean water. If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.
(3) Start the engine and operate it for 15 minutes to thoroughly circulate the water.
(4) Drain the cooling system completely. 5) Refill the system with the solution required for the coming season.

53.8 Cooling System Cleaners

If the engine overheats and the fan belt tension and water level are satisfactory, it will be necessary to clean and flush the entire cooling system. Scale formation should be removed by using a quality descaling solvent. Immediately after using the solvent, neutralize a system with a neutralizer. It is important that the directions printed on the container of the descaling solvent be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and flush it with clean water. Then fill the system with the proper cooling solution.

Note: Whenever water is added to a hot engine, it must be done slowly to avoid rapid cooling which may cause distortion and possible cracking of engine castings.

53.9 Reverse-Flushing

After the engine and radiator have been thoroughly cleaned, they should be reverse-flushed. The water pump should be removed and the radiator and engine reverse-flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump. Reverse-flushing is accomplished with hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, thus loosening and forcing the scale deposits out.

Reverse-flush the radiator as follows:

(1) Remove the radiator inlet and outlet hoses and replace the radiator cap.
(2) Attach a hose at the top of the radiator to direct the water away from the engine.
(3) Attach a hose to the bottom of the radiator and insert a flushing gun in the hose.
(4) Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.
(5) Turn on the water and, when the radiator is full, turn on the air in short blasts.

Note: Apply air gradually. Do not exert more than 30 psi (207 kPa) air pressure. Too great a pressure may rupture a radiator tube .

(6) Continue flushing until only clean water is expelled from the radiator.

Reverse-flush the cylinder block and cylinder head water passage as follows:

(1) Remove the thermostat and the water pump.
(2) Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.
(3) Attach a hose to the water outlet at the top of the engine and insert the flushing gun in the hose.
(4) Block the bottom opening and fill the coolant passages with water; then unblock the bottom opening and blow the water from the engine with full air pressure from the flushing gun.
(5) Again fill the engine cooling system with water and blow clean with full air pressure. Repeat this procedure until the flushing water runs clean.

If the scale deposits in the radiator cannot be removed by chemical cleaners or reverse-flushing, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

53.10 Miscellaneous Cooling System Checks

In addition to the above cleaning procedure, the other components of the cooling system should be checked periodically to keep the engine operating at peak efficiency. The thermostat and the radiator pressure cap should be checked and replaced, if found defective.

When water connection seals and hoses are installed be sure the connecting parts are properly aligned and the seal or hose is in its proper position before tightening the clamps. All external leaks should be corrected as soon as detected. The fan belt must be adjusted to provide the proper tension and the fan shroud must be tight against the radiator core to prevent recirculation of air which may lower the cooling efficiency.

53.11 Contaminated Engine

When the cooling system or lubricating system becomes contaminated, it should be flushed thoroughly to remove the contaminants before the engine is seriously damaged. One possible cause of such contamination is a cracked oil cooler core. In such a case oil will be forced into the cooling system while the engine is operating and coolant will leak into the lubricating system when the engine is stopped.

Coolant contamination of the lubricating system is especially harmful to an engine during the cold season when the cooling system is normally filled with an ethylene glycol antifreeze solution. If mixed with the oil in the crankcase, this antifreeze forms a varnish which quickly immobilizes moving engine parts.

To remove such contaminants from the engine, both the cooling system and the lubrication system must be thoroughly flushed as outlined below:

COOLING SYSTEM

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, the following flushing procedure is recommended:

(1) Prepare a mixture of Calgon, or its equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.
(2) Remove the engine thermostat to permit the Calgon and water mixture to circulate through the engine and the radiator.
(3) Fill the cooling system with the Calgon solution.
(4) Run the engine for five minutes.
(5) Drain the cooling system.
(6) Repeat Steps 3 through 5.
(7) Fill the cooling system with clean water.
(8) Let the engine run five minutes.
(9) Drain the cooling system completely.
(10) Install the engine thermostat.
(11) Close all of the drains and refill the engine with fresh coolant.

LUBRICATION SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution or other soluble material, the following cleaning procedure, using Butyl Cellosolve, or its equivalent, is recommended.

**WARNING**

Use Extreme Care In The Handling Of These Chemicals To Prevent Serious Injury To The Person Or Damage To Finished Surfaces. Wash Off Spilled Fluid Immediately With Clean Water.

If the engine is still in running condition, proceed as follows:

(1) Drain all of the lubricating oil.
(2) Remove and discard the oil filter element. Clean and dry the filter shell and install a new element.
(3) Mix two parts of Butyl Cellosolve, or its equivalent, with one part SAE 10 engine oil. Fill the engine crankcase to the proper operating level with the mixture.
(4) Start and run the engine at a fast idle (1, 000 to 1, 200 rpm) for 30 minutes to one hour. Check the oil pressure frequently.
5) After the specified time, stop the engine and immediately drain the crankcase and the filter. Sufficient time must be allowed to drain all of the fluid.
(6) Refill the crankcase with SAE 10 engine oil after the drain plug is replaced, and run the engine at the same fast idle speed for ten or fifteen minutes. Then, stop the engine and drain the oil thoroughly.
(7) Remove and discard the filter element, clean the filter shell and install a new element.
(8) Install the drain plug and fill the crankcase to the proper level with the oil recommended for normal engine operation.
(9) To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1, 000 to 1, 200 rpm) for approximately 30 minutes. Then, stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.
(10) If the procedures for cleaning the lubricating oil system were not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

Note: Make certain that the cause of the internal coolant leak has been corrected before returning the engine to service.

The centrifugal-type water pump (Fig. 1) circulates the engine coolant through the cylinder block, cylinder head, radiator, and the oil cooler. The drive end of the pump shaft is supported by a sealed double-row combination radial and thrust ball bearing. The pump shaft serves as the inner race of the bearing.

A spring-loaded seal assembly and a water slinger, located between the seal and the bearing, prevent the coolant from passing along the shaft to the bearing. The carbon washer in the seal assembly bears against a steel insert that is pressed into the pump body. The insert may be replaced when worn.

The impeller is a press fit on one end of a stainless steel shaft.

The pump is mounted at the front end of the blower (Fig. 2) and is driven by the lower blower rotor shaft. The drive coupling, pressed on the end of the pump shaft, has an integral oil thrower that shrouds-the flange end of the pump body and deflects the oil away from the bearing.

54.1 Lubrication

The sealed type ball bearing is filled with lubricant at the time it is assembled to the pump shaft, and no further lubrication is required.

54.2 Remove Water Pump

Refer to Figs. 2 and 3 and remove the pump as follows:

(1) Open the drain cock in the pump body and drain the cooling system.
(2) Loosen the hose clamps and slide the water pump inlet hose back against the pump cover.
(3) Remove the two bolts and lockwashers that attach the pump outlet flange to the cylinder block. Remove the flange and packing ring.

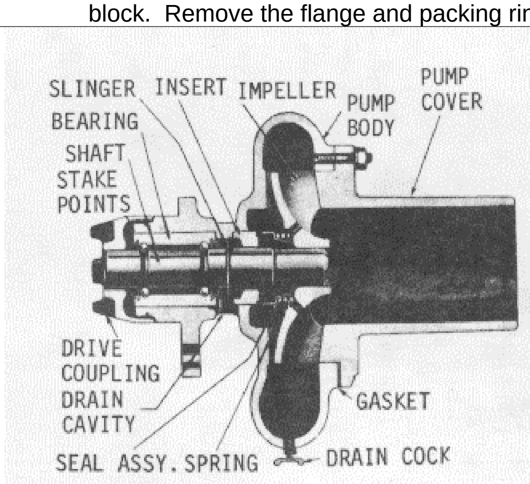



*Fig. 1*
*Water Pump Assembly*

(4) Remove the three bolt and seal assemblies that attach the pump to the blower assembly.
(5) Withdraw the pump and remove the gasket.

54.3 Disassemble Water Pump

(1) Remove the pump cover and gasket.

Note: Clean the corrosion from around the impeller and shaft before separating the shaft and bearing assembly from the impeller, seal and pump body.

(2) Support the pump on its mounting flange in an arbor press (Fig. 4). Place a short steel rod on the end of the shaft and press the shaft and bearing assembly from the impeller, seal and pump body. If the impeller is pinned to the shaft, considerably more pressure will be required to shear the pin.
(3) Remove the impeller and seal assembly from the pump body.
(4) If the steel insert is worn or scratched excessively, tap or press it out of the pump body.
(5) Remove the water slinger from the shaft.
(6) If the impeller was pinned to the shaft, re- - move the sheared taper pin from the shaft and impeller by tapping against the small end of the pin with a punch and hammer.
(7) If necessary, remove the pump drive coupling from the shaft with tool J 1930 as shown in Fig. 5.

54.4 Inspection

Clean all of the parts except the shaft and bearing assembly. The sealed type pump shaft bearing must not be immersed in a cleaning fluid since dirt may be washed in and the fluid cannot be entirely removed.

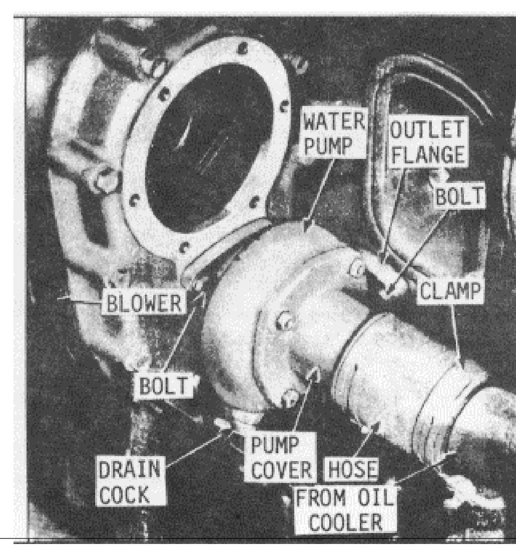



*Fig. 2*
*Water Pump Assembly Water Pump Mounting*

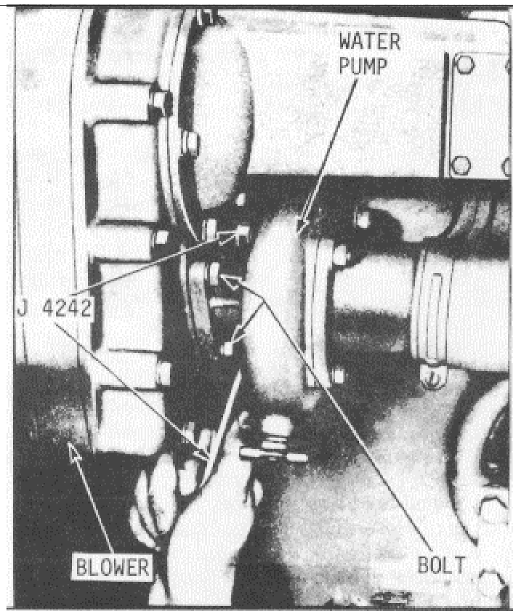



*Fig. 3*
*Loosening Inner Pump-to-Blower Attaching Bolt with Tool J 4242*

Revolve the pump shaft bearing slowly by hand. If rough spots are detected, replace the shaft and bearing assembly and the seal assembly.

Examine the impeller and the seal components for wear and replace them, if necessary.

Examine the studs in the pump body. If it is necessary to replace a stud, use a good grade of sealant on the threads and drive the stud in to 6-8 ft-lbs (8-11 Nm) torque.

54.5 Assemble Water Pump

Refer to Figs. 1 and 6 and assemble the pump as follows:

(1) If a new steel insert is to be used, make sure the counterbore in the pump body is thoroughly clean before installing the new insert. Dirt in the counterbore can cause misalignment between the insert and the carbon washer and result in a leak at this point. Start the counterbored end of the insert into the pump body. Then press the insert in until it contacts the shoulder in the pump body. The insert has a .0015" -.0035" press fit in the pump body.

**CAUTION**

Do Not Mar The Highly Finished Seal Contact Surface Of The Insert When Pressing It Into The Pump Body.

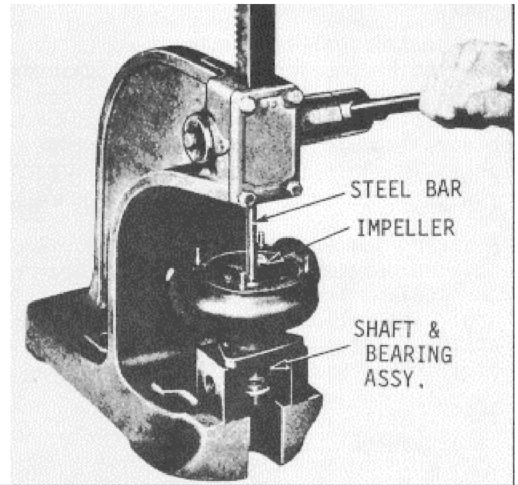



*Fig. 4*
*Pressing Pump Shaft from Impeller*

(2) Install the slinger on the pump shaft with the flange of the slinger approximately .1875" from the end of the outer race of the bearing.

(3) Support the impeller end of the pump body on an arbor press and insert the coupling end of the shaft and bearing assembly into the pump body. Then press against the outer race of the bearing until the bearing contacts the shoulder in the pump body.

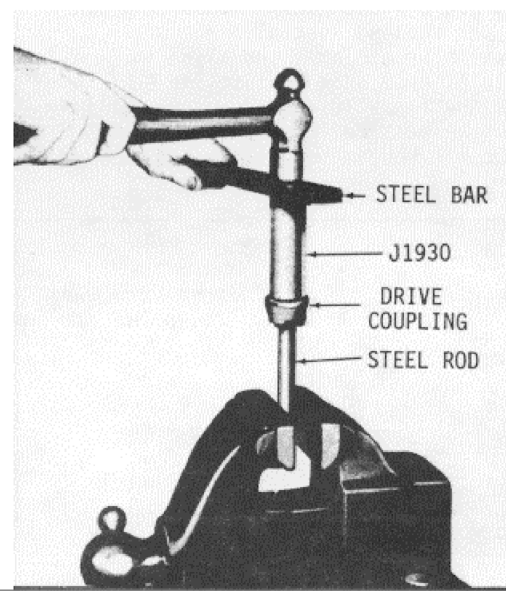



*Fig. 5*
*Removing Pump Drive Coupling from Shaft with Tool J 1930*

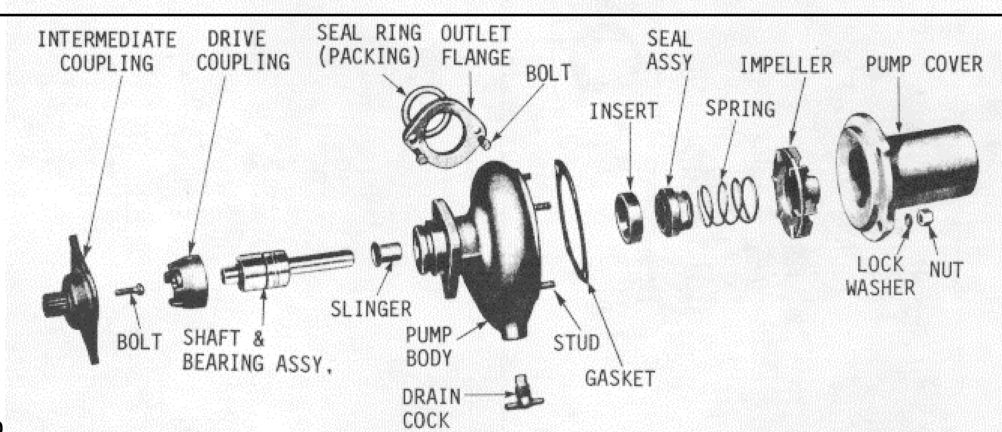



*Fig. 6 Water Pump Details and Relative Location of Parts*

(4) With the surface of the pump seal clean and free from dirt and metallic particles, apply a thin coat of liquid soap on the in- side diameter of the rubber seal. Do not scratch or mar the surface of the carbon seal washer. Slide the seal assembly on the pump shaft until the carbon seal washer is seated firmly against the pump body insert. Then install the spring with the small end toward the seal.

(5) Support the bearing end of the shaft on the bed of an arbor press. Then press the impeller on the shaft. Do not press against the outer race of the bearing. The end of the shaft must be flush with the face of the impeller hub with the bearing held against the shoulder in the pump body.

(6) Support the impeller end of the pump shaft on a suitable arbor and press the coupling on the shaft. The drive coupling must be flush with the end of the shaft. Make sure the drive coupling is tight on the shaft.

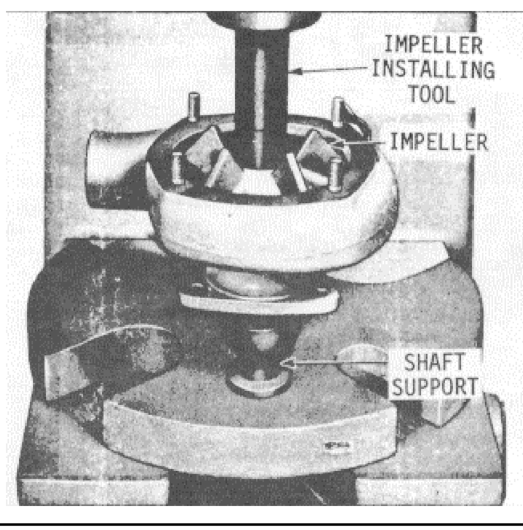



*Fig. 7 Installing Pump Impeller*

(7) Rotate the shaft by hand to be sure the rear face of the impeller blades does not rub the pump body.

(8) Place a new pump cover gasket against the bolting flange of the pump body. Slide the pump cover over the studs and secure it to the pump body with four lockwashers and nuts.

(9) If previously removed, install the drain cock in the pump body.

## 54.6 Install Water Pump

Refer to Fig. 2 and install the water pump on the engine as follows:

(1) Make sure the intermediate shaft coupling is secure. If it was previously removed, insert the splined end of the coupling into the mating splines in the blower rotor shaft. Then draw the coupling in place with the 5/16"-24 x 1-1/2" bolt. Tighten the bolt to 15-19 ft-lbs (20-26 Nm) torque.

(2) Place the pump outlet flange over the pump outlet with the flat side of the flange facing the pump body. Slip the packing ring over the pump outlet and next to the flange.

(3) Use a new gasket at the bolting flange and place the pump against the blower end plate cover so that the lugs on the drive coupling mesh with the lugs on the intermediate shaft coupling. Secure the pump to the blower with the three bolts and seal washers.

(4) Slide the pump outlet packing ring and packing flange against the cylinder block and secure the flange with two bolts and lock- washers.

(5) Slide the water pump inlet hose in place and secure it with the hose clamps.

(6) Close the pump drain cock and fill the engine cooling system.

Note: When filling the cooling system of certain models, it is necessary to open the vent valve at the top of the thermostat housing,

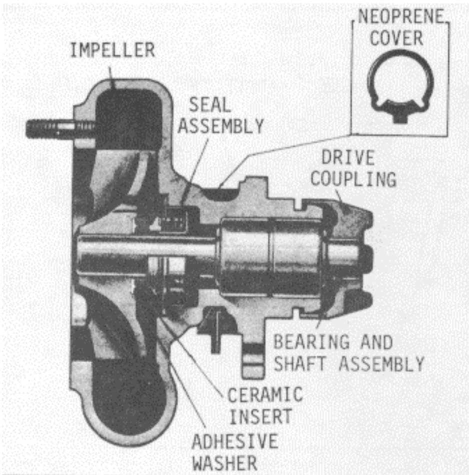



*Fig. 8 Water Pump With Ceramic Insert in Impeller*

54.7 Water Pump with Ceramic Insert in Impeller

Certain pumps are built with an impeller assembly that includes a ceramic insert (Fig. 8). The spring-loaded water pump seal assembly bears against the insert. This pump does not include a slinger. Disassembly and assembly of this pump is the same as the standard water pump except as follows:

When removing the impeller, protect the ceramic insert from damage at all times during pump overhaul. Always lay the impeller on the bench with the ceramic insert up to prevent damage to the insert.

Inspect the ceramic insert for cracks, scratches and bond to the impeller. If the insert is damaged, replace it as follows:

(1) Bake the insert and impeller assembly at 500°F (2600C) for one hour. The insert can be removed easily while the adhesive is hot. After removing the insert, clean the insert area on the impeller with sandpaper, wire brush or a buffing wheel to remove the old adhesive, oxide, scale, etc.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(2) Wet a clean cloth with a suitable solvent such as alcohol and thoroughly clean the impeller-insert area and the grooved side of a new ceramic insert. Then wipe the parts with a clean, dry cloth.

(3) Place the adhesive washer in the impeller bond area with the ceramic insert on top. The polished face of the ceramic insert should be visible to the assembler. Clamp the insert and impeller together with a 3/8"

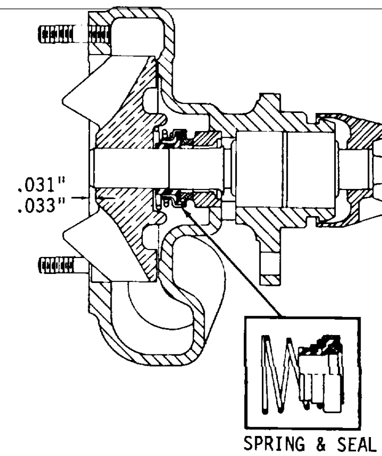



*Fig. 9 High Capacity Water Pump*

bolt and nut and two smooth .125" thick washers. Tighten the bolt to 10 ft-lbs (14 Nm) torque.

**CAUTION**

Do Not Mar The Polished Surface Of The Ceramic Insert.

(4) Place the impeller assembly in a level position, with the ceramic insert up, in an oven preheated to 3500F (177oC) aid bake it for one hour.

Note: The face of the ceramic insert must be square with the axis of the tapered bore within .004". The pump shaft may be used as a mandrel for inspection.

(5) Remove the impeller from the oven and, after it has cooled to room temperature, install it in the pump. Do not loosen the clamping bolt until the assembly cools. Make sure the mating surfaces of the water seal and the ceramic insert are free of dirt, metal particles and oil film.

When installing the shaft and bearing assembly, it will not be necessary to stake the end of the pump body

To reduce possible coolant leakage, apply a light coat of non-hardening sealant on the outside diameter of a new water seal. Then press the seal assembly in place with a suitable sleeve until it seats firmly against the pump body.

Press the impeller on the shaft, using impeller installer J 22437 (Fig. 7), until the distance between the end of the shaft and the face of the impeller hub is .031" - .033" (Fig. 9), with the bearing held against the shoulder in the pump body.

Some pumps include a neoprene cover (Fig. 8) to allow coolant to drain, but still keep dust and dirt out of the pump body at the weep hole. The neoprene cover will stretch for removal or installation.

Note: Be sure the tip of the cover is located below the weep hole in the pump body.

54.8 High Capacity Water Pump

This engine is equipped with a water pump of greater capacity to provide increased circulation of the coolant. The ratio of blower speed (pump speed) to engine speed is 2.00:1.

54.9 Service

The high capacity pump (Fig. 9) is serviced in the same manner as the standard pump. However, press the impeller on the shaft with impeller installer J 22437 until the distance between the end of the shaft and the face of the impeller hub is .031" - .033" (Fig. 9), with the bearing held against the shoulder in the pump body.

Cooling water, leaving the cylinder head through an opening over each exhaust port, enters the water manifold which is attached to the head with two nuts and lockwashers at four of the six water openings, as shown in Fig. 1. A separate gasket is used at each attaching flange between the manifold and the cylinder head.

A gradually increasing area in the case manifold from the gear end terminates in a mounting flange to which the thermostat housing is attached by means of bolts and lockwashers.

55.1 Remove Water Manifold

The water manifold may be removed as follows:

(1) Drain the cooling system to level necessary by opening the valve in the bottom of the fresh water pump and the valve in the thermostat housing.
(2) Loosen the bolts which secure the outlet elbow and the thermostat housing to the water manifold.
(3) Remove the cooling water temperature gauge adaptor from the rear end of the water manifold.
(4) Remove the water manifold stud nuts and lockwashers and lift the manifold straight up off the studs. Remove the manifold to cylinder head gaskets.

55.2 Install Water Manifold

(1) With new gaskets in place, lower the water manifold down over the studs and secure it to the cylinder head with two nuts and lock- washer at each riser. Tighten the nuts to 25-30 ft-lbs (34-41 Nm) torque.
(2) Install the temperature gauge adaptor in the end of the manifold.
(3) On radiator units, attach the thermostat housing and outlet elbow to the water manifold with bolts and lockwashers.
(4) Fill cooling system to proper level.

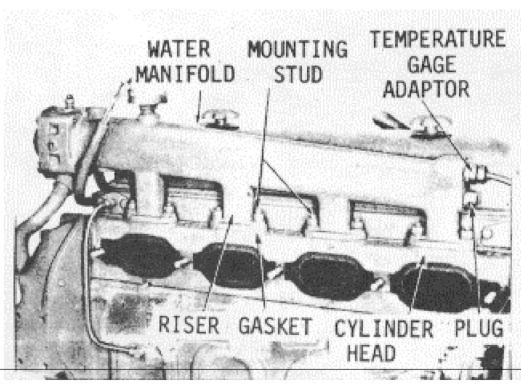



*Fig. 1 Typical Water Manifold Mounting Industrial Unit*

Note: When filling cooling system on certain models, it is necessary to open the vent valve at the top of thermostat housing.

**Service Manual** SM6-5-56.0 Thermostat

The temperature of the engine coolant is automatic-ally controlled by a thermostat located in a housing connected to the outlet end of the water manifold.

56.1 Operation

At coolant temperatures below approximately 170°F, the thermostat valves remain closed and block the flow of coolant to the radiator. During this period, all of the coolant in the system is circulated through the engine and is directed back to the suction side of the water pump via the by-pass tube. As the coolant temperature rises above 170°F, the thermostat valves start to open, restricting the by-pass system, and permit a portion of the coolant to circulate through the radiator. When the cool- ant temperature reaches approximately 1850F, the thermostat valves are fully open, the by-pass system is partially blocked off, and most of the coolant is directed through the radiator.

A properly operating thermostat is essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 160' to 185°F, remove the thermostat and check it.

56.2 Remove Thermostat

(1) Drain the cooling system to the necessary level by opening the drain valve.
(2) Remove the bolts which secure the outlet elbow and the thermostat housing (bypass tube) to the water manifold (Fig. 1).
(3) Remove the thermostat and the deflector (if used) and clean the seat for the thermostat in the outlet elbow.
(4) Remove and discard the seals pressed in the water outlet elbow.

56.3 Inspect Thermostat

If the action of the thermostat has become impaired due to accumulated rust and corrosion from the engine coolant so that it remains closed, or only partially open, thereby restrict-

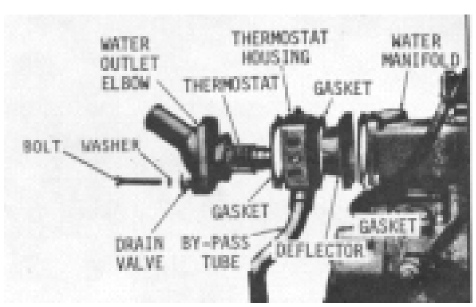



*Fig. 1 Typical Thermostat Housing Mounting (Radiator and Fan Cooling System)*

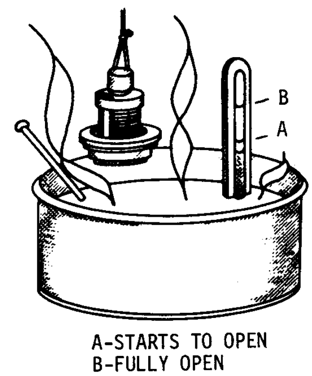



*Fig. 2 Method of Checking Thermostat Operation*

ing the flow of water, overheating of the engine will result. A thermostat which is stuck in the wide open position may not permit the engine to reach its normal operating temperature, thus resulting in incomplete combustion of fuel and in build-up of carbon deposits on the pistons, rings and valves.

The operation of the thermostat may be checked by immersing it in a container of hot water (Fig. 2). Place a thermometer in the container, but do not allow it to touch the bottom of the container. Agitate the water to maintain an even temperature throughout the container. As the water is heated, the thermostat should be- gin to open when the water temperature reaches approximately 170'F (the opening temperature is usually stamped on the thermostat). The thermostat should be fully open at approximately 1850F with the exception of a few types of thermostats which are fully open at 1950F.

56.4 Install Thermostat

(1) Affix new gaskets to each side of the thermostat housing.
(2) Set the deflector and new gasket (if used) and the thermostat in the housing. Attach the outlet elbow and the thermostat housing to the water manifold.

Using a new seal connect the thermostat housing to the water manifold.

(3) Connect any other piping which may have been disconnected.
(4) Fill the cooling system and check for leaks.

The radiator assembly is bolted to the front of the engine base.

A grille in front of the core helps keep the radiator fins free from obstructions and protects the core.

To insure more efficient use of all air moved through the radiator, a shroud is provided back of the core. A guard attached to the shroud encloses the fan blades, eliminating the possibility of pulling loose clothing or other objects into the blades.

At temperatures above freezing, the cooling system should be filled with clean soft water plus a good commercial rust inhibitor (see SM6-5-53.0). When the temperature is below freezing, use soft water plus sufficient quantity of high boiling point type antifreeze to prevent the solution from freezing.

Hard water will form scale in the radiator, engine block and head. These scale formations cause hot spots within the engine and clog the tubes in the radiator core. Dirty water will close the tubes in the core thus restricting the flow of water and, in extreme cases, will collect in the engine causing overheating.

If the engine overheats and the fan and water level have been found to be satisfactory,. it will be necessary to clean and flush the entire cooling system to correct the overheating (see SM6-5-53.0).

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Scale formations should be removed by the use of a reputable and safe descaling solvent. Immediately after using a descaling solvent, neutralize the cooling system with a neutralizer (see SM6-5-53.0).

After the solvent and neutralizer have been used, drain the engine and radiator, then fill the cooling system slowly with clean, soft water, and run the engine for fifteen minutes. Completely drain the entire system again and fill with clean, soft water plus a rust inhibitor or high boiling point type antifreeze. After filling system, inspect radiator and engine for water leaks.

A drain is provided at the bottom of the oil cooler housing, see Fig. 2.

Note: When draining the cooling system of certain models, it is necessary to open the vent valve at the top of thermostat housing.

Remove all grease, oil and dirt from the radiator core so the entire cooling area can transmit the heat of the coolant to the air stream.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Clean the fins by means of an air blast, carrying a grease solvent such as oleum spirits or trichloroethylene, directed at the front side of core. The grille, fan guard and shroud must be removed before performing the above operation.

Note: Provide adequate ventilation of the working area to avoid possible toxic effects of the cleaning spray.

Install fan shroud, guards and grille before resuming engine operation.

If removal of the radiator is desired, use the following procedure:

57.1 Remove Radiator

Refer to Fig. 2, for radiator mounting and remove radiator as follows:

(1) Drain cooling system.

Note: When draining the cooling system on certain models, it is necessary to open the vent valve at the top of thermostat housing.

(2) Remove bolts, nuts, plain washers, and lock- washers which attach fan belt guards (171) to the rear of fan guard (153) and remove guards.

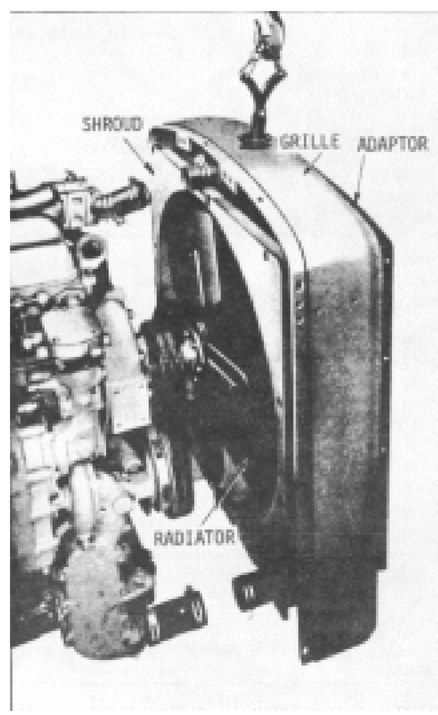



*Fig. 1 Removing Radiator, Shell, and Shroud with Lifting Hook and Chain Hoist*

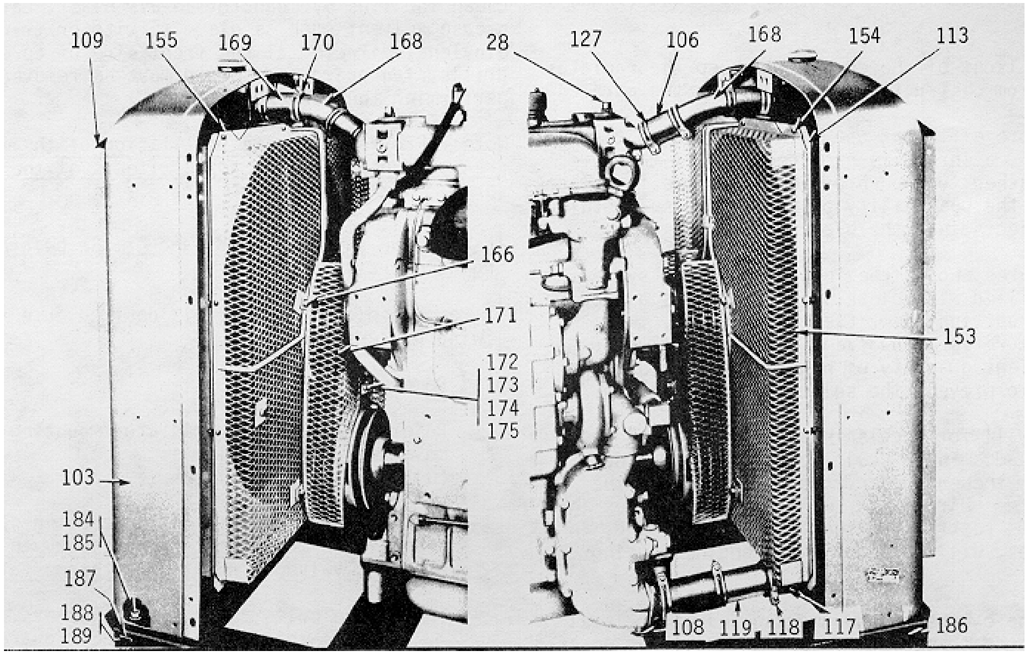



*Fig. 2 Typical Radiator Grille, Shroud, and Fan Guard Mounting*

28. Plug—Pipe
103. Grille Assy.
106. Hose--Inlet Elbow to Radiator Inlet Pipe
108. Plug--Drain
109. Adaptor--Air Duct
113. Shroud—Fan
117. Hose—Radiator Outlet Pipe
118. Clamp—Hose
119. Tube--Outlet Pipe Extension
127. Clamp—Hose
153. Guard—Fan
154. Screw--Fan Guard-to-Shroud
155. Nut--Fan Guard-to-Shroud
166. Bolt--Fan Belt Guard Nut
168. Elbow--Radiator Inlet Pipe
169. Hose--Radiator Inlet Pipe Elbow-to-Pipe
170. Clamp--Hose
171. Guard--Fan Belt
172. Bolt--Fan Belt Guard Connecting
173. Plain Washer
174. Lockwasher
175. Nut--Fan Belt Guard Bolt
184. Bolt--Radiator to Base
185. Plain Washer
186. Base--Engine
187. Washer--Bevel
188. Lockwasher
189. Nut

(3) Withdraw screws releasing fan guard (153) from shroud (113).

(4) Loosen hose clamp (127) at radiator inlet pipe elbow (168). Remove elbow.

(5) Loosen hose clamps (118) at radiator outlet pipe extension tube (119) and remove tube.

(6) Remove bolts (184), nuts (189), plain washer, lockwasher and bevel washer (187) holding radiator assembly to base.

(7) Lift the radiator assembly with a chain hoist and lifting hook as shown in Fig. 1, enough to clear the engine base; then move it away from engine.

**CAUTION**

Be Careful Not To Damage Fan Blades Or Shroud When Lifting Radiator.

(8) The fan shroud (113) and radiator grille (103) may be removed from the radiator by removing the attaching bolts, flat washers, and lockwashers.

57.2 Inspect Radiator Parts

Clean all parts thoroughly, removing dirt, scale, and other deposits. Repair or replace grille, shroud, or guard if damaged. Radiator core fins must be straight and evenly spaced to permit the full flow of cooling air. Core tubes must be straight, clean inside and outside, and have no leaks.

57.3 Install Radiator

Refer to Fig. 3 and assemble the radiator, grille, and shroud, then mount the assembly on engine base by reversing the procedure given for removal.

Check the clearance between tip of fan blades and radiator shroud after radiator is in place. There must be clearance between these parts or damage will result when the engine is started.

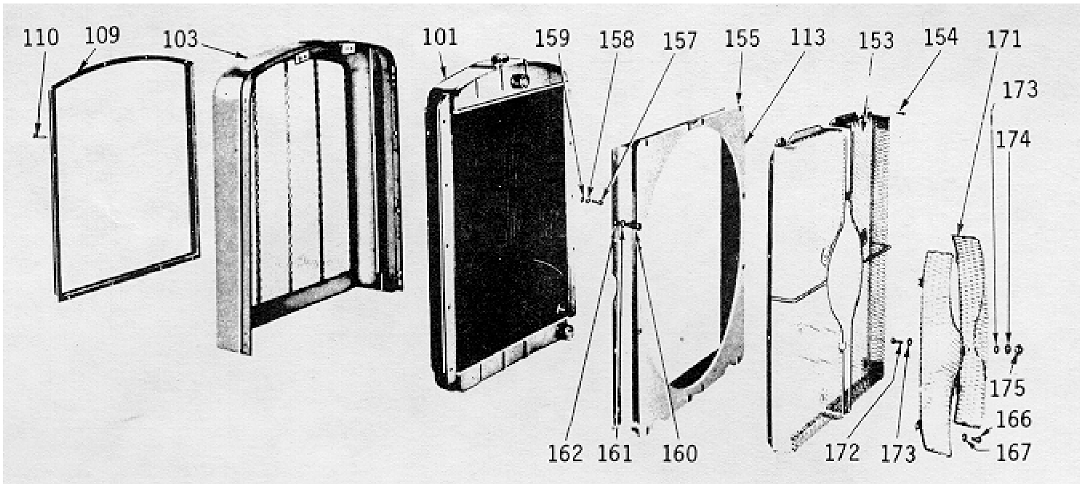



*Fig. 3 Radiator, Grille, Shroud and Fan Guard Details and Relative Location of Parts*

| | | | |
|---|---|---|---|
| 101. Radiator Assy. | 154. Screw | 160. Bolt--Shroud-to-Grille | 171. Guard--Fan Belt |
| 103. Grille Assy. | 155. Nut--Fan | 161. Lockwasher | 172. Bolt--Fan Belt |
| 109. Adaptor | Air Guard-to-Shroud | 162. Flat Washer Guard Connecting 6 | |
| Duct | 157. Bolt--Radiator | 166. Bolt--Fan Belt | 173. Plain Washer |
| 110. Screw—Tapping | Flange-to-Grille Guard Nut | 174. Lockwasher | |
| 113. Shroud--Fan | 158. Lockwasher | 167. Lockwasher--Fan | 175. Nut--Fan Belt |
| 153. Guard--Fan | 159. Flat Washer Belt Guard | Guard Bolt | |

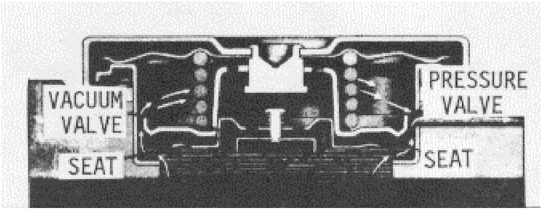



*Fig. 1 Pressure Control Cap (Pressure Valve Open)*

The radiator (or expansion tank) has a pressure control cap with a normally closed valve. The cap, with a number 7 stamped on its top, is designed to permit a pressure of approximately seven pounds in the system before the valve opens. This pressure raises the boiling point of the cooling liquid and permits somewhat higher engine operating temperatures without loss of any coolant from boiling. To prevent the collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools.

**WARNING**

Use Extreme Care When Removing The Coolant Pressure Control Cap. Remove The Cap Slowly After The Engine Has Cooled. The Sudden Release Of Pressure From A Heated Cooling System Can Result In Loss Of Coolant And Possible Personal Injury (Scalding) From The Hot Liquid.

To ensure against possible damage to the cooling system from either excessive pressure or vacuum, check both valves periodically for proper opening and closing pressures. If the pressure valve does not open between 6.25 psi (43.1 kPa) and 7.5 psi (51.7 kPa) or the vacuum valve does not open at .625 psi (4.3 kPa) (differential pressure), replace the pressure control cap.

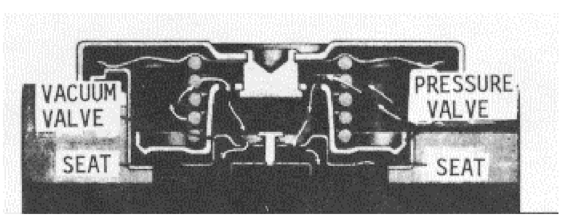



*Fig. 2 Pressure Control Cap (Vacuum Valve Open)*

The engine cooling fan is belt driven from the crankshaft pulley (Fig. 1).

The fan is bolted to a hub and pulley which is carried on two bearings. The bracket and shaft is mounted on the fan support which is in turn attached to the balance weight cover. The bracket is slotted to permit adjustment of the fan belt tension by moving the bracket and shaft on the attaching bolts (Fig. 2). The pulley hub turns on tapered roller bearings (Fig. 8).

59.1 Lubrication

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to Operator's Manual for the maintenance schedule.

59.2 Fan Belt Adjustment

Adjust the fan belt(s) periodically as outlined in Operator's Manual.

59.3 Remove and Install Fan Blades

If enough clearance exists between the fan blades and the face of the radiator core, the fan blade and spacer may be removed by taking out the six mounting bolts, nuts and lockwashers. If the blades cannot be removed in this manner, the fan, hub and bracket may be removed as an assembly. See the procedure for removing the fan, hub and bracket.

The fan blades may be installed by reversing the procedure used for removal.

59.4 Remove Fan, Hub and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core. Before removing the fan, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

(1) Remove the belt and fan guards.
(2) Remove the attaching bolts, lockwashers and nuts, then remove the fan and spacer.

Note: <u>If insufficient clearance exists between the fan and radiator, remove the fan, hub and adjusting bracket as an assembly.</u>

(3) Remove the two adjusting bolts, lockwashers and plain washers, then remove the drive belts.
(4) Loosen the adjusting bracket pivot or adjusting bolts until the bracket is free. Re- move the hub and bracket assembly from the engine.

59.5 Disassemble Fan, Hub and Bracket

Refer to Figs. 2, 6 and 7 and disassemble the fan, hub and adjusting bracket as follows:

(1) Remove the fan attaching bolts and lockwashers and detach the fan and the spacer.
(2) Remove the hub bolt and washer.
(3) Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.
(4) Remove the bearings and oil seal as follows:
    (a) Remove the snap ring (if used) from the groove in the outer (front) of the hub.
    (b) Remove the current ball bearing by tapping alternately around the outer edge of the bearing with a small brass rod and hammer.
    (c) Remove the former roller bearing inner race from the outer (front) roller bearing.
    (d) Remove the shims and bearing spacer (if used).
    (e) Tap the outer race of the former roller bearing out of the pulley hub by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.

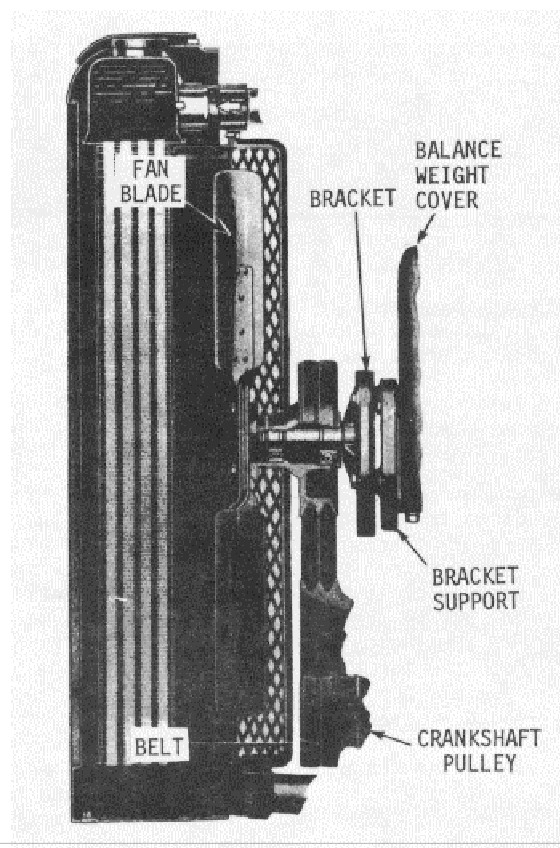



*Fig. 1 Typical Fan and Fan Hub Assembly*

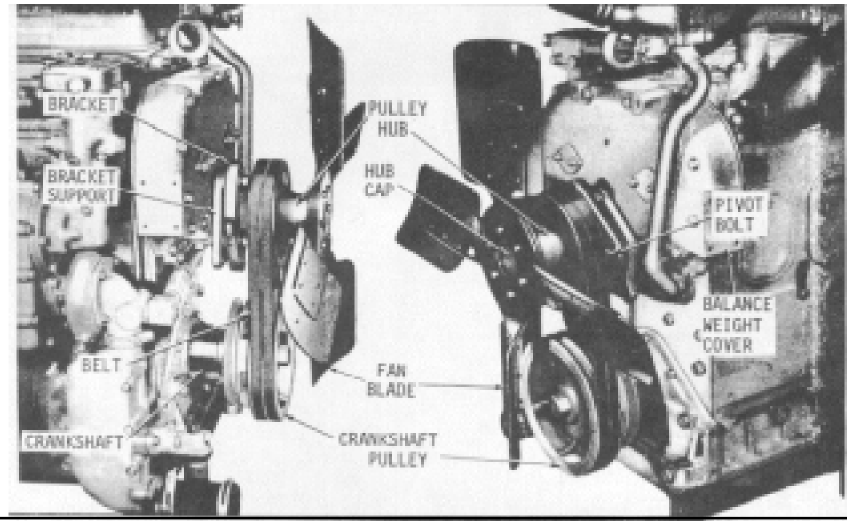



*Fig. 2 Fan Mounting*

(f) Reverse the pulley hub and remove the dust cap (if used). Then drive the oil seal from the hub. Discard the oil seal.

(g) Remove the inner (rear) roller in the same manner as outlined in Steps c and e.

(h) Remove the grease retainer (if used) from the pulley hub.

## 59.6 Inspection

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean the fan and related parts with fuel oil and dry them with compressed air. Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Examine the bearings for any indication of corrosion or pitting. Hold the inner race or cone and revolve the outer race or cup slowly by hand. If rough spots are found, replace the bearings.

Check the fan blades for cracks. Replace the fan if the blades are badly bent, since straightening may weaken the blades, particularly in the hub area.

Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severely worn, replace the pulleys.

Check for cracks in the adjusting and support bracket castings.

New .560" thick and .800" thick fan hub spacers and a new fan hub cap replaces the former spacer and cap assemblies to provide spacers compatible with the six bolt hole mounting fan hub assemblies. The spacers (individually or in combination) also provide a means for setting the different clearances between the back of the fan blades and front groove of the crankshaft pulley.

The spacers have a flange on one side that serves as a pilot for the fan as well as a spacer pilot for the second spacer when two or more spacers are used together.

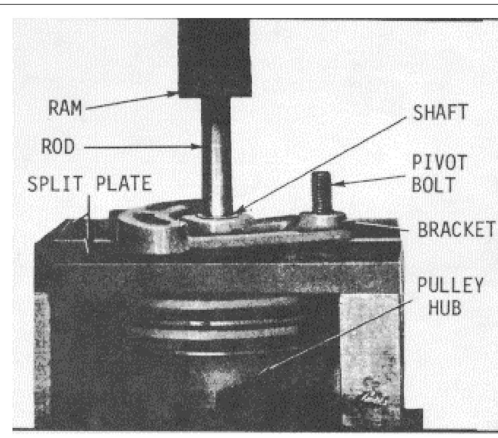
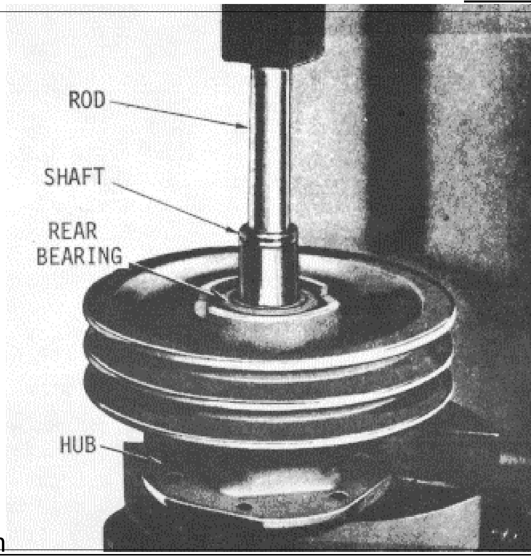



*Fig. 3 Removing Fan Shaft from Fan Adjusting Bracket*




Fan

*Fig. 4*
*Removing Fan Shaft and Front Roller Bearing From Hub*

EXAMPLE: A former 1.800" thick spacer and cap assembly have been replaced by two .560" (was .500") thick spacers are .800" thick spacer (refer to SM6-5-71.0) and the new fan hub cap.

When replacing the former fan hub spacer, be sure and include the new cap.
The current fan shaft rear bearing inner race should be inspected for any measurable wear. Replace the inner race if the outer diameter is less than 1.7299".

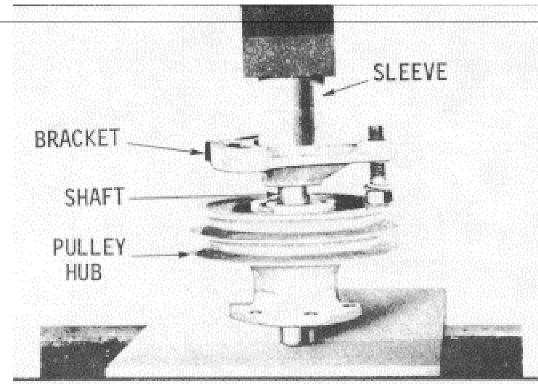



*Fig. 5*
*Installing Adjusting Bracket and Bolt on Fan Shaft*

Note: The inner and outer races are only serviced as a rear roller bearing assembly.

When installing the rear bearing inner race, press it on the shaft and position it 1.35" to 1.37" from the end of the shaft. 9.7 Assemble Fan, Hub and Bracket

Assemble the fan hub and bracket shown in Figs. 6 and 7 as follows:
(1) Apply Texaco Premium RB grease, or an equivalent Lithium base multipurpose grease, to the rollers of both bearings before installing them in the pulley hub.
(2) Install the inner (rear) roller bearing assembly (inner and outer race), with the protruding face of the inner race facing outward from the hub, (1.31" from end of shaft), by tapping alternately around the face of the bearing outer race with a small brass rod and hammer.

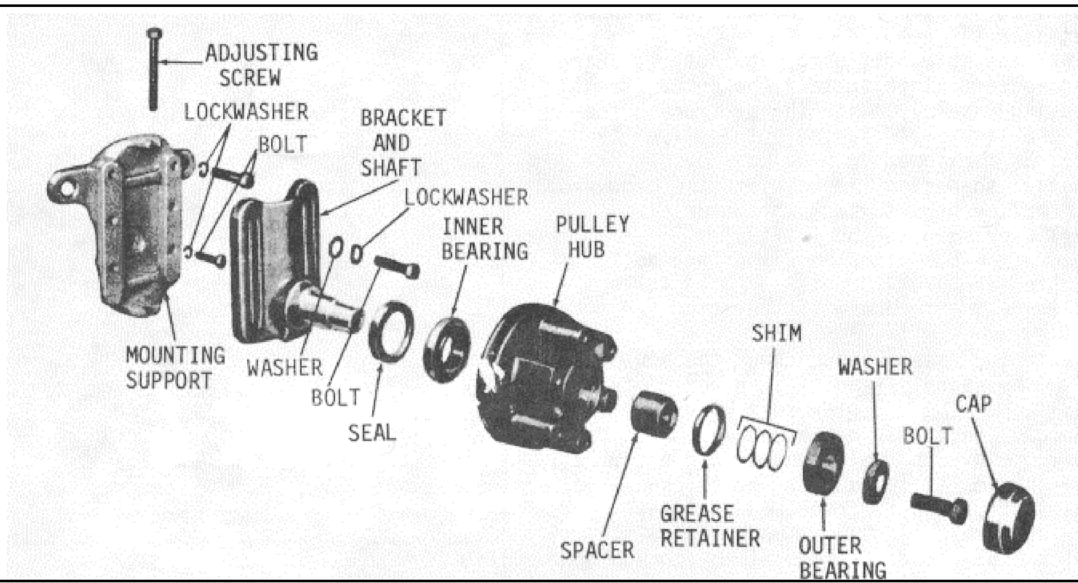



*Fig. 6*
*Shaft Type Fan Hub Assembly Details for Compact Front End Engine*

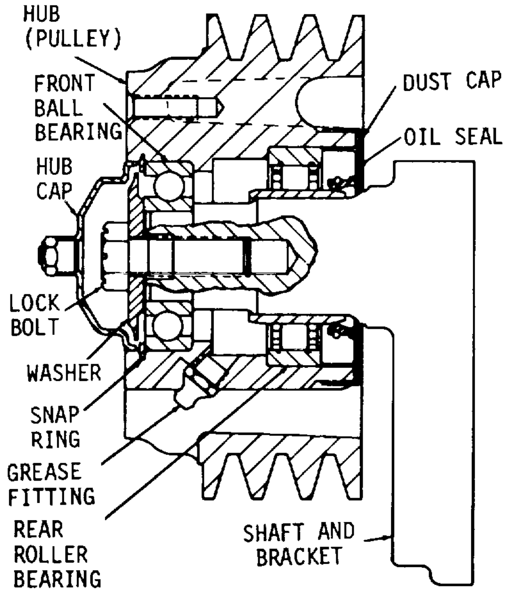



*Fig. 7*
*Shaft Type Fan Hub Assembly*

(3) Install a new oil seal with the rubber side flush with the outer edge of the hub.

Note: Certain engines use a rubber lip type oil seal.

(4) Install the dust cap over the oil seal (if used).
(5) Place the adjusting bracket assembly on wood blocks setting on the bed of an arbor press. Then press the pulley hub on the fan shaft and install the bearing spacer (if used).
(6) Pack the cavity 20-30% full with grease as outlined in Step 1 and install the grease retainer (if used).
(7) Place the shims (if used) against the bearing spacer. Then install the outer (front) bearing assembly, with the protruding face of the inner race facing outward from the hub, as mentioned in Step 2.
(8) Install snap ring (if used) in the groove of the pulley hub, to lock the outer (front) ball bearing onto the shaft.
(9) Secure the hub with the washer and bolt. Tighten the 1/2"-20 bolt to 83-93 ft-lbs (113-126 Nm) torque while rotating the pulley.
(10) Rotate the assembly and check the end play with the spindle (shaft) in a horizontal position. The end play must be within .001" to .006" on former hub assembly. If necessary, remove the bolt, washer and outer bearing and adjust the number and thickness of shims to obtain the required end play. Shims are available in .015", .020" and .025" thickness. Then reassemble the fan hub and check the end play.
(11) Fill a new fan hub cap 75% minimum full of grease and install it in the end of the fan hub (pulley).

Note: The cap must not protrude beyond the face of the hub.

(12) Secure the fan blade and spacers to the pulley hub with six bolts, nuts and lock-washers. Tighten the nuts to 15-29 ft-lbs (20-26 Nm) torque.

59.8 Install Fan, Hub and Bracket

(1) Attach the fan hub and adjusting bracket assembly to the support bracket on the engine with bolts, lockwashers and plain washers. Do not tighten the bolts.
(2) Install the drive belts and adjust the belt tension as outlined in Operator's Manual.
(3) Install the fan (and fan spacer and cap, if used) on the hub and secure it with bolts and lockwashers.

59.9 Thermo-Modulated Fan

A thermo-modulated suction fan assembly has been provided on some engines (Fig. 8).

This fan assembly is designed to regulate the fan speed and maintain an efficient engine cool-and temperature regardless of the variations in the engine load or outside air temperature.

The entire fan drive assembly is a compact integral unit (Fig. 9) which requires no external piping or controls and operates on a simple principle. This principle consists of transmitting torque from the input shaft to the fan

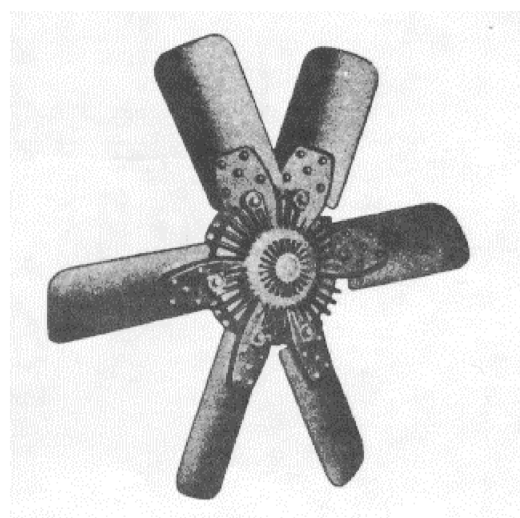


*Fig. 8*
*Thermo-Modulated Fan Assembly*

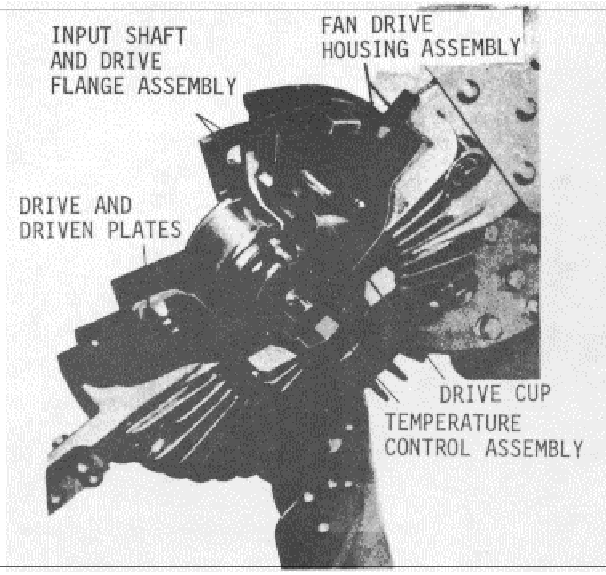



*Fig. 9*
*Thermo-Modulated Fan Drive Assembly*

by the shearing of a silicon fluid film between the input and output plates in a sealed multiplate, fluid filled clutch housing.

The thermostatic control element, which is an integral part of the fan drive, reacts to changes in engine temperature and varies the fluid film thickness between the plates and thereby changes the fan speed. Proper selection of the control element setting is determined by the vehicle manufacturer to maintain optimum cooling and no further adjustment should be necessary.

The thermo-modulated fan is mounted and driven by the engine in the same manner as the conventional fan.

59.10 Lubrication

The fan drive assembly is prelubricated by the manufacturer, however the drive fluid level and the roller bearing should be checked periodically (refer to Operator's Manual).

59.11 Adjust Fan Belt

The adjustment of the fan belt tension is the same as on the conventional type fans.

59.12 Remove and Install Fan and Drive Assembly

The fan blades and fan drive may be taken off by removing the four shaft to pulley mounting bolts, and installed by reversing this procedure.

Fan and radiator cooled engines are equipped with an air-cooled exhaust manifold.

The outlet flange is located at the mid-section of the exhaust manifold.

The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

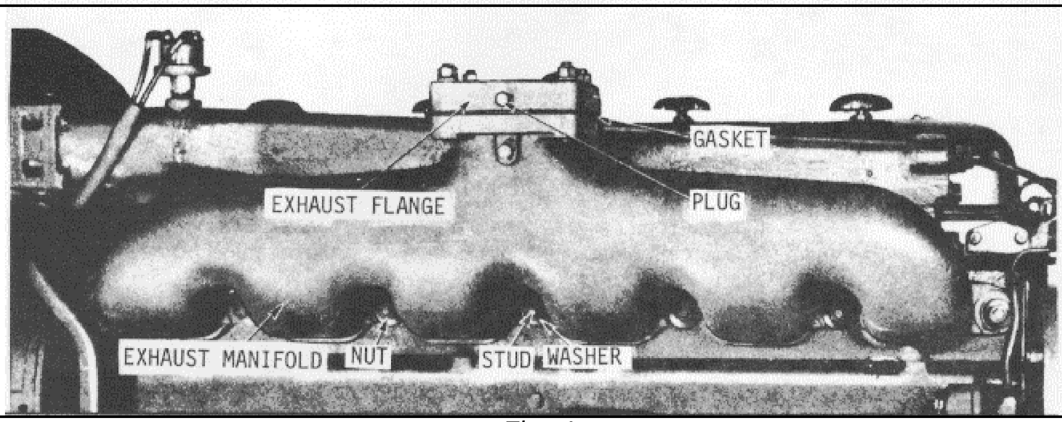



*Fig. 1*
*Typical Air-Cooled Exhaust Manifold Mounting*

The air-cooled exhaust manifold (Fig. 1) is mounted on the cylinder head.

A exhaust manifold hold-down crab is used.

Also a special washer is used at the center portions of the exhaust manifolds.

61.1 Remove Exhaust Manifold

Remove the manifold as follows:

(1) Disconnect the exhaust pipe or muffler from the exhaust manifold.
(2) Remove the nuts and bevel washers that attach the exhaust manifold to the cylinder head. It is suggested that, as a safety measure, the nut be loosened but left on the center stud until all of the other nuts and washers have been removed.
(3) Support the manifold and remove the nut and washer from the center stud.
(4) Lift the manifold away from the cylinder head.
(5) Remove the manifold gaskets.

61.2 Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold.

Examine the exhaust manifold studs for damage. If necessary, replace the studs. New studs are driven in to 25-40 ft-lbs (34-54 Nm) torque.

61.3 Install Exhaust Manifold

Install the exhaust manifold on the cylinder head as follows:

(1) Place new gaskets over the studs and up against the cylinder head.

Note: When installing the metal clad exhaust manifold gaskets, be sure the crimped side of the gasket (Fig. 2) faces the cylinder head.

(2) Position the exhaust manifold over the studs and against the gaskets.
(3) Install the bevel washers on the studs.

Note: Install the bevel washers with the crowned sides toward the nuts.

(4) Thread the nuts on the studs. Then, starting with the center nut and working alternately toward each end, tighten the manifold nuts to 30-35 ft-lbs (41-47 Nm) torque (cast iron head) or 25-30 ft-lbs (34-41 Nm) torque (aluminum head).

Note: If the cylinder head was removed from the engine, do not tighten the manifold nuts until AFTER the head is reinstalled. Otherwise, interference may be encountered between the manifold and cylinder block bosses which serve as a support for the manifold when the cylinder head is installed.

(5) Connect the exhaust pipe or muffler to the manifold. Tighten the brass exhaust manifold outlet flange nuts to 20-25 ft-lbs (27-34 Nm) torque.

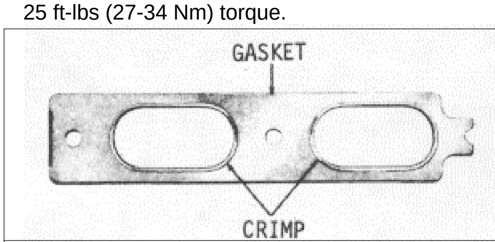



*Fig. 2*
*Metal Clad Exhaust Manifold Gasket*

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Allison. For electrical equipment manufactured by Delco-Remy Division, repair service and parts are available through AC-Delco branches and repair stations.

The battery-charging circuit consists of a alternator and the wiring. The battery-charging alternator (Fig. 1) is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the generator or alternator.

63.1 Hinge-Mounted Alternator (Belt-Driven)

The hinge-mounted alternating current self-rectifying alternator is belt driven. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.

To adjust the voltage setting on the current alternators, remove the rectifier end plate. The voltage regulator adjustment is located on the voltage regulator circuit board. Refer to the pertinent Delco Service Bulletin for complete adjustment procedure.

63.2 Alternator Maintenance

(1) Maintain the proper drive belt tension. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the generator or alternator drive.

Note: When installing or adjusting the drive belt, be sure the bolt at the pivot point is properly tightened, as well as the bolt in the adjusting slot.

(2) Lubricate the generator bearings as outlined in the Lubrication and Preventive Maintenance Chart in Operator's Manual.

(3) Alternator bearings are permanently lubricated. There are no external oiler fittings.

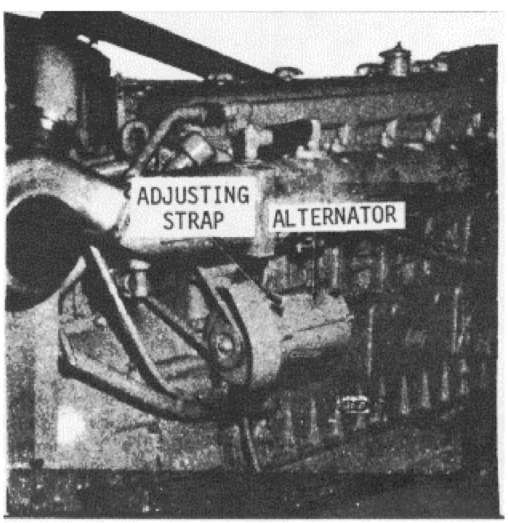



*Fig. 1*
*Typical Hinge-Mounted Alternator*

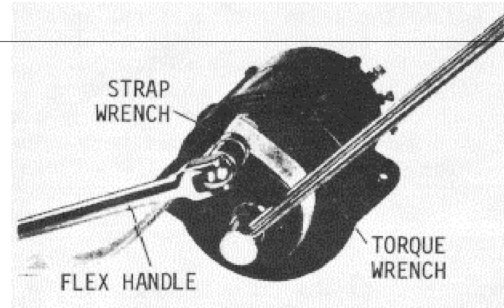



*Fig. 2*
*Tighten Generator or Alternator Pulley Retaining Nut*

63.3 Remove Alternator

(1) Disconnect the cables at the battery supply. Disconnect all other leads from the alternator and tag each one to ensure correct reinstallation.

(2) Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.

(3) While supporting the alternator, remove the adjusting strap bolt and washers. Then remove the mounting bolts, washers and nuts. Remove the alternator carefully and protect it from costly physical damage.

(4) Remove the pulley assembly if the alternator is to be replaced.

63.4 Alternator Service

Repairs and overhaul work on alternators should be referred to an authorized repair station of the manufacturer of this equipment. Replacement parts for alternators should be ordered through the equipment manufacturer's outlets. For alternators manufactured by Delco-Remy Division, repair service and parts are available through AC Delco branches and repair stations.

63.5 Install Alternator

(1) Install the drive pulley, if it was removed. Tighten the pulley retaining nut to 50-60 ft-lbs (68-81 Nm) torque (Fig. 2).

Note: If the pulley was not removed, check the retaining nut for proper torque.

(2) Position the alternator on the mounting brackets and start the bolts with washers in place, through the bolt holes in the end frames. If nuts are used, insert the bolts through the bolt holes in the mounting bracket and end frame. Make sure that the washers and nuts are in their proper locations.

(3) Align the threaded hole in the adjusting lug of the drive end frame with the slot in the adjusting strap. Start the bolt, with the washers, through the slot of the adjusting strap and into the threaded hole in the end frame.

(4) Place the drive belts in the grooves of the pulleys.

(5) Adjust the belt tension as outlined in Operator's Manual. Tighten all of the bolts after the belt tightening is completed.
(6) Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

63.6 Alternator Precautions
Precautions must be taken when working on or around alternators. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator. Never run an alternator on an open circuit.

Grounding an alternator's output wire or terminals, which are always "hot" regardless of whether or not the engine is running or accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme caution be used.

Accidentally reversing the battery connections must be avoided.
Never disconnect the battery while an alternator is in operation. Disconnecting the battery will result in damage to the diodes due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

Never use a fast charger with the battery connected or as a booster for battery output.
Never attempt to polarize the alternator.

The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc.

If faulty operation of an alternator occurs on an engine equipped with an insulated starting motor, check to be sure that a ground strap is present and is correctly installed.

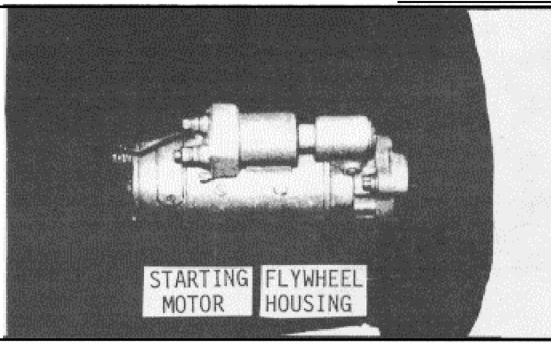



*Fig. 1*
*Sprag Overrunning Clutch Type Starting Motor Mounting*

The starting motor is mounted on the flywheel housing as illustrated in Fig. 1. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the starting motor. To accomplish this, the starting motor is equipped with a heavy-duty sprag overrunning clutch.

A solenoid switch, mounted on the starting motor housing, operates the current sprag type overrunning clutch drive by linkage and a shift lever (Fig. 2). When the starting switch is engaged, the solenoid is energized and shifts the starting motor pinion into mesh with the flywheel ring gear and closes the main contacts within the solenoid. Once engaged, the clutch will not disengage during intermittent engine firing. To protect the armature from excessive speed when the engine starts, the clutch "overruns", or turns faster than the armature, which permits the pinion to disengage itself from the flywheel ring gear.

The solenoid plunger and shift lever on this type of starting motor is totally enclosed to protect them from dirt, water and other foreign material.

An oil seal, between the shaft and the lever housing, and a linkage seal (Fig. 2) prevents the entry of transmission oil into the main frame of the starting motor and solenoid case, allowing the motor to be used on wet clutch applications.

The nose housing on the sprag clutch type starting motor can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. The nose housing, on starters equipped with the heavy- duty clutch, is attached to the lever housing by six bolts located around the outside of the housing (Fig.2).

64.1 Lubrication
Starting motors which are provided with lubrication fittings (hinge cap oilers, oil tubes sealed with pipe plugs, or grease cups) should be lubricated periodically (refer to Operator's Manual).

64.2 Flywheel Ring Gears
The starting motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth.

Flywheel ring gears with no chamfer are used with starting motors equipped with an overrunning clutch drive.

If the wrong type of ring gear is used, repeated starting attempts will be required for engagement of the drive pinion and burring of the gear teeth will result.

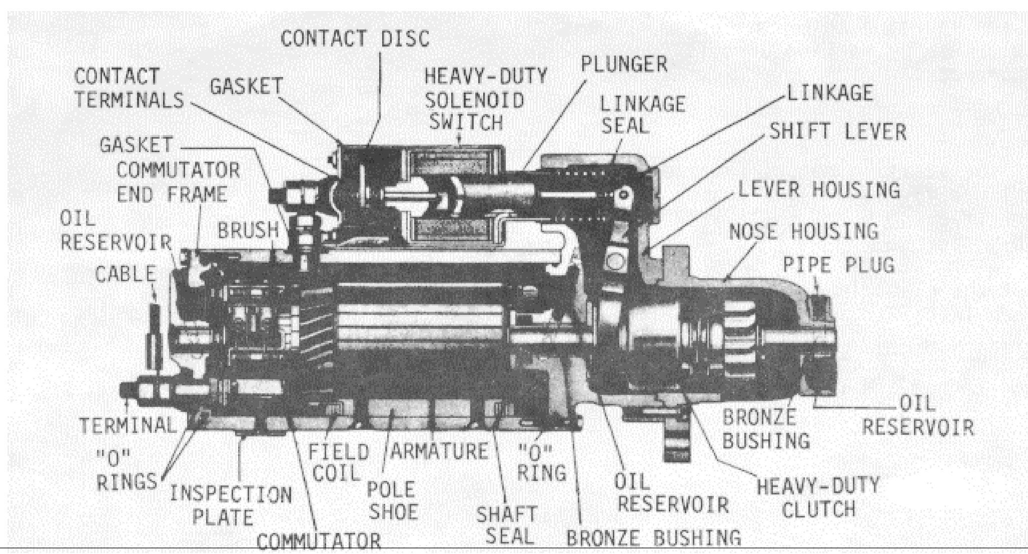



*Fig. 2*
*Cross-Section of Starting Motor with Sprag Heavy-Duty Clutch Drive*

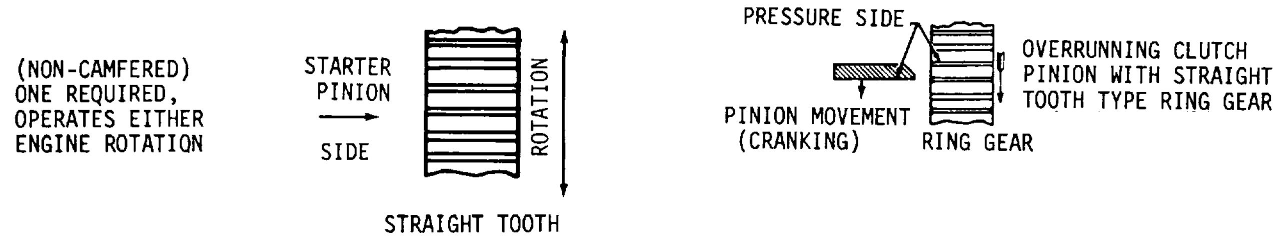



*Fig. 3*
*Types of Flywheel Ring Gears*

64.3 Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine or a defective starting motor.

If the engine, battery and cranking circuit are in good condition, remove the starting motor as follows:

(1) Remove the ground strap or cable from the battery or the cable from the starting motor solenoid, Tape the end of the cable to prevent discharging the battery from a direct short.

(2) Disconnect the starting motor cables and solenoid wiring.

Note: Tag each lead to ensure correct connections when the starting motor is reinstalled.

(3) Support the motor and remove the three bolts and lockwashers which secure it to the flywheel housing. Then pull the motor forward to remove it from the flywheel housing.

Check the starting motor in accordance with the Delco-Remy "Cranking Circuit" maintenance handbook.

64.4 Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the 5/8"-11 starter attaching bolts to 137-147 ft-lbs (183-196 N.m) torque.

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connections to 16-30 ft-lbs (21-40 N-m) torque and the 1/2"-13 connections to 20-25 ft-lbs (27-33 N-m) torque.

A tachometer drive shaft may be installed at any one of several locations on the engine.

At the front end of the engine, the tachometer drive shaft is pressed into the end of the camshaft or balance shaft and extends through an adaptor attached to the balance weight cover.

At the rear of the engine, the tachometer drive shaft may be installed in the end of either the camshaft, balance shaft or the blower drive shaft (Fig. 1). A tachometer drive shaft adaptor is attached to the flywheel housing cover or the blower rear end plate cover.

When required, a tachometer drive cable adaptor is used to change speed or to change direction of rotation, depending upon the location of the tachometer drive. A special key is used to connect the drive shaft to the tachometer drive cable adaptor.

The cable connection at the current tachometer head is a 5/8" threaded connection in place of the former7/8" connection. To eliminate possible misalignment, the current tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output shaft key size has been increased from 5/32" to SAE 3/16". New flexible drive cables are also required with *the current* tachometers and *angle drives.*

65.1 Remove Tachometer Drive

If replacement is necessary, remove the tachometer drive shaft as follows:

(1) Disconnect the tachometer drive cable from the tachometer drive cable adaptor.

(2) If used, remove the tachometer drive cable adaptor and key (key and seal assembly if the tachometer drive shaft is driven by the blower drive shaft).

(3) Remove the tachometer drive shaft adaptor and gasket from the balance weight cover if the tachometer drive is located at the front of the engine. For a rear mounted tachometer drive, remove the flywheel housing cover and adaptor assembly and gasket. Examine the

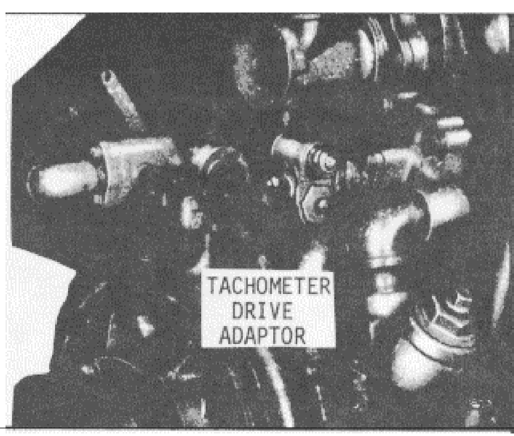



*Fig. 1*
*Typical Tachometer Drive Mounting*

oil seal, if used, for wear or damage. Replace the oil seal (camshaft drive) or oil seal unit (blower drive shaft drive), if necessary.

(4) If the tachometer drive shaft is driven by the blower drive shaft, remove the blower drive shaft.

(5) If the tachometer drive shaft is pressed into the end of the camshaft or blower drive shaft it cannot be turned since the end is either square or knurled. Remove the drive shaft as follows:

- (a) If threads (5/16"-24 or 3/8"-24) are provided on the outer end of the tachometer drive shaft to accommodate a removing tool, thread remover J 5901-3 on the shaft; then attach slide hammer J 2619-5 to the remover. A few sharp blows of the weight against the slide hammer rod will remove the tachometer drive shaft.
- (b) If threads are not provided on the outer end of the tachometer drive shaft, or if the end of the shaft is broken off, drill and tap the shaft. Then thread a stud into the shaft and remove the shaft with the remover and slide hammer.

Note: Use adequate protective measures *to prevent* metal *particles from* falling into the gear train and oil pan.

65.2 Install Tachometer Drive

(1) Start the tachometer drive shaft in the end of the camshaft or blower drive shaft. Then, using a suitable sleeve, tap or press against the shoulder on the tachometer drive shaft until the shoulder contacts the camshaft or blower drive shaft.

(2) Install the blower drive shaft.

(3) Install the tachometer drive cover and adaptor on the flywheel housing. Use a new gasket.

(4) Align the tachometer drive *cover and adaptor* with the tachometer drive shaft.

(5) Install the oil seal and key assembly (blower drive shaft driven tachometer drive).

(6) If used, install the tachometer drive cable adaptor and key. Lubricate the tachometer drive cable adaptor with grease through the fitting provided.

(7) Attach the tachometer drive cable.

66.1 Manual Shutdown System

A manually operated emergency engine shutdown device enables the engine operator to stop the engine in the event an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the NO FUEL position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing overspeeding of the engine, the shutdown device will prevent damage to the engine by cutting off the air supply and thus stopping the engine. The shutdown device consists of a flap valve mounted in the air inlet housing and a suitable operating mechanism.

66.2 Operation

The manually operated shutdown device is operated by a knob located on the instrument panel and connected to the valve shaft lever by a control wire, see Fig. 1. Pulling the knob all the way out will stop the engine. Push the knob all the way in and manually reset the valve on the blower air inlet housing before the engine is started again.

66.3 Inspection

Accumulation of dirt behind the steel ball in the detent lever may prevent the lever from moving when an attempt is made to close the valve. Make sure the ball detent is clean.

For disassembly and assembly of the emergency shutdown valve, refer to SM6-5-43.0.

66.4 Disassemble Shutdown

If required, the emergency shutdown may be disassembled after the air inlet housing assembly has been removed from the blower. Refer to Fig. 1 and proceed as follows:

(1) Use a small punch to remove the pins (136) locking the valve lever (142) to the valve shaft (133).

(2) Remove the lever and withdraw the shaft (133) from the housing and the two valves.

(3) Remove two screws (140) and lockwashers, lockplate (139) and felt seal (137) from the counterbore at the shaft beneath the plate. Also, remove the felt seal in the counterbore of the housing at opposite end of shaft.

66.5 Inspect Shutdown Parts

The striker plate must be perfectly flat and the gasket (130) on the plate for the valve must be in good condition. The finished face of valve (131) must be perfectly flat to assure a tight seal against the gasket.

If felt seals (137) do not form a tight fit on the shaft, use new seals.

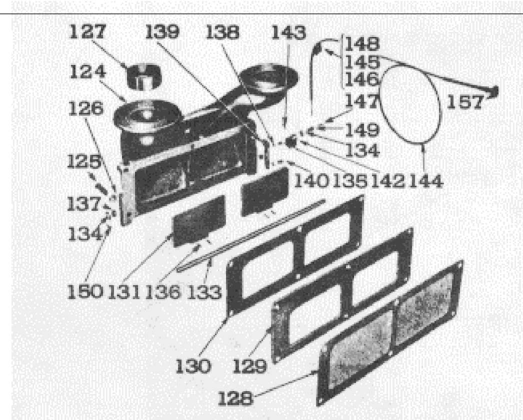



*Fig. 1*

*Emergency Engine Shutdown Details and Relative Location of Parts*

| | |
|---|---|
| 124. Housing--Air Inlet | 138. Ball--Valve Tension Spring |
| 125. Bolt | 139. Lock Plate--Shutdown |
| 126. Lockwasher | 140. Bolt--Lock Plate |
| 127. Tube--Air Cleaner Mounting | 142. Lever--Valve |
| 128. Screen--Housing | 143. Pin--Valve Lever |
| 129. Plate--Striker | 144. Bowden wire Assy. |
| 130. Gasket--Striker Plate | 145. Bolt--Wire Assy. |
| 131. Valve--Shutdown | 146. Nut--Wire Assy. |
| 133. Shaft--Valve | 147. Screw--Wire Assy. |
| 134. Washer--Valve Lever | 148. Clip--Wire Assy. |
| 135. Spring--Valve Tension | 149. Nut--Valve Lever |
| 136. Pin--Valve | 150. Pin--Housing |
| 137. Seal--Valve Shaft | 157. Knob--Control |

66.6 Assemble Shutdown

The valve shaft lever for the shutdown is located at the rear end of the air inlet housing.

(1) Place a felt seal (137) in the counterbore at each end of the housing.

(2) Determine the correct end of the inlet housing to attach the lock plate (139). Refer to Fig. 2 and determine the proper position of the lock plate for either manual.

The lock plate is stamped manual and automatic for easy installation.

(3) Note that a small hole is drilled nearer to one end of the valve shaft (133) than the other end. The hole farthest from the end is for locking the valve shaft lever at the rear end of the air inlet housing. With this identification in mind, lock the valve lever (142) to the shaft (133) with the pin (143); then insert the shaft from the rear end of the housing through the lock plate (139) and through the bore in the valve (131). Slide a plain washer (134) over the front end of the shaft next to the felt seal (137) and secure it with the cotter pin.

(4) Insert two valve pins (136) through the valve and into the holes in the shaft, keeping in mind that on the manual shutdown the valve is in the open position, and on the automatic shutdown the valve is in the closed position.

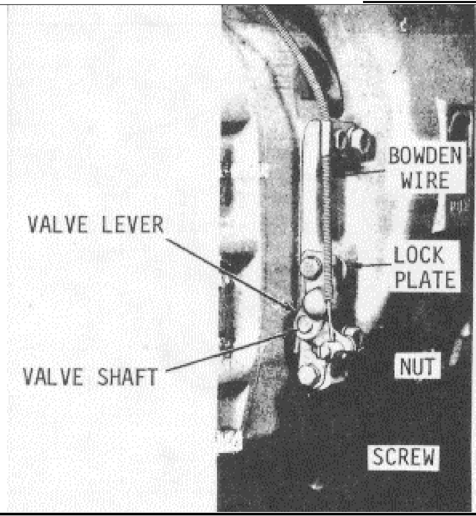



*Fig. 2*
*Position of Lock Plate on Manual Shut-Down*

If a new shaft is installed, it will be necessary to drill two pin holes in the shaft with the valves in their proper position.

(5) Attach the lock plate (139) in its proper position with two lockwashers and bolts (140).

(6) Install the spring (135) and ball (138) in the detent in the lever (142); then, move the valve into either the open or closed position, depending upon the type of shutdown. This will cause the ball (138) to seat in the top hole of the lock plate.

(7) Make sure that the valve assembly works freely.

66.7 Attach Air Inlet Housing to Blower

Since the function of the shutdown device is to completely choke off the air to the blower when the flap valve or valves are closed, the valves must set tightly against the striker plate gasket when the control wire is pulled all the way out.

Before attaching the shutdown assembly to the blower, place a steel straight-edge lengthwise on the finished face of the housing bolting flange and close the valves against the straightedge. The finished pads at each end of both valves must be flush against the straight-edge when it is moved from the top to the bottom of the inlet housing flange. Now, turn the straight edge crosswise on the housing flange and draw it from end-to-end. Both the upper and lower finished pads of the valves must be flush against the straight-edge throughout the length of the valves. Furthermore, when the lock ball within the lever mates with the hole in the lock plate, or when the control wire is pushed all the way in, the valves must move back into the inlet housing so as not to restrict the air passing to the blower.

Attach the air inlet housing to the blower as

(1) Affix a new gasket (130) to the striker plate (129).

(2) Place a lockwasher on each housing bolt (125) and insert the bolts through the blower housing.

(3) With the gasket (130) facing the valves, slide the striker plate (129) and screen (128) over the bolts (125) and set the housing in place against the blower.

(4) Push the control wire button all the way in; then, move the valve shaft lever (142) to the open position and attach the control wire (144) to the lever (142).

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners or bearings, the engine should be "Run-In" on a dynamometer prior to release for service.

he dynamometer is a device for applying specific loads to an engine. It permits the serviceman to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (160-185°F or 71-850C) should be maintained throughout the Run-In.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than **100** higher than the water inlet temperature. Though a 100 rise across an engine is recommended, it has been found that a $^{15^{\circ}}$ temperature rise maximum can be permitted.

A thermostat is used in the engine to control the coolant flow. Therefore, be sure it is in place and fully operative or the engine will overheat during a Run-In. However, if the dyanmometer has a water standpipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without the thermostat.

The Basic Engine Run-In Schedule is shown in Table 1. The horsepower shown is at SAE conditions: dry air density .0705 lb/cu. ft. (1.129 Kg/m3), air temperature of 85°F (29.40C), and 500 ft. (152m) elevation.

67.1 Dynamometer Test and Run-In Procedure

67.2 The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the Basic Engine Run-In Schedule. The following items are included on the basic engine; blower, fuel pump, water pump and governor. The fan and battery-charging generator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the Engine Test Report. The effects of this additional equipment on engine performance should then be considered when evaluating test results.

BASIC ENGINE RUN-IN SCHEDULE

| Speed (rpm) | Time (minutes) | Horsepower 71N |
|---|---|---|
| 1200 | 10 | 42 |
| 1800 | 30 | 135 |
| *1800 | 30 | 164 |
| *2100 | 30 | 180 |
| *2300 | 30 | 196 |

*Run at only one of the speeds shown, whichever is at or nearest to the governed speed and reset governor after final run, if necessary.

FINAL ENGINE RUN-IN SCHEDULE
(Trunk-Type Pistons)

| Speed (rpm) | Time (minutes) | Horsepower 6-71T |
|---|---|---|
| 1200 | 10 (minimum) | 0 |
| 2300 | 60 | 0 |
| 2100 | 30 | 86 |
| 2100 | 30 | 172 |
| 2100 | 30 | + |

+ Within $\pm$ 5% of rated bhp.

67.3 Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (ft-lbs) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

BHP = (T x RPM)/5250
Where:
BHP = brake horsepower
T = torque in ft-lbs
RPM = revolutions per minute
Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded' immediately on an Engine Test Report (see sample on page 3).

67.4 Instrumentation
Certain instrumentation is necessary so that data required to complete the Engine Test Report may be obtained. The following list contains both the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

(1) Oil pressure gauge installed in one of the engine main oil galleries.
(2) Oil temperature gauge installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.
(3) Adaptor for connecting a pressure gauge or mercury manometer to the engine air box.
(4) Water temperature gauge installed in the thermostat housing or water outlet manifold.
(5) Adaptor for connecting a pressure gauge or water manometer to the crankcase.
(6) Adaptor for connecting a pressure gauge or mercury manometer to the exhaust manifold at the flange.
(7) Adaptor for connecting a vacuum gauge or water manometer to the blower inlet.
(8) Adaptor for connecting a fuel pressure gauge to the fuel manifold inlet passage.
(9) Adaptor for connecting a pressure gauge or mercury manometer to the turbocharger.

In some cases, gauges reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gauge be of low range and finely divided if accuracy is desired. This is especially true of a gauge reading in psi, the reading of which is to be converted to inches of water. The following conversion factors may be helpful

Inches of water = psi x 27.7"
Inches of mercury = psi x 2.04"

Note: Before starting the Run-In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on Preparation for Starting Engine First Time in Operatores Manual.

67.5 Run-In Procedure
The procedure outlined below will follow the order of the sample Engine Test Report.

A. PRE-STARTING

(1) Fill the lubrication system as outlined under Lubrication System -- Preparation for Starting Engine First Time in Operator's Manual.
(2) Prime the fuel system as outlined under Fuel System -- Preparation for Starting Engine First Time in Operator's Manual.
(3) A preliminary valve clearance adjustment must be made before the engine is started. See Valve Clearance Adjustment in SM6-5-68.0.
(4) A preliminary injector timing check must be made before starting the engine. See Fuel Injector Timing in SM6-5-68.O.
(5) Preliminary governor adjustments must be made as outlined in Sn6-5-68.0.
(6) Preliminary injector rack adjustment must be made (SM6-5-68.O).

B. BASIC ENGINE RUN-IN

The operator should be observant at all times, so that any malfunction which may develop will be detected. Since the engine has just been reconditioned, this Run-In will be a test of the workmanship of the serviceman who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also inspect the exhaust system, being sure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 ft-lbs on the torque gauge (or10-15 HP on a horsepower gauge). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the Engine Test Report sample which establishes the sequence of events for the test and Run-In, and to the Basic Engine Run-In Schedule which indicates the speed (rpm), length of time and the brake horsepower required for each phase of the test. Also refer to the Operating Conditions in SM6-5-70.0 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

# ENGINE TEST REPORT

Date ____________________ Unit Number ____________________

Repair Order Number ____________________ Model Number ____________________

**A** **PRE-STARTING**

| 1. PRIME LUBE OIL SYSTEM | 2. PRIME FUEL SYSTEM | 3. ADJUST VALVES | 4. TIME INJ. | 5. ADJ. GOV. | 6. ADJUST INJ. RACKS |
|---|---|---|---|---|---|
| | | | | | |

**B** **BASIC ENGINE RUN-IN**

| TIME AT SPEED | TIME START | TIME STOP | RPM | BHP | WATER TEMP. | LUBE OIL PRESS. |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**C** **BASIC RUN-IN INSPECTION**

| | |
|---|---|
| 1. Check oil at rocker arm mechanism | |
| 2. Inspect for lube oil leaks | |
| 3. Inspect for fuel oil leaks | |
| 4. Inspect for water leaks | |
| 5. Check and tighten all external bolts | |
| 6. | |

**D** **INSPECTION AFTER BASIC RUN-IN**

| | | | |
|---|---|---|---|
| 1. Tighten Cylinder Head & Rocker Shaft Bolts | | 4. Adjust Governor Gap | |
| 2. Adjust Valves (Hot) | | 5. Adjust Injector Racks | |
| 3. Time Injectors | | 6. | |

**E** **FINAL RUN-IN**

| TIME START | TIME STOP | TOP RPM NO LOAD | TOP RPM FULL LOAD | BHP | AIR BOX PRESSURE FULL LOAD | EXHAUST BACK PRESSURE F/L | CRANKCASE PRESSURE F/L |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

| BLOWER INTAKE RES. - F/L | FUEL OIL PRESSURE RET. MAN. F/L | WATER TEMP. FULL LOAD | LUBE OIL TEMP. F/L | LUBE OIL PRESSURE FULL LOAD | LUBE OIL PRESSURE IDLE | IDLE SPEED |
|---|---|---|---|---|---|---|
| | | | | | | |

**F** **INSPECTION AFTER FINAL RUN**

| | |
|---|---|
| 1. Inspect Air Box, Pistons, Liners, Rings | 6. Tighten Oil Pump Bolts |
| 2. Inspect Blower | 7. Inspect Oil Pump Drive |
| 3. Check Generator Charging Plate | 8. Replace Lube Filter Elements |
| 4. Wash Oil Pan, Check Gasket | 9. Tighten Flywheel Bolts |
| 5. Clean Oil Pump Screen | 10. Rust Proof Cooling System |

REMARKS:

Final Run OK'd ____________ Dynamometer Operator ____________ Date ____________

NOTE: Operator must initial each check and sign this report.

Any six cylinder engine to be run at speeds in excess of 1800 rpm must be quipped with a vibration damper.

Engine governors in most cases must be reset at the maximum full-load speed designated for the Run-In. If a governor is encountered which can not be adjusted to this speed, a stock governor should be installed for the Run-In.

After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the Basic Engine Run-In Schedule.

The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature and lubricating oil pressure on the Engine Test Report.

Run the engine at each speed and rating for the length of time indicated in the Basic Engine Run-In Schedule. This is the Basic Run-In. During this time, engine performance will improve as new parts begin to "seat in". Record all of the required data.

C. BASIC RUN-IN INSPECTION

While the engine is undergoing the Basic Run-In, check each item indicated in Section "C" of the Engine Test Report. Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Basic Run-In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Basic Run-In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN-IN

The primary purpose of this inspection is to provide a fine engine tune-up. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next, complete the applicable tune-up procedure. Refer to SM6-5-68.0.

E. FINAL RUN-IN

After all of the tests have been made and the Engine Test Report is completed through Section "D", the engine is ready for final test. This portion of the test and Run-In procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm-up period of 10 minutes at the same speed and load used for warm-up in the Basic Run-In. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic Run-In, the entire Basic Run-In must be repeated as though the Run-In and test procedure were started anew.

All readings observed during the Final Run-In should fall within the range specified in the Operating Conditions in SM6-5-70.0 and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

The engine water temperature should be taken during the last portion of the Basic Run-In at full load. It should be recorded and should be within the specified range.

The lubricating oil temperature reading must be taken while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range.

The lubricating oil pressure should be recorded in psi after being taken at engine speeds indicated in the Operating Conditions, SM6-5-70.0. The fuel oil pressure at the fuel manifold inlet passage should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine speed during the Final Run-In.

Check the air box pressure while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gauge (0-15 psi) or manometer (15-0-15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the crankcase pressure while the engine is operating at maximum Run-In speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the Run-In indicating that new rings are beginning to "seat-in" .

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4" pipe tapped hole in the engine air inlet housing. If a hole is not provided, a stock housing should be drilled, tapped and kept on hand for future use.

The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of the turbocharger. The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air intake vacuum at various speeds (at no-load) and compare the results with the Engine Operating Conditions in SM6-5-70.0. Record these readings on the Engine Test Report.

Check the exhaust back pressure at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adaptor installed at the tapped hole. If the exhaust manifold does not provide a 1/8" pipe tapped hole, such a hole can be incorporated by reworking the exhaust manifold. Install a fitting for a pressure gauge or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet. The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is below the Maximum Exhaust Back Pressure for the engine (refer to SM6-5-70.0).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full-load and no-load speeds.

Refer to the Final Engine Run-In Schedule and determine the maximum rated brake horsepower and the full-load speed to be used during the Final Run-In. Apply the load thus determined to the dynamometer. The engine should be run at this speed and load for 1/2 hour. While making the Final Run-In, the engine should develop, within 5%, the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Basic Run-In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run-In, of the Engine Test Report should be determined and filled in. After the prescribed time for the Final Run-In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run-In is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the Final Run-In and before the Engine Test Report is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rust proofing the fuel system as outlined in Operator’s Manual and adding a rust inhibitor into the cooling system (refer to Operator’s Manual). The lubricating oil filters should also be changed.

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc., should only be required periodically to compensate for normal wear on parts.

The mechanical engine governors are identified by a name plate attached to the governor housing. The letters D.W.-L.S. stamped on the name plate denote a double-weight limiting speed governor. A single weight variable speed governor name plate is stamped S.W.-V.S.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if the cylinder head, governor, or injectors have been replaced or overhauled, then certain preliminary adjustments are required before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

To tune-up an engine completely, all of the adjustments, except the valve bridge adjustment on four valve cylinder heads, are made by following the applicable tune-up sequence given below, after the engine has reached normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Note: The exhaust valve bridges on the four valve cylinder head are adjusted at the time the cylinder head is installed on the engine and, until wear occurs, no further adjustment is required. When wear is evident perform a complete valve bridge adjustment as outlined on the following page.

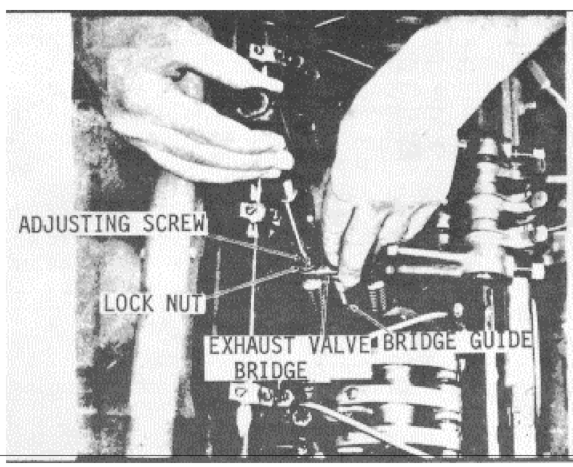



*Fig. 1*
*Valve Bridge Adjustment*

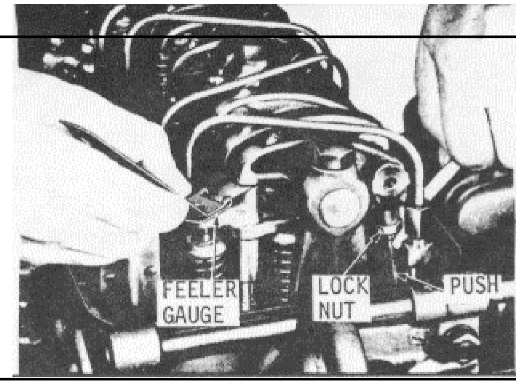



*Fig. 2*
*Adjusting Valve Clearance*

68.1 Tune-Up Sequence for Mechanical Governor

Note: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the serviceman must determine that the injector racks move to the no fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no-fuel with the governor stop lever.

(1) Adjust the exhaust valve clearance.
(2) Time the fuel injectors.
(3) Adjust the governor gap.
(4) Position the injector rack control levers.
(5) Adjust the maximum no-load speed.
(6) Adjust the idle speed.
(7) Adjust the buffer screw.
(8) Adjust the supplementary governing device.

68.2 Exhaust Valve Clearance Adjustment

The correct exhaust valve clearance at normal engine operating temperature is important for smooth efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, especially in the low speed range.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

The exhaust valve bridges must be adjusted and the adjustment screws locked securely at the time the cylinder head is installed on the engine. Until wear occurs, no further adjustment is required on the exhaust valve bridges. When wear is evident, make the necessary adjustments as outlined.

68.3 Exhaust Valve Bridge Adjustment

(1) Remove the loose dirt from the valve rocker cover and remove the cover. Remove the injector fuel pipes and the rocker arm retaining bolts. Move the rocker arms away from the exhaust valve bridges.
(2) Remove the exhaust valve bridge (Fig. 1).
(3) Place the bridge in a vice or holding fixture J 21772 and loosen the locknut on the bridge adjusting screw.

Note: Loosening or tightening the locknut with the bridge in place may result in bending the bridge guide or the rear valve stem.

(4) Install the bridge on the bridge guide.
(5) While firmly pressing straight down on the pallet surface of the bridge, turn the adjusting screw clockwise until it just touches the valve stem. Then turn the screw an additional 1/8 to 1/4 turn clockwise and tighten the locknut finger tight.
(6) Remove the bridge and place it in a vise. Hold the screw from turning with a screwdriver and tighten the locknut on the adjusting screw. Complete the operation by tightening the locknut with a torque wrench to 25 ft-lbs (34 Nm), being sure that the screw does not turn.
(7) Lubricate the bridge guide and bridge pilot with engine oil.
(8) Reinstall the bridge in its original position.
(9) Place a .0015" feeler gauge under each end of the bridge. When pressing down on the pallet surface of the bridge, both feeler gauges must be tight. If both feeler gauges are not tight, readjust the screw as outlined in Steps 5 and 6.
(10) Adjust the remaining bridges as outlined above.
(11) Swing the rocker arm assembly into position being sure the bridges are properly positioned on the rear valve stems. This precaution is necessary to prevent valve damage due to mislocated bridges.
(12) Tighten the rocker bracket bolts to 90-100 ft-lbs (122-136 Nm) torque.
(13) Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932 to tighten the connectors to 12-15 ft-lbs (16-20 Nm) torque.

Note: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

68.4 Exhaust Valve Clearance Adjustment (Cold Engine)

Adjust the exhaust valve clearance at the push rod. Do not disturb the exhaust valve bridge adjusting screw.

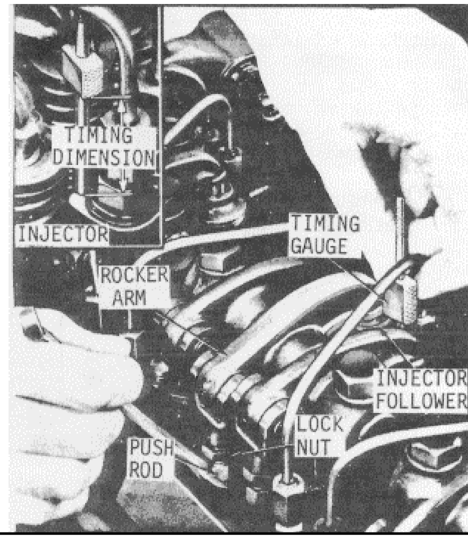



*Fig. 3*
*Timing Fuel Injector*

All of the exhaust valves may be adjusted, in firing order sequence, during one full revolution of the crankshaft. Refer to the general specifications in the Operator's Manual for the engine firing order.

(1) Place the governor stop lever in the no-fuel position.
(2) Remove the loose dirt from the valve rocker cover and remove the cover.
(3) Rotate the crankshaft manually, or with the starting motor, until the injector follower is fully depressed on the cylinder to be adjusted.

Note: If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the engine in a left-hand direction of rotation as the bolt will be loosened.

(4) Loosen the exhaust valve rocker arm push rod locknut.
(5) Place a .017" feeler gauge, J 9708, between the valve bridge and the valve rocker arm pallet (Fig. 2). Adjust the push rod to obtain a smooth "pull" on the feeler gauge.
(6) Remove the feeler gauge. Hold the push rod with a 5/16" wrench and tighten the locknut with a 1/2" wrench.
(7) Recheck the clearance. At this time, if the adjustment is correct, the .015" feeler gauge will pass freely between the valve bridge and the rocker arm pallet but the .017" feeler gauge will not pass through.
(8) Check and adjust the remaining valves in the same manner as outlined above.

68.5 Exhaust Valve Clearance Adjustment (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the final valve clearance adjustment. If the engine is allowed to cool off before setting any of the valves, the clearance when running at full load may become insufficient.

(1) With the engine at normal operating temperature (160-1850F or 71-85°C), recheck the exhaust valve clearance with feeler gauge J 9708. At this time, if the valve clearance is correct, the .013" feeler gauge will pass freely between the valve bridge and the rocker arm pallet, but the .015" gauge will not pass through. Adjust the push rod, if necessary.

(2) After the exhaust valve clearance has been adjusted, check the fuel injector timing.

## 68.6 Timing Fuel Injector

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed, in firing order sequence, during one full revolution of the crankshaft. Refer to the general specifications in the Operator's Manual for the engine firing order.

Use the proper timing gauge as indicated in the following chart.

## 68.7 Time Fuel Injector

After the exhaust valve clearance has been adjusted, time the fuel injectors as follows:

(1) Place the speed control lever in the idle speed position. If a stop lever is provided, secure it in the no-fuel position.

(2) Rotate the crankshaft until the exhaust valves are fully depressed on the particular cylinder to be timed.

Note: <u>If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation as the bolt will be loosened.</u>

(3) Place the small end of the injector timing gauge in the hole provided in the top of the injector body, with the flat of the gauge toward the injector follower (Fig. 3).

(4) Loosen the push rod locknut.

(5) Turn the push rod and adjust the injector rocker arm until the extended part of the gauge will just pass over the top of the injector follower.

(6) Hold the push rod and tighten the locknut. Check the adjustment and, if necessary, readjust the push rod.

(7) Time the remaining injectors in the same manner as outlined in Steps I through 6.

(8) If no further engine tune-up is required, use a new gasket and install the valve rocker cover.

| Injector | Timing Dimension | Timing Gauge | Camshaft Timing |
|---|---|---|---|
| Generator Set Applications | | | |
| All | 1.460” | J 1853 | Standard |
| ALL OTHER APPLICATIONS | | | |
| N55 | *1.460” | J 1853 | *Standard |

*Use 1.484” timing gauge (J 1242) when engine has advanced camshaft timing. Correct to standard camshaft timing and 1.460” injector timing at first opportunity to be consistent with current production build.

Note: <u>Advanced camshaft timing is indicated by “ADV—CAM—“TIMING” stamped on lower right-hand side of option plate.</u>

Injector Timing Gauge Chart (Needle Valve)

## 68.8 Variable Speed Mechanical Governor and Injector Rack Control Adjustment

The single weight governor is mounted on the front of the blower and is driven by the upper blower rotor.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and the injector rack control levers.

Note: <u>Before proceeding with the governor and injector rack adjustments, disconnect *any sup*plementary governing device'. After the adjustments are completed, reconnect and adjust the supplementary governing device.</u>

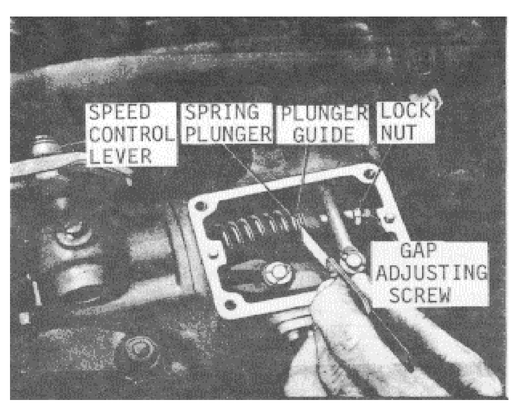



*Fig. 4 Adjusting Governor Gap*

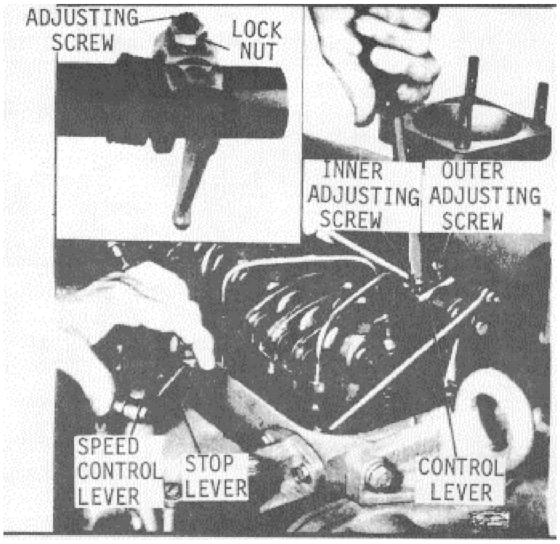



*Fig. 5 Positioning No. 1 Injector Rack Control Lever*

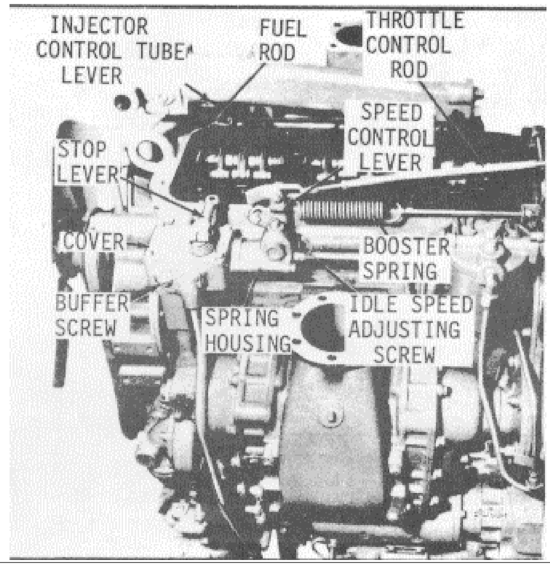



*Fig. 6 Buffer and Idle Speed Adjusting Screw*

68.9 Adjust Governor Gap

With the engine stopped and at operating temperatures, adjust the governor gap as follows:

(1) Disconnect any linkage attached to the governor levers.
(2) Back out the buffer screw until it extends approximately 5/8" from the locknut.
(3) Remove the governor cover.
(4) Place the speed control lever (Fig. 4) in the maximum speed position.
(5) Insert a .006" feeler gauge between the spring plunger and the plunger guide as shown in Fig. 4. If required loosen the locknut and turn the adjusting screw in or out until a slight drag is noted on the feeler gauge.
(6) Hold the adjusting screw and tighten the locknut. Check the gap and readjust, if necessary.
(7) Secure the governor cover to the governor housing with three regular screws, one special screw and lockwashers.
(8) Hook the torsion retracting spring on the special cover screw and the stop lever (Fig. 5).

68.10 Position Injector Rack Control Levers

The position of the injector rack control levers must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Certain engines use spring-loaded injector control tube assemblies which have a yield spring at each injector rack control lever and only one screw and locknut to keep each injector rack properly positioned. Adjust the single screw and locknut on each injector rack control lever the same as for the two screw rack control lever.

Properly positioned injector rack control levers with the engine at full load will result in the following:

(1) Speed control lever at the maximum speed position.
(2) Stop lever in the RUN position.
(3) High-speed spring plunger on the seat in the governor control housing.
(4) Injector fuel control racks in the full-fuel position.

Adjust the No. 1 injector rack control lever (Fig. 5) first, to establish a guide for adjusting the remaining injector rack control levers.

(1) Loosen all of the inner and outer adjusting screws (Fig. 5). Be sure all of the injector rack control levers are free on the injector control tube.
(2) Move the speed control lever to the full fuel position.
(3) Move the stop lever to the run position. Hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. 1 injector rack control lever down until a step-up in effort is noted. This will place the No. 1 injector rack in the full-fuel position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

Note: <u>Overtightening the injector rack control lever adjusting screws can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 in-lb (3-4 Nm).</u>

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

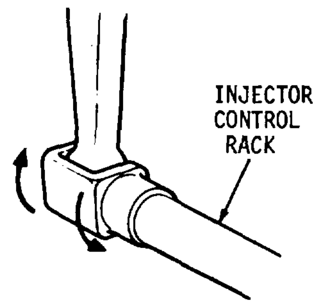



*Fig. 7 Checking Rotating Movement of Injector Control Rack*

(4) To be sure of proper rack adjustment, hold the stop lever in the run position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack (Fig. 7) when the stop lever is in the run position. Hold the stop lever in the full-fuel position and, using a screwdriver, press down- ward on the injector control rack. The rack should tilt downward (Fig. 8) and when the pressure of the screwdriver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct, back off the outer adjusting screw slightly and tighten the inner adjusting screw.

The setting is too tight if, when moving the stop lever from the STOP to the RUN position, the injector rack becomes tight before the stop lever reaches the end of its travel as determined by the stop under the governor cover. This will result in a step-up in effort required to move the stop lever to the end of its travel. To correct this condition, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

(5) To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rod and the injector control tube lever, hold the injector control racks in the full-fuel position by means of the lever on the end of the control tube. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

(6) Recheck the No. 1 injector rack to be sure that it has remained snug on the ball end of the rack control lever while positioning the adjacent injector rack. If the rack of the No. 1 injector has become loose, back off the inner adjusting screw lightly on the adjacent injector control lever.

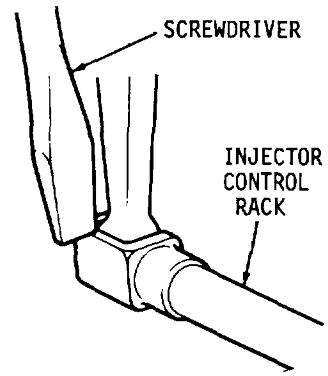



*Fig. 8 Checking Injector Control Rack Movement*

Tighten the outer adjusting screw.

(7) Position the remaining injector rack control levers as outlined in Steps 4 and 5.

(8) When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the full-fuel position, check each control rack as in Step 4. All of the control racks must have the same "spring" condition with the control tube lever in the *full-fuel* position.

(9) Insert the clevis pin in the fuel rod and the injector control tube lever.

(10) Use a new gasket and replace the valve rocker cover.

## 68.11 Adjust Maximum No-Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to en- sure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, set the maximum no-load speed as outlined below.

Start the engine and, after normal operating temperature is reached, use an accurate tachometer to determine the maximum no-load speed of the engine. Then stop the engine and make the following adjustments, if required.

(1) Refer to Fig. 6 and disconnect the booster spring.

| Full-Load Speed | Stops | Shims |
|---|---|---|
| 1450 to 1650 rpm | 2 | |
| 1651 to 2150 rpm | 1 | Amount required to get necessary speed. |
| 2151 to 2300 rpm | 0 | |

Table 1 - Four Valve Cylinder Heads

(2) Remove the variable speed spring housing and the variable speed spring plunger from inside the spring housing.

(3) Refer to Table I and Fig. 9 and determine the stops or shims required for the desired full-load speed for engines with four valve cylinder heads.

Refer to Table 1 and determine the stops or shims required for the desired full-load speeds for engines with four valve cylinder heads.

(4) Install the variable speed spring plunger and housing and tighten the two bolts. Start the engine and recheck the maximum no-load speed.

(5) If required, add shims to obtain the necessary operating speed. For each .001" shim added, the operating speed will increase approximately 1 rpm.

Important: <u>If the maximum no-load speed is raised or lowered more than 50 rpm by the installation or removal of the governor shims, the governor gap should be rechecked.</u>

Note: <u>Governor stops are used to limit the compression of the governor spring which determines the maximum speed of the engine.</u>

If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

## 68.12 Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

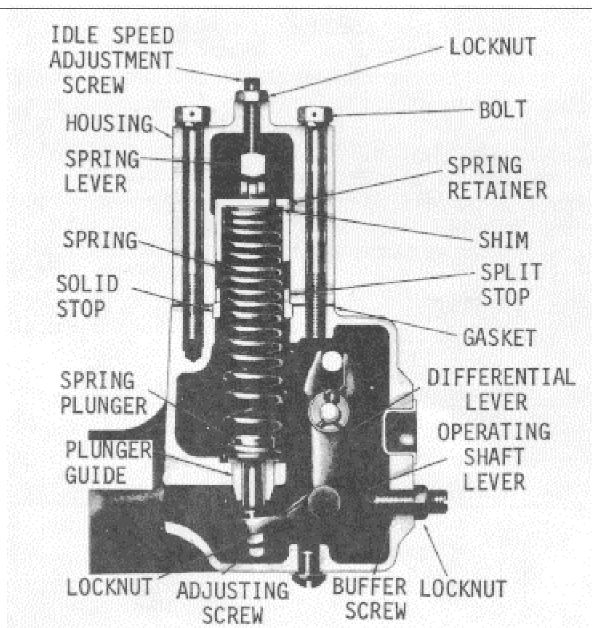



*Fig. 9 Location of Stops and Shims*

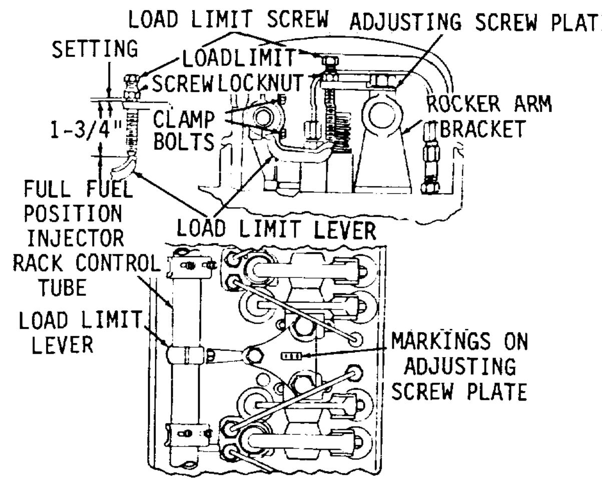



*Fig. 10 Engine Load Limit Device*

(1) Place the speed control lever in the idle position and the stop lever in the run position.

(2) With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

(3) Loosen the locknut and turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed. The recommended idle speed is 500-600 rpm, but may vary with special engine applications.

(4) Hold the idle speed adjusting screw and tighten the locknut.

## 68.13 Adjust Buffer Screw

With the idle speed set at approximately 15 rpm below the recommended idle speed, the buffer screw may be set as follows:

(1) With the engine running at normal operating temperature, turn the buffer screw in so that it contacts the differential lever as lightly as possible and still eliminates engine roll.

Note: <u>Do not increase the engine speed more than 15 rpm with the buffer screw.</u>

(2) Hold the buffer screw and tighten the locknut.

## 68.14 Adjust Booster Spring

With the engine idle speed adjusted, adjust the booster spring as follows:

(1) Move the speed control lever to the idle speed position.

(2) Refer to Fig. 6 and loosen the booster spring retaining nut on the speed control lever. Loosen the nut and locknut on the eye bolt at the opposite end of the booster spring.

(3) Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center toward the idle position of an imaginary line through the bolt, lever shaft and eye bolt. Hold the bolt and tighten the lock- nut.

(4) Start the engine and move the speed control lever to the maximum speed position and release it. The lever should return to the idle speed position. If it does not, reduce the booster spring tension. If it does, continue to increase the spring tension until the point is reached where it will not return to idle. Then reduce the spring tension until the point is reached where it will not return to idle. Then reduce the spring tension until the lever does not return to idle and tighten the locknut on the eye bolt. This setting will result in the minimum force required to operate the speed control lever.

68.15 Supplementary Governing Device Adjustment (Engine Load Limit Device)

Engines with mechanical governors may be equipped with a load limit device (Fig. 10) to reduce the maximum horsepower.

This device consists of a load limit screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a load limit lever clamped to the injector control tube.

The load limit device is located between the No. 1 and No. 2 cylinders of a three cylinder engine, between the No. 2 and No. 3 cylinders of a four cylinder engine or between the No. 3 and No. 4 cylinders of a six cylinder engine.

When properly adjusted for the maximum horse-power desired, this device limits the travel of the injector control racks and thereby the fuel output of the injectors.

68.16 Adjustment

After the engine tune-up is completed, make sure the load limit device is properly installed as shown in Fig. 10. Make sure the counterbores in the adjusting screw plate are up. The rocker arm shaft bracket bolts which fasten the adjusting screw plate to the brackets are tightened to 75-85 ft-lbs (102-115 Nm) torque. All other rocker arm shaft bracket bolts are tightened to 90-100 ft-lbs (122-136 Nm) torque. Then adjust the load limit device as follows:

(1) Loosen the load limit screw locknut and remove the screw.

(2) Loosen the load limit lever clamp bolts so the lever is free to turn on the injector rack control tube.

(3) With the screw out of the plate, adjust the load limit screw locknut so the bottom of the locknut is 1-3/4" from the bottom of the load limit screw (Fig. 10) for the initial setting.

(4) Thread the load limit screw into the adjusting screw plate until the locknut bottoms against the top of the plate.

(5) Hold the injector rack control tube in the full-fuel position and place the load limit lever against the bottom of the load limit screw. Then tighten the load limit lever clamp bolts.

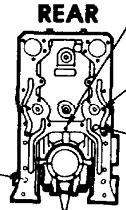
(6) Check to ensure that the injector racks will just go into the full-fuel position readjust the load limit lever if necessary.

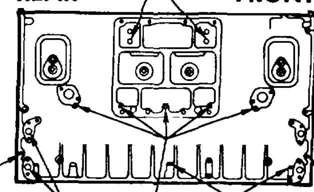
(7) Hold the load limit screw to keep it from turning, then set the locknut until the distance between the bottom of the locknut and the top of the adjusting screw plate corresponds to the dimension (or number of turns) stamped on the plate. Each full turn of the screw equals .042", or .007" for each flat on the hexagon head.

Note: <u>If the plate is not stamped, adjust the load limit screw while operating the engine on a dynamometer test stand and note tie number of turns required to obtain the desired horsepower. Then stamp the plate accordingly.</u>

(8) Thread the load limit screw into the plate the screw into the plate until the locknut bottoms against the top of the plate. Be sure the nut turns with the screw.

(9) Hold the load limit screw to keep it from turning, then tighten the locknut to secure the setting.

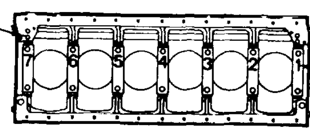


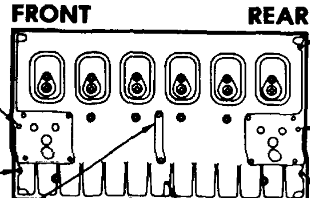



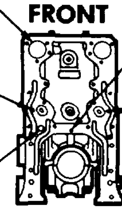

STANDARD PIPE PLUG TORQUE*

| Pipe Plug Size | Torque Ft/Lbs. |
|---|---|
| 1/8 | 10-12 |
| 1/4 | 14-16 |
| 3/8 | 18-22 |
| 1/2 | 23-27 |
| 3/4 | 33-37 |

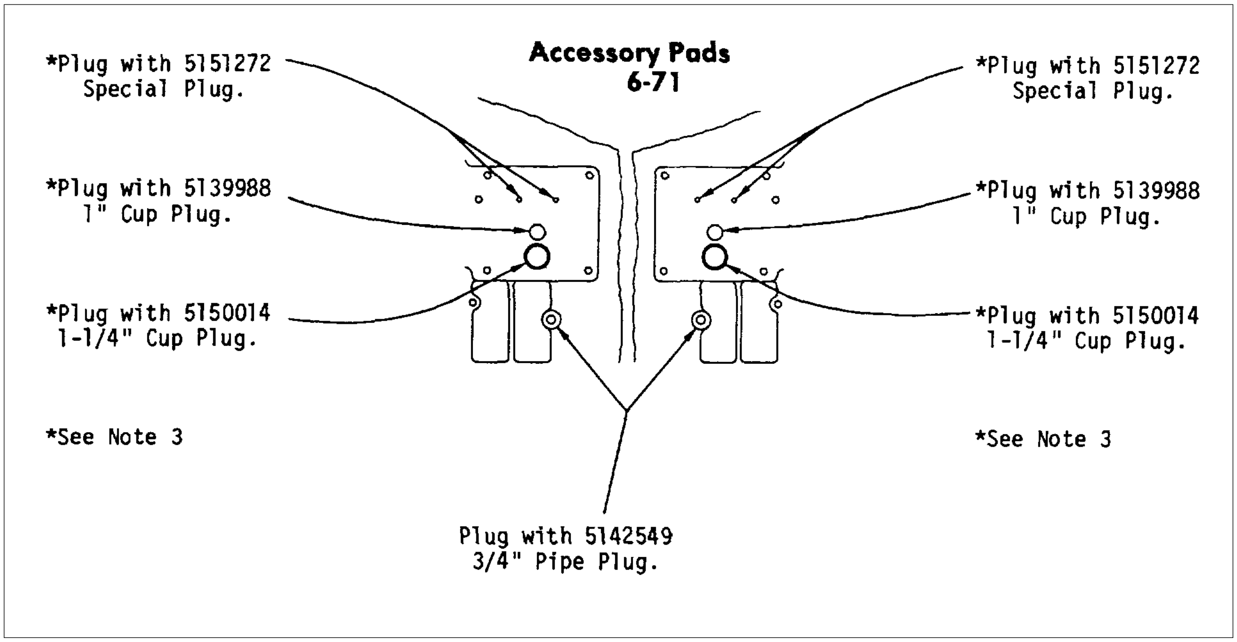
*Caution: Do Not Over Torque Teflon Wrapped Pipe Plugs. (See Note 2)



**Service Manual** SM6-5-69.0 Cylinder Block Plugging Instructions For 6-71 Engines




NOTES:

(1) Assemble 225815 Elbow and 5158825 Tube Assembly in each of the two air box drain holes on the blower side of the block for GMC Truck Models. Assemble 5145009 Plugs in the two corresponding holes on the opposite side of the block.

For single engine generator units, assemble 225815 Elbow and 5171700 Tube Assembly to the front of the block on the handhole cover side. Assemble 225815 Elbow and Tube Assembly 5171502 to the rear on the same side of the block. Assemble 5145009 Plugs in the two corresponding holes on the opposite side of the block.

(2) Use "viation Permatex", Minnesota Mining EC-712 Sealant or equivalent when assembling all plugs except Teflon wrapped plugs. Apply Sealant to plug only.

(3) Do not install plugs when crankcase-breather is to be installed on accessory pad.

* Not included with service block.

## 71N ENGINES

| | 1200 rpm | 1800 rpm | 2100 rpm | |
|---|---|---|---|---|
| **Lubricating System** | | | | |
| Lubricating oil pressure (psi): | | | | |
| Normal........................................ | 30-60 | 43-65 | 45-65 | |
| Minimum for safe operation ........................................ | 18 | 28 | 30 | |
| *Lubricating oil temperature (degrees F.): | | | | |
| Normal........................................ | 200-225 | 200-225 | 200-225 | |
| **Air System** | | | | |
| Air box pressure (inches mercury) - min. at full load: | | | | |
| At zero exhaust back pressure ........................................ | 0.1 | 2.8 | 4.6 | |
| At max. full-load exhaust back pressure ........................................ | 1.2 | 5.3 | 7.6 | |
| Air inlet restriction (inches water) - full-load speed, max.: | | | | |
| ........................................ Dirty air cleaner (oil bath or dry) | | 12.4 | 25.0 | 25.0 |
| ........................................ Clean air cleaner (with pre-cleaner) (oil bath or dry) | | 8.7 | 13.4 | 15.9 |
| ........................................Clean air cleaner (less pre-cleaner) (dry) | | 5.2 | 9.1 | 11.5 |
| Crankcase pressure (inches water) - max.: | | | | |
| ........................................ 6-71N Engine | | 2.0 | 2.8 | 3.1 |
| Exhaust back pressure (inches mercury) - max.: | | | | |
| ........................................ Full load | | 1.5 | 3.3 | 4.0 |
| ........................................No load | | 1.0 | 2.1 | 2.6 |
| **Fuel System** | | | | |
| Fuel pressure at inlet manifold (psi): | | | | |
| ........................................Normal (.080" orifice) | | 30-65 | 45-70 | 45-70 |
| Fuel spill (gpm) - min. at no load: | | | | |
| ........................................(.080" orifice) | | 0.8 | 0.9 | 0.9 |
| Fuel pump suction at pump inlet (inches mercury) - max.: | | | | |
| ........................................ Clean system | | 6.0 | 6.0 | 6.0 |
| ........................................ Dirty system | | 12.0 | 12.0 | 12.0 |
| **Cooling System** | | | | |
| Coolant temperature (degrees F.) - normal ........................................ | 160-185 | 160-185 | 160-185 | |
| **Compression** | | | | |
| Compression pressure (psi at seal level): | | | | |
| ........................................Average - new engine at 600 rpm | | 565 | | |
| ........................................ Minimum at 600 rpm | | 515 | | |

* The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

| THREAD SIZE | 260M BOLTS TORQUE (ft/lb) | 260M BOLTS TORQUE (N-m) | THREAD SIZE | 280M OR BETTER TORQUE (ft/lb) | 280M OR BETTER TORQUE (N-m) |
|---|---|---|---|---|---|
| 1/4 -20 .......... | 5-7 | 7-9 | 1/4 -20 .............................. | 7-9 | 10-12 |
| 1/4 -28 .......... | 6-8 | 8-11 | 1/4 -28 .............................. | 8-10 | 11-14 |
| 5/16-18 ......... | 10-13 | 14-18 | 5/16-18 .............................. | 13-17 | 18-23 |
| 5/16-24 ......... | 11-14 | 15-19 | 5/16-24 .............................. | 15-19 | 20-26 |
| 3/8 -16 .......... | 23-26 | 31-35 | 3/8 -16 .............................. | 30-35 | 41-47 |
| 3/8 -24 .......... | 26-29 | 35-40 | 3/8 -24 .............................. | 35-39 | 47-53 |
| 7/16-14 ......... | 35-38 | 47-51 | 7/16-14 .............................. | 46-50 | 62-68 |
| 7/16-20 ......... | 43-46 | 58-62 | 7/16-20 .............................. | 57-61 | 77-83 |
| 1/2 -13 .......... | 53-56 | 72-76 | 1/2 -13 .............................. | 71-75 | 96-102 |
| 1/2 -20 .......... | 62-70 | 84-95 | 1/2 -20 .............................. | 83-93 | 113-126 |
| 9/16-12 ......... | 68-75 | 92-102 | 9/16-12 .............................. | 90-100 | 122-136 |
| 9/16-18 ......... | 80-88 | 109-119 | 9/16-18 .............................. | 107-117 | 146-159 |
| 5/8 -11 .......... | 103-110 | 140-149 | 5/8 -11 .............................. | 137-147 | 186-200 |
| 5/8 -18 .......... | 126-134 | 171-181 | 5/8 -18 .............................. | 168-178 | 228-242 |
| 3/4 -10 .......... | 180-188 | 244-254 | 3/4-10 .............................. | 240-250 | 325-339 |
| 3/4 -16 .......... | 218-225 | 295-305 | 3/4 -16 .............................. | 290-300 | 393-407 |
| 7/8 - 9 ........... | 308-315 | 417-427 | 7/8 - 9 .............................. | 410-420 | 556-569 |
| 7/8 -14 .......... | 356-364 | 483-494 | 7/8 -14 .............................. | 475-485 | 644-657 |
| 1- 8 ............... | 435-443 | 590-600 | 1 - 8 .............................. | 580-593 | 786-800 |
| 1-14 .............. | 514-521 | 697-705 | 1 -14 .............................. | 685-695 | 928-942 |

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

| Grade Identification Strength Marking on Bolt Head | GM Number | SAE Grade Designation | Nominal Size Diameter (inch) | Tensile Min. (psi) |
|---|---|---|---|---|
| None | GM 255-M | 1 | No. 6 thru 1 1/2 | 60,000 |
| | | | over 3/4 to 1 1/2 | 60,000 |
| None | GM 260-M | 2 | No. 6 thru 3/4 | 74,000 |
| | | | over 1 to 1 1/2 | 105,000 |
| Bolts and Screws | GM 280-M | 5 | No. 6 thru 1 | 120,000 |
| Hex Head Sems Only | GM 275-M | 5.1 | No. 6 thru 3/8 | 120,000 |
| )I=Bolts and Screws | GM 290-M | 7 | 1/4 thru 1 1/2 | 133,000 |
| ok<Bolts and Screws | GM 300-M | 8 | 1/4 thru 1 1/2 | 150,000 |
| Bolts and Screws | GM 455-M | None | No. 6 thru 1 1/2 | 55,000 |

BOLT IDENTIFICATION CHART

## EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

| APPLICATION | THREAD SIZE | TORQUE (ft/lb) | TORQUE (N-m) |
|---|---|---|---|
| Limiting speed low weight set screw................................ | 10-32 | 20 in-lb | 2.26 |
| Variable speed spring lever set screw ........................... | 5/16-24 | 5-7 | 7-10 |
| Injector clamp bolt .............................. ......................... | 3/8-16 | 20-25 | 27-34 |
| Injector clamp stud .............................. ........................ | 3/8-16 | 10-25 | 14-34 |
| Fuel pipe nut ................................... .......................... | 3/8-24 | 12-15 | 16-20 |
| Injector clamp nut ............................... ......................... | 3/8-24 | 20-25 | 27-34 |
| Fuel manifold connector nut ....................... .................. | 7/16-20 | 30-35 | 41-47 |
| *Fuel manifold connector (nylon insert) ............ ............. | 7/16-20 | 30-35 | 41-47 |
| *Fuel manifold connector (steel washer) ........................ | 7/16-20 | 40-45 | 54-61 |
| #Rocker arm bracket bolt ............................................... | 1/2-13 | 90-100 | 122-136 |
| Injector filter cap............................................................. | 5/8-24 | 65-75 | 88-102 |
| Injector nut (needle valve) ....................... ..................... | 15/16-24 | 75-85 | 102-115 |
| Oil pan bolts ................................................................. | 5/16-18 | 10-20 | 14-27 |
| Oil pump drive idler gear nut .......................................... | 1/2-20 | 60-70 | 81-95 |
| Oil pump-to-bearing cap bolt .......................................... | 3/8-24 | | |
| Oil pan drain plug (nylon washer)................................... | 18mm | 25-35 | 34-47 |
| Oil pump relief valve plug ............................................... | 7/8-18 | 15-25 | 20-34 |
| Bypass valve plug .......................................................... | 1-1/4-16 | 95-105 | 129-143 |
| Water pump cooling bolt (current) .................................. | 5/16-24 | 18 min. | 24 min. |
| Water manifold nut......................................................... | 3/8-24 | 25-30 | 34-41 |
| Water pump coupling bolt (former tapered shaft) ............ | 7/16-24 | 25-30 | 34-41 |
| Raw water pump (Jabsco) drive gear retaining nut....... ... | 5/8-18 | 25-30 | 34-41 |
| Generator drive pulley nut .............................................. | 1/2-13 | 50-60 | 68-81 |
| Starting motor connector ................................................ | 1/2-13 | 20-25 | 27-34 |
| Starting motor connector ................................................ | No. 10-32 | @ | @ |
| Starting motor switch mounting nut ................................ | | + | + |
| Blower drive hub-to-blower rotor gear bolt...................... | 5/16-24 | 25-30 | 34-41 |
| Blower drive plate-to-drive hub bolt ................................ | 5/16-24 | 25-30 | 34-41 |
| (Allen head) .................................................................. | 5/16-24 | 18 | 24 |
| Blower lower front bearing retaining bolt | | | |
| Air inlet housing-to-blower housing bolt ......................... | 3/8-16 | 16-20 | 22-27 |
| Blower housing-to-cylinder block bolt ............................. | 7/16-14 | 55-60 | 75-81 |
| Blower rotor timing gear bolt .......................................... | 7/16-20 | 55-65 | 75-88 |
| Blower rotor timing gear bolt........................................... | 1/2-20 | 55-65 | 75-88 |
| Fuel pump drive disc bolt ............................................... | 1/2-20 | 55-65 | 75-88 |
| Crankshaft front cover bolts............................................ | 1/2-13 | 80-90 | 108-122 |
| Flywheel housing bolts................................................... | 1/2-13 | 90-100 | 122-136 |
| Generator drive bearing retaining bolt ............................ | 1/2-13 | 30-35 | 41-47 |
| Generator drive oil seal retaining bolt ............................. | 1/2-13 | 30-35 | 41-47 |
| Idler gear and dummy hub bolt....................................... | 1/2-13 | 80-90 | 108-122 |
| &Rocker shaft bolts ........................................................ | 1/2-13 | 90-100 | 122-136 |
| Tachometer drive cover bolt ........................................... | 1/2-13 | 30-35 | 41-47 |
| Blower rotor gear retaining nut ....................................... | 1/2-20 | 55-65 | 75-88 |

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS - CONTINUED

| APPLICATION | THREAD SIZE | TORQUE (ft/lb) | TORQUE (N-m) |
|---|---|---|---|
| Cam follower guide bolt ................................................ | 1/4-20 | 12-15 | 16-20 |
| Injector control shaft bracket bolt .................................. | 1/4-20 | 10-12 | 14-16 |
| Oil pan bolts ................................................................. | 5/16-18 | 10-20 | 14-27 |
| Blower drive coupling to gear hub bolt ........................... | 5/16-24 | 20-25 | 27-34 |
| locknut ......................................................................... | 5/16-24 | 20-25 | 27-34 |
| Exhaust valve bridge adjusting screw | | | |
| Idler gear bearing retainer bolts .................................... | 5/16-24 | 24-29 | 33-39 |
| Air box cover bolt .......................................................... | 3/8-16 | 10-15 | 14-20 |
| Balance weight cover bolts ............................................ | 3/8-16 | 25-30 | 34-41 |
| Cam and balance shaft end bearing bolts ...................... | 3/8-16 | 35-40 | 47-54 |
| Crankshaft front cover bolts............................................ | 3/8-16 | --- | --- |
| Engine drive shaft flexible coupling ............................... | 3/8-16 | 25-30 | 34-41 |
| Flywheel housing bolts .................................................. | 3/8-16 | --- | --- |
| **Idler gear hub and spacer bolts .................................. | 3/8-16 | 40-45 | 54-61 |
| ?Idler gear hub and spacer bolts .................................... | 3/8-16 | 25-40 | 35-54 |
| Injector clamp bolts ....................................................... | 3/8-16 | 20-25 | 27-34 |
| Accessory drive to gear bolt (steel disc) ......................... | 3/8-24 | 45-50 | 61-68 |
| Balance weight cover bolts ............................................ | 3/8-24 | 25-30 | 34-41 |
| Balance weight to hub bolt ............................................ | 3/8-24 | 25-30 | 34-41 |
| Balance weight to timing gear bolt ................................. | 3/8-24 | 25-30 | 34-41 |
| bolts and nuts ............................................................... | 3/8-24 | 25-30 | 34-41 |
| Blower drive gear hub bearing support | | | |
| Camshaft intermediate bearing lock screw .................... | 3/8-24 | 15-20 | 20-27 |
| Crankshaft front cover bolts ........................................... | 3/8-24 | 25-30 | 34-41 |
| Exhaust manifold outlet flange nuts (brass).................... | 3/8-24 | 20-25 | 27-34 |
| Flywheel housing bolts .................................................. | 3/8-24 | 25-30 | 34-41 |
| Fuel pipe nuts ............................................................... | 3/8-24 | 12-15 | 16-20 |
| Injector clamp nut .......................................................... | 3/8-24 | 20-25 | 27-34 |
| Water manifold nuts ...................................................... | 3/8-24 | 25-30 | 34-41 |
| Air compressor adjusting support | | | |
| pivot bolt (300M) ............................................................ | 7/16-14 | 72-77 | 98-104 |
| Generator drive bearing retaining bolt ............................ | 7/16-14 | 30-35 | 41-47 |
| Generator drive oil seal retaining bolt ............................. | 7/16-14 | 30-35 | 41-47 |
| Lifter bracket bolt ........................................................... | 7/16-14 | 55-60 | 75-81 |
| Tachometer drive cover bolt........................................... | 7/16-14 | 30-35 | 41-47 |
| Connecting rod nut (castellated) .................................... | 7/16-20 | 65-75 | 88-102 |
| Connecting rod nut (lubrite)............................................ | 7/16-20 | 60-70 | 81-95 |
| ***Cross-head piston pin to conn. rod bolt ...................... | 7/16-20 | 55-60 | 75-81 |
| Exhaust manifold nuts.................................................... | 7/16-20 | 30-35 | 41-47 |
| Fuel manifold connectors (steel washer) ....................... | 7/16-20 | 40-45 | 54-61 |
| Fuel manifold connectors (nylon insert).......................... | 7/16-20 | 30-35 | 41-47 |
| Fuel manifold connector nuts ........................................ | 7/16-20 | 30-35 | 41-47 |
| ***Cylinder head bolts .................................................... | 5/8-11 | 175-185 | 238-251 |
| ***Main bearing bolts (assembly) | | | |
| (see SM6-5-12.0) ........................................................... | 5/8-11 | --- | --- |
| ***Main bearing bolts (boring)......................................... | 5/8-11 | 165-175 | 224-238 |
| ***Cylinder head nuts .................................................... | 5/8-18 | 175-185 | 238-251 |
| ***Main bearing nuts (assembly) .................................... | 5/8-18 | 155-185 | 211-251 |
| ***Main bearing nuts (boring).......................................... | 5/8-18 | 140-155 | 190-211 |
| ***Flywheel bolts (see SM6-5-16.O) ............................... | 9/16-18 | --- | --- |
| Accessory drive pulley nut.............................................. | 3/4-16 | 120-140 | 163-190 |

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS - CONTINUED

| APPLICATION | THREAD SIZE | TORQUE (ft/lb) | TORQUE (N-m) |
|---|---|---|---|
| Crankshaft end bolt .................................................... | 1-14 | 290-310 | 393-421 |
| Camshaft and balance shaft nut .................................... | 1-1/8-18 | 300-325 | 407-441 |
| Blower drive gear hub nut ............................................ | 1-1/2-16 | 50-60 | 68-81 |

* Lubricate before assembly.
# 75-85 ft-lb (102-115 Nm) torque on the two bolts attaching load limit or power control screw bracket (if used) to the rocker arm shaft brackets.
@ 16-30 in/lb (2-3.5 Nm)
+ 36-48 in/lb (4-5.5 Nm)
** Self-locking only
? Wired head only
& 75-85 ft-lb (102-115 Nm) torque on the two bolts attaching load limit or power control screw bracket (if used) to the rocker arm shaft bracket.
*** Lubricate at assembly with International Compound No. 2.

STUD TORQUE SPECIFICATIONS

| APPLICATION | THREAD SIZE | TORQUE (ft/lb) | TORQUE (N-m) |
|---|---|---|---|
| Oil filter center stud ...................................................... | 50-60 | 68-81 | --- |
| Water manifold stud ...................................................... | 10-25 | 14-34 | |
| Cylinder head stud ("high").............................................. | 75 min. | 102 min. | 4.3750" |
| Main bearing stud (cast iron block) ................................. | 35-70 | 47-95 | 4.0000" |
| Exhaust manifold stud .................................................... | 25-40 | 34-54 | --- |
| Injector clamp stud ......................................................... | 10-25 | 14-34 | |
| Water manifold stud ........................................................ | 10-25 | 14-34 | |

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or teflon.

| NPTF SIZE THREAD | TORQUE | | NPTF SIZE THREAD | TORQUE | |
|---|---|---|---|---|---|
| | ft/lb | N-m | | ft/lb | N-m |
| 1/8................... | 10-12 | 14-16 | 1..................................... | 75-85 | 102-115 |
| ¼..................... | 14-16 | 19-22 | 1-1/16 ............................ | 85-95 | 115-129 |
| 3/8................... | 18-22 | 24-30 | 1-1/4 .............................. | 95-105 | 129-143 |
| ½..................... | 23-27 | 31-37 | 1-1/2 .............................. | 110-130 | 150-177 |
| ¾..................... | 33-37 | 45-50 | | | |

## SPECIAL PLUG TORQUE SPECIFICATIONS

| APPLICATION | * PLUG | ASSEMBLY |
|---|---|---|
| Oil gallery plug ............................................... | 3/8" Dryseal PTF thread | # Assemble with max. 0.0625" protrusion from surface. |
| Cylinder head (side) ....................................... | 3/8-16" | Assemble flush to 0.0625" protrusion from surface. |
| Cylinder head (top).......................................... | {1/2" PTF-SAE short | Flush to 1.1250" recessed |
| Cylinder head (end)......................................... | 3/4" Dryseal PTF-SAE short | Flush to 0.1250" recessed |
| Water hole plug .............................................. | 1" NPTF thread | Assemble 2.000" to 2.250" below machined surface |
| Core hole plug................................................ | 1-3/4"-16 | 150-180 ft-lb (204-244 Nm) torque |
| Oil drain plug (Nylon washer) ......................... | 18mm | 25-34 ft-lb (34-37 Nm) torque |

* Apply sealing compound to plugs used without gaskets or teflon.
# After installation, a 1.2187" diameter rod inserted in oil line must pass inner face of plug.

## SPRING SPECIFICATIONS

| SPRING | IS LESS THAN: REPLACE WHEN LOAD |
|---|---|
| Cam follower (11 coils - .177" wire) ................................................................................... | 172 lbs.@2.1250" |
| Cam follower (11-1/2 coils - .162" wire) ............................................................................ | 133 lbs.@2.1094" |
| Exhaust valve (8-3/4 coils - .148" wire)............................................................................. | 25 lbs.@1.8000" |

## TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

Note: Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replace in engine overhaul work. For additional information, refer to the text.

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Blower | | | |
| Backlash (timing gears) ..................................................... | 0005" | .0025" | .0040" |
| Backlash (reduction gears) ................................................ | 0020" | .0060" | .0080" |
| Oil seal or seal collar (below end plate surface)................ | 0020" | .0080" | -- |
| Dowel pin (projection beyond inside face of end plates)... | .3800" | -- | -- |
| Cylinder Block | | | |
| Diameter ............................................................................ | 4.6256" | 4.6270" | -- |
| Out-of-round ....................................................................... | -- | .0010" | .0020" |
| Taper .................................................................................. | -- | .0010" | .0020" |

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Cylinder liner counterbore: | | | |
| Diameter | 5.0460" | 5.0485" | -- |
| Depth | | | |
| Main bearing bore: | | | |
| Inside diameter (vertical axis) | 3.8120" | 3.8130" | -- |
| Top surface of block: | | | |
| Centerline of main bearing bore to top of block | 16.1840" | 16.1890" | 16.176"min. |
| Flatness-transverse | -- | -- | .0030" |
| Flatness--longitudinal | -- | -- | .0090" |
| Depth of counterbores (top surface): | | | |
| Cylinder head seal strip groove | 0920" | .1070" | -- |
| Large water holes (between cylinders) | .1090 | .1200" | -- |
| Small water holes (at ends) | .0870" | .0980" | -- |
| Combination water and oil holes | .0870" | .0980" | -- |
| Cylinder Liner | | | |
| Outside diameter | 4.6250" | 4.6265" | -- |
| Inside diameter (long port) | 4.2495" | 4.2511" | -- |
| Inside diameter (short port) | 4.2495" | 4.2516" | -- |
| Clearance--liner-to-block: | | | |
| Cast iron block (high) | .0000" | .0020" | .0025" |
| Out-of-round--inside diameter | -- | .0020" | .0025" |
| Taper--inside diameter | -- | .0010" | .0020" |
| Depth of flange BELOW (high block) | .0450" | .0500" | .0500" |
| Variation in depth between adjacent liners | -- | .0020" | .0020" |
| Insert thickness | .1795" | .1800" | -- |
| Piston Pins (Trunk Pistons) | | | |
| Length | 3.6050" | 3.6200" | -- |
| Diameter | 1.4996" | 1.5000" | 1.4980" |
| Clearance--pin to piston bushing | .0025" | .0034" | .0100" |
| Clearance--pin to conn. rod bushing | .0025" | .0034" | .0100" |
| Clearance--end (pin-to-retainer-- retainer with lock ring) | .0160" | .0640" | .0640" |
| Piston bushing--inside diameter | 1.5025" | 1.5030" | 1.5050" |
| Connecting Rod | | | |
| Inside diameter (upper bushing) | 1.5025" | 1.5030" | 1.5080" |
| Normal side clearance | .0060" | .0120" | -- |
| 71N Engines | | | |
| Piston: | | | |
| Height (centerline of bushing to top) | 3.5430" | 3.5480" | -- |
| Diameter (above compression rings) | 4.2225" | 4.2255" | -- |
| Diameter (at skirt) | 4.2428" | 4.2450" | -- |
| Clearance--piston skirt-to-liner | .0045" | .0083" | .0120" |
| Out-of-round | -- | .0005" | -- |
| Taper | -- | .0005" | -- |
| Compression rings: | | | |
| Gap (top-fire ring) | .0230" | .0380" | .0600" |
| Gap (No. 2, 3 and 4) | .0180" | .0430" | .0600" |
| Clearance--ring-to-groove: | | | |
| No. 1 (top-fire ring) | .0040" | .0060" | .0100" |
| No. 2 | .0100" | .0130" | .0220" |
| No. 3 and 4 | .0040" | .0070" | .0130" |
| Oil control rings: | | | |
| Gap | .0080" | .0230" | .0430" |
| Clearance | .0015" | .0055" | .0080" |
| Connecting Rod Bearings | | | |
| Inside diameter (vertical axis) | 2.7514" | 2.7534" | -- |
| Bearing-to-journal clearance | .0014" | .0044" | .0060" |
| Bearing thickness 90° from parting line | .1548" | .1553" | .153" min. |

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Main Bearings | | | |
| Inside diameter (vertical axis) | 3.5014" | 3.5034" | -- |
| Bearing-to-journal clearance | .0014" | .0044" | .0060" |
| Bearing thickness 900 from parting line | .1548" | .1553" | .153" min. |
| Camshaft | | | |
| Diameter (at bearing journals): | | | |
| Front and rear | 1.4970" | 1.4975" | -- |
| Center and intermediate | 1.4980" | 1.4985" | -- |
| Runout at center bearing (when mounted on end bearings) | | -- | .0020" |
| Shaft diameter at gear | 1.1875" | 1.1880" | -- |
| Balance Shaft | | | |
| Shaft diameter at bearings | | 1.4970" | 1.4975" -- |
| Shaft diameter at gear | 1.1875" | 1.1880" | -- |
| Length--thrust bearing end journal | 2.8740" | 2.8760" | -- |
| End thrust | 0040" | .0120" | .0180" |
| Thrust washer thickness | 1190" | .1220" | -- |
| Camshaft and Balance Shaft Bearings | | | |
| Inside diameter: | | | |
| Front and rear | 1.5000" | 1.5010" | -- |
| Center and intermediate | 1.5010" | 1.5030" | -- |
| Clearance--bearing-to-shaft: | | | |
| Front and rear | .0025" | .0040" | .0060" |
| Center and intermediate | .0025" | .0050" | .0090" |
| Outside diameter: | | | |
| Front and rear | 2.1875" | 2.1880" | -- |
| Center and intermediate | 2.1840" | 2.1860" | -- |
| Diameter of *cylinder* block bore | 2.1875" | 2.1885" | -- |
| Clearance--bearlngs-to-block: | | | |
| Front and rear | .001" press. | 0005" loose | -- |
| Intermediate (extruded) | .0015" | .0065" | -- |
| Intermediate (die cast) | .0015" | .0105" | -- |
| Camshaft and Balance Shaft Gears | | | |
| Inside diameter | 1.1865" | 1.1875" | -- |
| Clearance--gear-to-shaft | .0015" press. | .0000" | -- |
| Backlash | .0030" | .0080" | .0100" |
| Idler Gear | | | |
| Backlash | .0030" | .0080" | .0100" |
| Pre-load--Variation on pull 2 lbs. 11 oz. | 1/2 lb. | 4 lbs. | -- |
| Crankshaft Timing Gear | | | |
| Inside diameter | 4.7490" | 4.7500" | -- |
| Clearance--gear-to-shaft | .001" press. | .001" loose | -- |
| Backlash | .0030" | .0080" | .0100" |
| Blower Drive Gear | | | |
| Backlash | .0030" | .0080" | .0100" |
| Gear-to-hub fit | .0005" press. | .001" loose | -- |
| Support-to-end pl1ate | .0005" press. | 0025" loose | -- |
| Inside diameter (support bushing) | 1.6260" | 1.6265" | -- |
| Hub diameter (at bearing ) | 1.6240" | 1.6250" | -- |
| Hub-to-support bushing clearance | .0010" | .0025" | .0050" |
| Hub-to-cam clearance | .0020" | .0070" | -- |
| End thrust | .0060" | .0140" | -- |
| Cylinder Head | | | |
| Flatness--transverse | -- | -- | .0040" |
| Flatness--longitudinal | -- | -- | .0100" |
| Distance between top deck and fire deck | 3.5560" | 3.5680" | 3.5360" |
| Water nozzles | .0312"recess | Flush | -- |
| Cam follower bores | 1.0620" | 1.0630" | 1.0650" |

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| Exhaust Valve Seat Inserts | | | |
| Seat width--31° (4-valve) | .0468" | .0937" | .0937" |
| Valve seat runout (4-valve) | 3100" | .0020" | .0020" |
| Exhaust Valves | | | |
| Stem diameter (4-valve) | .3100" | .3105" | .3090" |
| Valve head-to-cylinder head: | | | |
| 30° (4-valve) | .023"recess. | .006"protr. | .038"recess. |
| Valve Guides | | | |
| 4-valve (machined guide) | .6900" | .6900" | -- |
| Height above cylinder head: | | | |
| Diameter--inside (4-valve) | .3125" | .3135" | .3140" |
| Clearance--valve-to-guide (4 valve) | .0020" | .0035" | .0050" |
| Valve Bridge Guides | | | |
| Height above cylinder head (4 valve) | 2.0400" | 2.0400" | -- |
| Rocker Arms and Shafts | | | |
| Diameter--rocker shaft | .8735" | .8740" | |
| Diameter--inside (rocker arm bushing) | .8750" | .8760" | -- |
| Clearance--shaft-to-bushing | .0010" | .0025" | .0040" |
| Cam Followers | | | |
| Diameter | 1.0600" | 1.0610" | -- |
| Clearance--follower-to-head | .0010" | .0030" | .0060" |
| Rollers and pins: | | | |
| Clearance--pin-to-bushing | .0013" | .0021" | .010"Horiz. |
| Side clearance--roller-to-follower | .0110" | .0230" | .0230" |

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:
(1) An adequate supply of air compressed to a sufficiently high compression pressure.
(2) The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

## 72.1 Locating a Misfiring Cylinder

(1) Start the engine and run it at part load until it reaches normal operating temperature.
(2) Stop the engine and remove the valve rocker cover.
(3) Check the valve clearance (SM6-5-68.0).
(4) Start the engine. Then hold an injector follower down with a screwdriver (Fig. 1) to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.
(5) If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.
(6) If the cylinder is misfiring, check the following:
(a) Check the injector timing (refer to S1M6-5-68. 0).
(b) Check the compression pressure.
(c) Install a new injector.
(d) If the cylinder still misfires, remove the cam follower (refer to SM6-5-6.0) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

## 72.2 Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:
(1) Start the engine and run it at approximately one half rated load until normal operating temperature is reached.
(2) Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.
(3) Remove the injector and install an adapter and pressure gauge (Fig. 2) from Diagnosis Kit J 9531-01.
(4) Use one of the fuel pipes as a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.
(5) Start the engine and run it at a 600 rpm. Observe and record the compression pressure indicated on the gauge. Do not crank the engine with the starting motor to obtain the compression pressure.
(6) Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above seal level should not be less than the minimum shown in Table 1. In addition, the variation in compression pressures between cylinders must not exceed 25 psi (172 kPa) at 600 rpm.

Low compression pressure may result from any one of several causes:
(1) Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool (Fig. 3). A broken or stuck ring will not have a "spring-like" action.
(2) Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

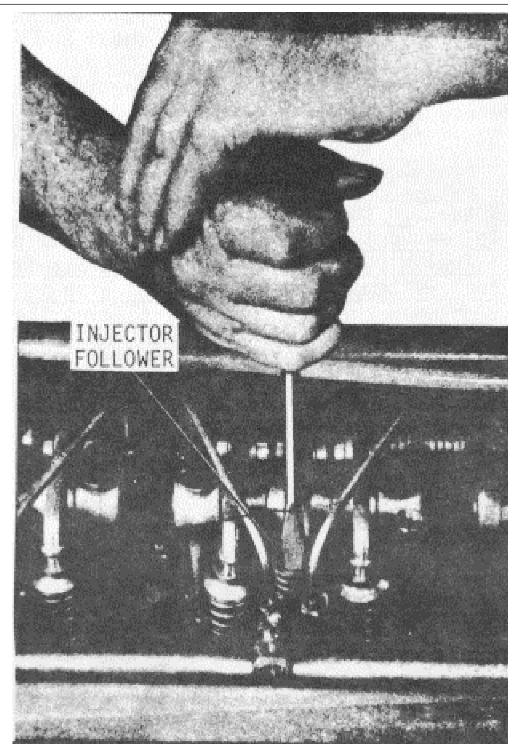



*Fig. 1 Locating a Misfiring Cylinder*

| Minimum Compression Pressure at 600 rpm Engine 71N | | Altitude Above Sea Level | | + Air Density |
|---|---|---|---|---|
| psi | kPa | feet | meters | |
| 515 | 3551 | 0 | 0 | |
| 480 | 3310 | 2,500 | 762 | .0663 |
| 440 | 3034 | 5,000 | 1,524 | .0613 |
| 410 | 2827 | 7,500 | 2,286 | .0567 |
| 380 | 2620 | 10,000 | 3.048 | .0525 |

+ Air density at 500 ft. altitude based on 850F (29.4°C) and 29.38 in Hg (99.49 kPa) wet barometer.

Table 1

72.3 Engine Out of Fuel

The problem in restarting an engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes in- sufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

(1) Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons (38 liters) of fuel.
(2) Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.
(3) Remove and fill the fuel filter shell and element with fuel oil as in Step 2.
(4) Start the engine. Check the filter and strainer for leaks.

Note: In some instances, it may be necessary to remove the valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system, Be sure the fuel pipe is re- tightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

72.4 Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter as outlined in paragraphs 71.10 and 71.11.

72.5 Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the en- trance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder head or end plate gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

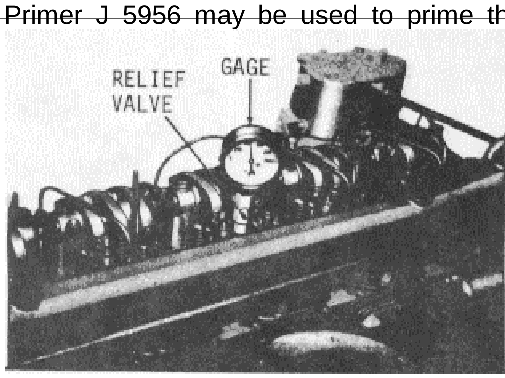



*Fig. 2 Checking Compression Pressure*

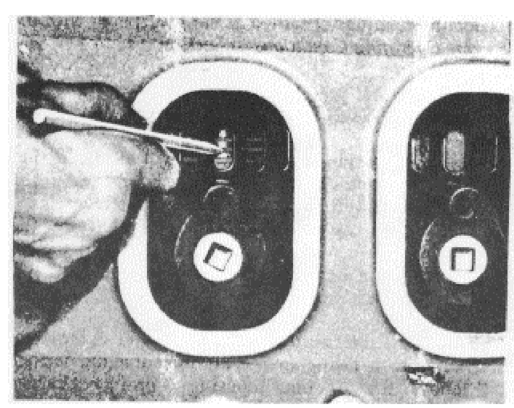


*Fig. 3 Inspecting Piston Rings*

Check the crankcase pressure with a manometer connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the Engine Operating Conditions in SM6-5-7O.0.

Note: The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.

72.6 Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

Check the exhaust back pressure, measured in inches of mercury, with a manometer. Connect the manometer to the exhaust manifold (except on turbocharged engines) by removing the 1/8" pipe plug which is provided for that purpose. If no opening is provided, drill an 11/32" hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8" pipe plug.

Check the readings obtained at various speeds (at no-load) with the Engine Operating Conditions in SM6-5-7n.O.

72.7 Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen. Lack of power or black or gray exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

Check the air box pressure with a manometer connected to an air box drain tube.

Check the readings obtained at various speeds with the Engine Operating Conditions in SM6-5- 70.0.

72.8 Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air in- let system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air in- let housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the Engine Operating Conditions in SM6-5- 70.0.

72.9 Proper Use of Manometer

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus

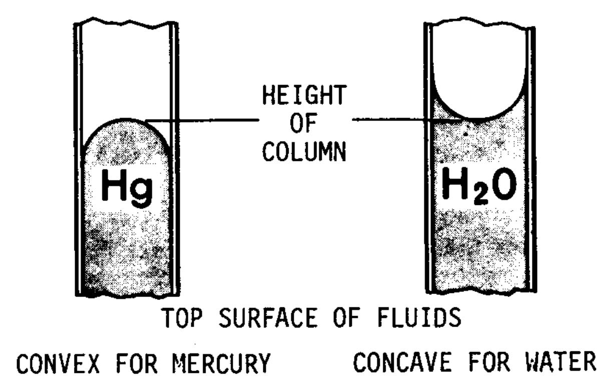



*Fig. 4 Comparison of Column Height for Mercury and Water Manometers*

PRESSURE CONVERSION CHART

| | | | |
|---|---|---|---|
| 1" Water | = | .0735" | Mercury |
| 1" Water | = | .0361 | psi |
| 1" Mercury | = | 13.6000" | Water |
| 1" Mercury | = | .4910 | psi |
| 1psi | = | 27.7000" | Water |
| 1psi | = | 2.0360" | Mercury |
| 1psi | = | 6.895 | kPa |
| 1kPa | = | .145 | psi |

Table 2

(shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 4) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 2 to convert the manometer reading into other units of measurement.

72.10 Fuel Pump

The fuel pump is so constructed as to be inherently trouble free. By using clean, water- free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

However, if the fuel pump fails to function satisfactorily, first check the fuel level in the fuel tank, then make sure the fuel supply valve is open. Also check for external fuel leaks at the fuel line connections and filter gaskets. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through the pump flange drain hole, then crank the engine momentarily and note whether the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the valve and its bore or seat. This permits the fuel to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. Reinstall the valve.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

72.11 Checking Fuel Flow

(1) Disconnect the fuel return hose from the fitting at the fuel tank and hold the open end in a convenient receptacle (Fig. 5).
(2) Start and run the engine at 1200 rpm and measure the fuel flow. Refer to SM6-5-70.0 for the specified quantity per minute.
(3) Immerse the end of the fuel hose in the fuel in the container. Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.
(4) If the fuel flow is insufficient for satisfactory engine performance, then:
    (a) Replace the element in the fuel strainer. Then start the engine and run it at 1200 rpm to check the fuel flow. If the flow is still unsatisfactory, perform Step "b" below:
    (b) Replace the element in the fuel filter. If the flow is still unsatisfactory, do as instructed in Step "c".

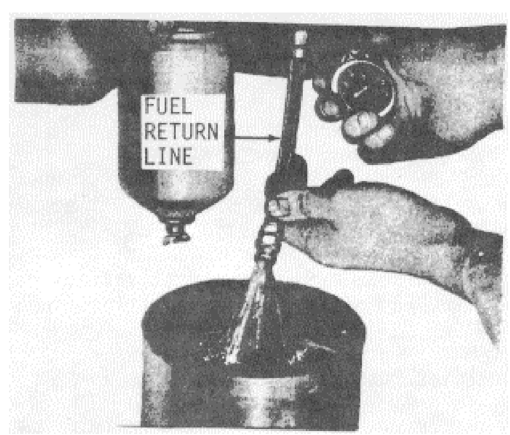



*Fig. 5 Measuring Fuel Flow*

(c) Substitute another fuel pump that is known to be in good condition and again check the fuel flow. When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

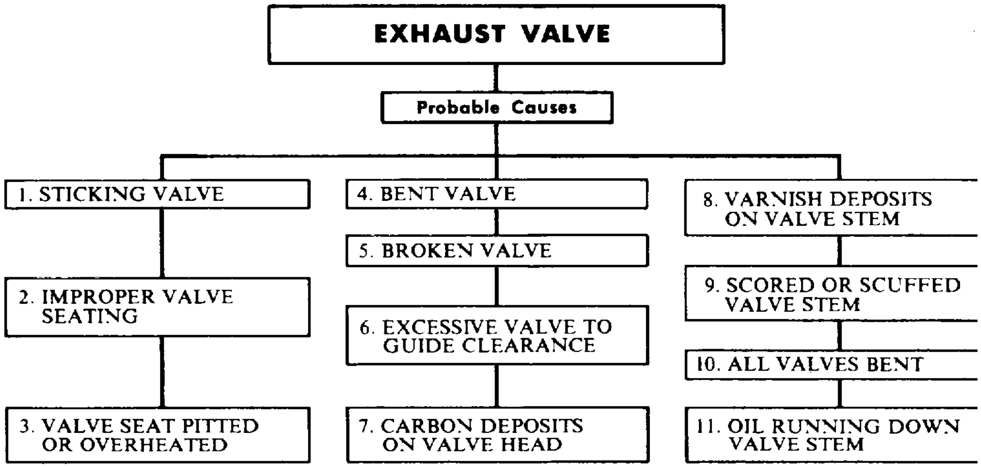
If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault and may be checked as follows:

(1) Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screwdriver. If a cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out.

(2) Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.

(3) Hold a finger over the injector fuel out- let and crank the engine with the starter. A gush of fuel while turning the engine indicates an ample fuel supply; otherwise, the injector filters are clogged and the injector must be removed for service.

## 72.12 Trouble Shooting Charts




### SUGGESTED REMEDY

(1) Check for carbon deposits, a bent valve guide, defective spring or antifreeze (glycol) in the lubricating oil. Replace a bent guide. Clean up and reface the valve. Replace the valve if necessary.

(2) Check for excessive valve-to-guide clearance, bent valve guide or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve if necessary.

(3) Check the operating conditions of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder-face valve if the operating conditions warrant.

(4) Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge or a defective spring. Check the valve guide, insert, cylinder head and piston for damage. Re- place damaged parts.

(5) Check for excessive valve-to-guide clearance, a defective valve spring or etching of the valve stem at the weld. Improper valve clearance is also a cause of this type of failure. Check the guide, insert, cylinder head and piston for damage. Replace damaged parts.

(6) Replace a worn valve guide. Check and replace the valve, if necessary.

(7) Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.

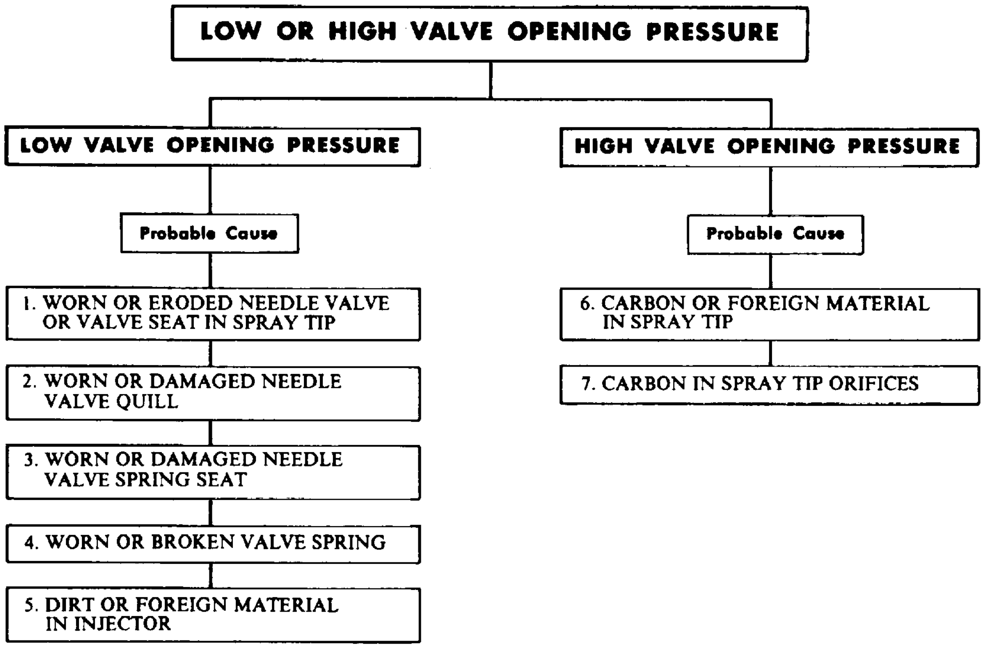
(8) Check for a worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace.

(9) Check for a bent valve stem or guide, metal chips or dirt, or for lack of lubrication. Clean up the valve stem with crocus cloth wet with fuel oil or replace the valve. Replace the guide. When installing a valve, use care in depressing the spring so that the spring cap DOES NOT scrape the valve stem.

(10) Check for a gear train failure or for improper gear train timing.

(11) Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

## FUEL INJECTOR




### SUGGESTED REMEDY

(1) Replace the needle valve and spray tip assembly.

(2) Replace the needle valve and spray tip assembly.

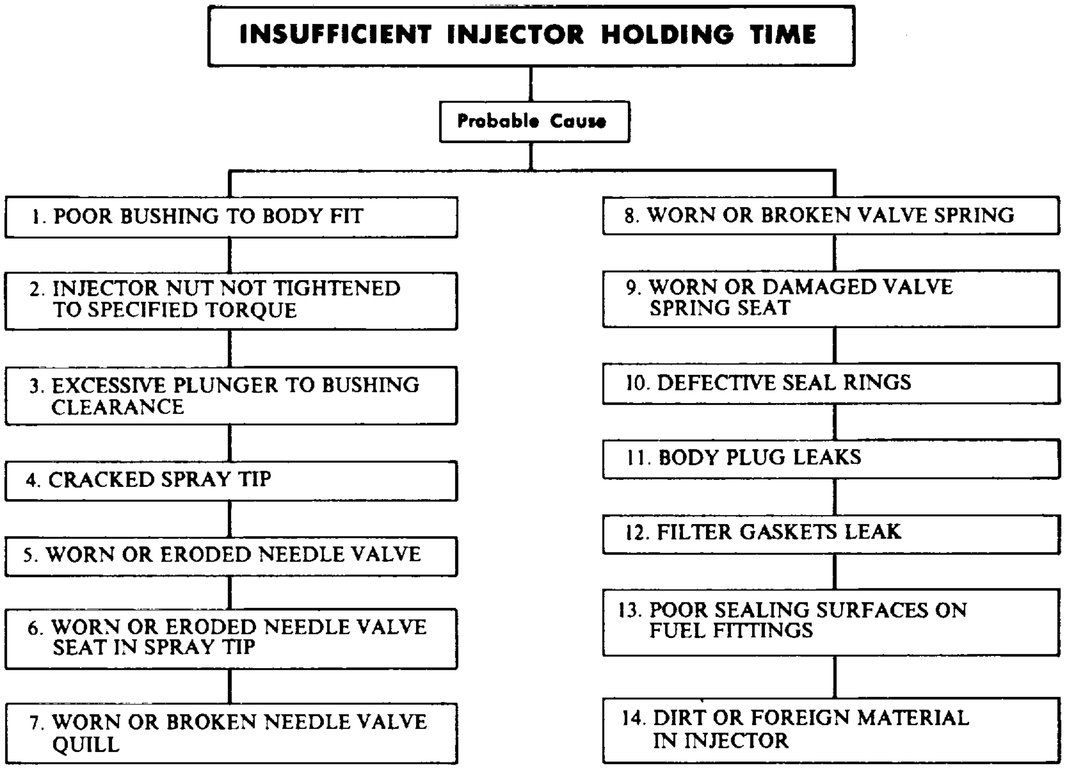
(3) Replace the spring seat.

(4) Replace the valve spring.

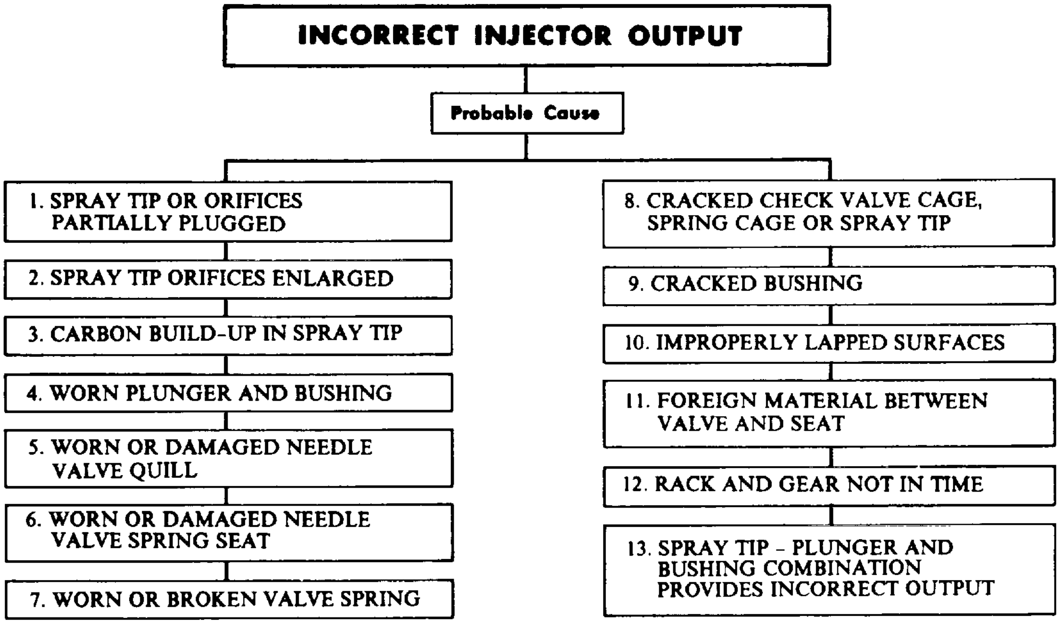
(5) Disassemble the injector and clean all of the parts.

(6) Remove the carbon in the spray tip with tip reamer J 9464-01 which is especially designed and ground for this purpose.

(7) Check the size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.




(1) Lap the injector body.
(2) Tighten the injector nut to 75-85 ft-lbs (102-115 Nm) torque. Do not exceed the specified torque.
(3) Replace the plunger and bushing. (4, 5, 6 and 7) Replace the needle valve and spray tip assembly.
(8) Replace the valve spring.
(9) Replace the valve spring seat.
(10) Replace the seal rings.
(11) Install new body plugs.
(12) Replace the filter cap gaskets and tighten the filter caps to 65-75 ft-lbs (88-102 Nm) torque. (13) Clean up the sealing surfaces or replace the filter caps, if necessary. Replace the filter if a cap is replaced.
(14) Disassemble the injector and clean all of the parts.

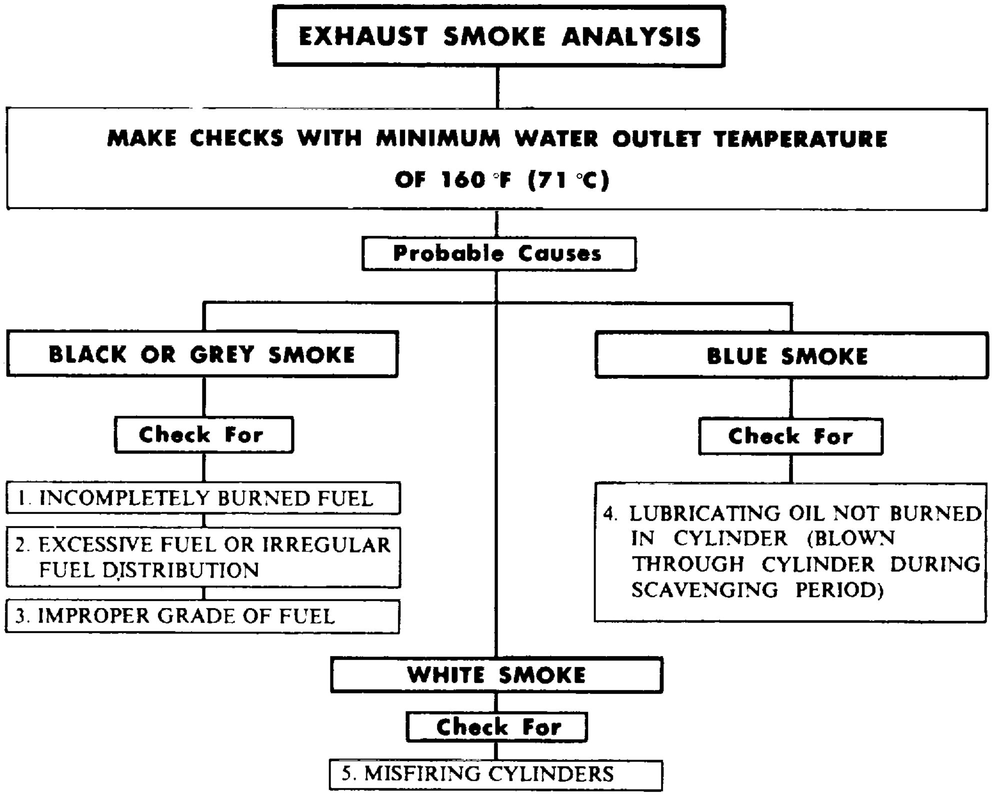



(1) Clean the spray tip as outlined under Clean Injector Parts.
(2) Replace the needle valve and spray tip assembly.
(3) Clean the spray tip with tool J 1243.
(4) After the possibility of an incorrect or faulty spray tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

Note: The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the Fuel Output Check Chart, try changing the spray tip. However, use only a tip specified for the injector being tested. -

(5) Replace the needle valve and spray tip assembly.
(6) Replace the spring seat.
(7) Replace the valve spring.
(8) Replace the cracked parts.
(9) Replace the plunger and bushing assembly.
(10) Lap the sealing surfaces.
(11) Disassemble the injector and clean all of the parts.
(12) Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth on the rack.
(13) Replace the spray tip and the plunger and bushing assembly to provide the correct output

72.13 Trouble Shooting Charts (Engine)




**SUGGESTED REMEDY**

(1) High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in Incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

(2) If the engine is equipped with a throttle delay, check for the proper setting, leaky check valve and restricted filling of the piston cavity with oil from the reservoir.

Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune-up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up.

Avoid lugging the engine as this will cause incomplete combustion.

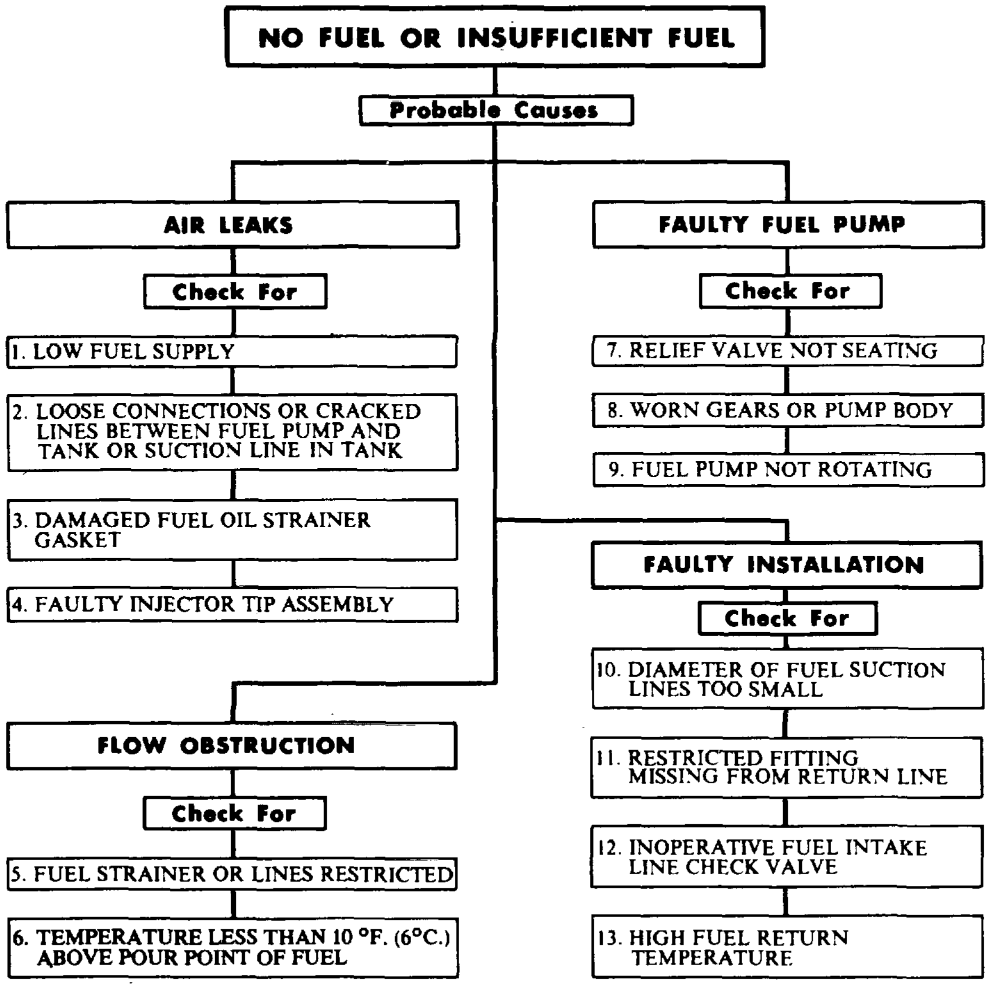
(3) Check for use of an improper grade of fuel. Refer to Fuel Oil Specifications in Operators Manual.

(4) Check for internal lubricating oil leaks and refer to the High Lubricating Oil Consumption chart.

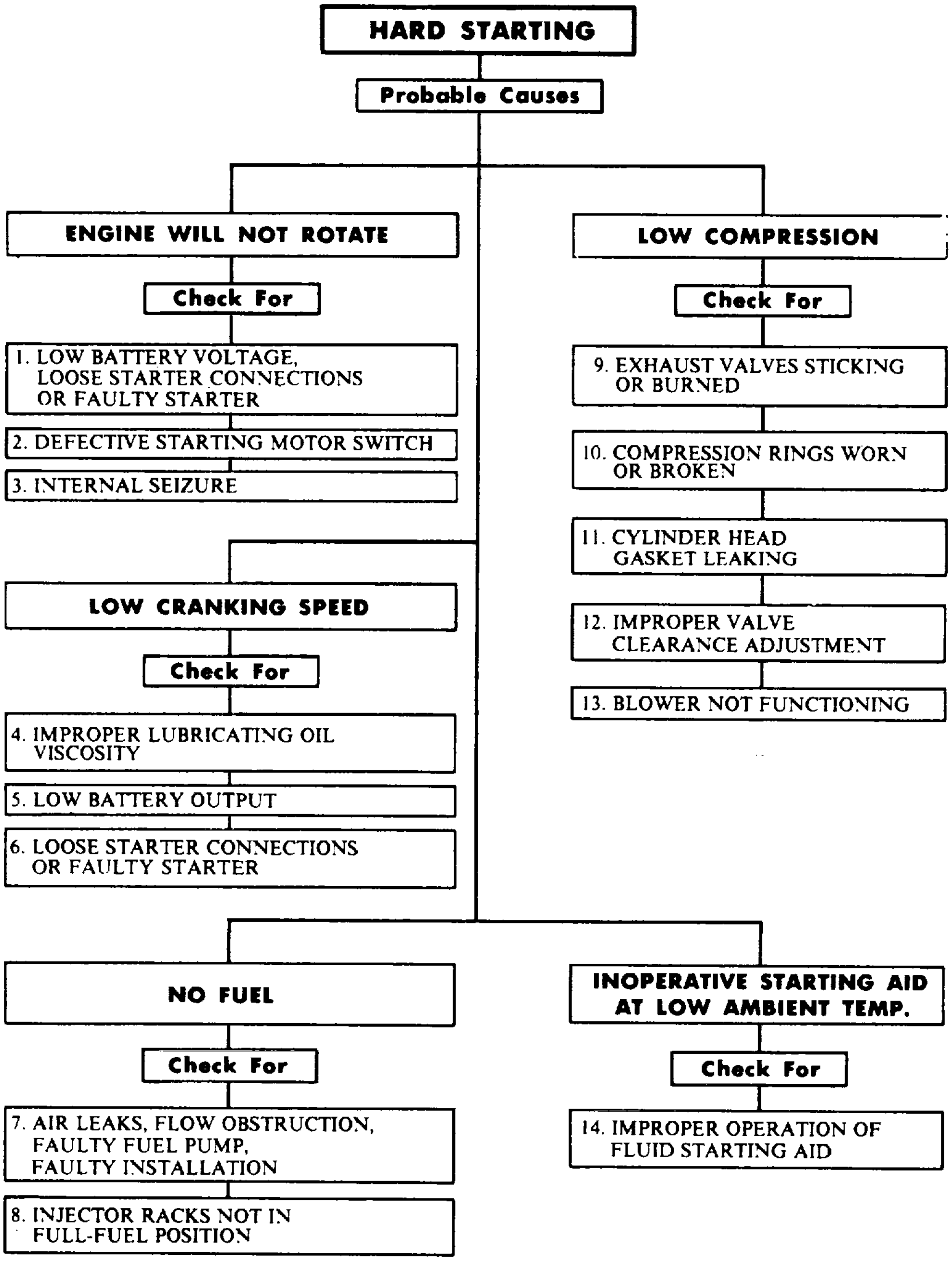
(5) Check for faulty injectors and replace as necessary.

Check for low compression and consult the Hard Starting chart.

The use of low cetane fuel will cause this condition. Refer to Fuel Oil Specifications in Operators Manual.




(1) The fuel tank should be filled above the level of the fuel suction tube.
(2) Perform a Fuel Flow Test and if air is present, tighten loose connections and replace cracked
(3) Perform a Fuel Flow Test and, if air is present, replace the fuel strainer gasket when changing the strainer element.
(4) Perform a Fuel Flow Test and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.
(5) Perform a Fuel Flow Test and replace the fuel strainer and filter elements and the fuel lines, if necessary.
(6) Consult the Fuel Oil Specifications for the recommended grade of fuel.
(7) Perform a Fuel Flow Test and, if inadequate, clean and inspect the valve seat assembly.
(8) Replace the gear and shaft assembly or the pump body.
(9) Check the condition of the fuel pump drive and blower drive and replace defective parts.
(10) Replace with larger tank-to-engine fuel lines.
(11) Install a restricted fitting in the return line.
(12) Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Re- position the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.
(13) Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150°F (660C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.


HARD STARTING
Probable Causes
ENGINE WILL NOT ROTATE
Check For
1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE
LOW CRANKING SPEED
Check For
4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER
LOW COMPRESSION
Check For
9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
NO FUEL
Check For
7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION
INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.
Check For
14. IMPROPER OPERATION OF FLUID STARTING AID

## SUGGESTED REMEDY

(1) Refer to Items 2, 3 and 5 and perform the operations listed.

(2) Replace the starting motor switch.

(3) Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.

(4) Refer to Lubricating Oil Specifications in Operators Manual for the recommended grade of oil.

(5) Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge. Replace terminal that are damaged or corroded. At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.

(6) Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.

(7) To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the No Fuel or Insufficient Fuel chart.

(8) Check for bind in the governor-to-injector linkage. Readjust the governor and injector controls if necessary.

(9) Remove the cylinder head and recondition the exhaust valves.

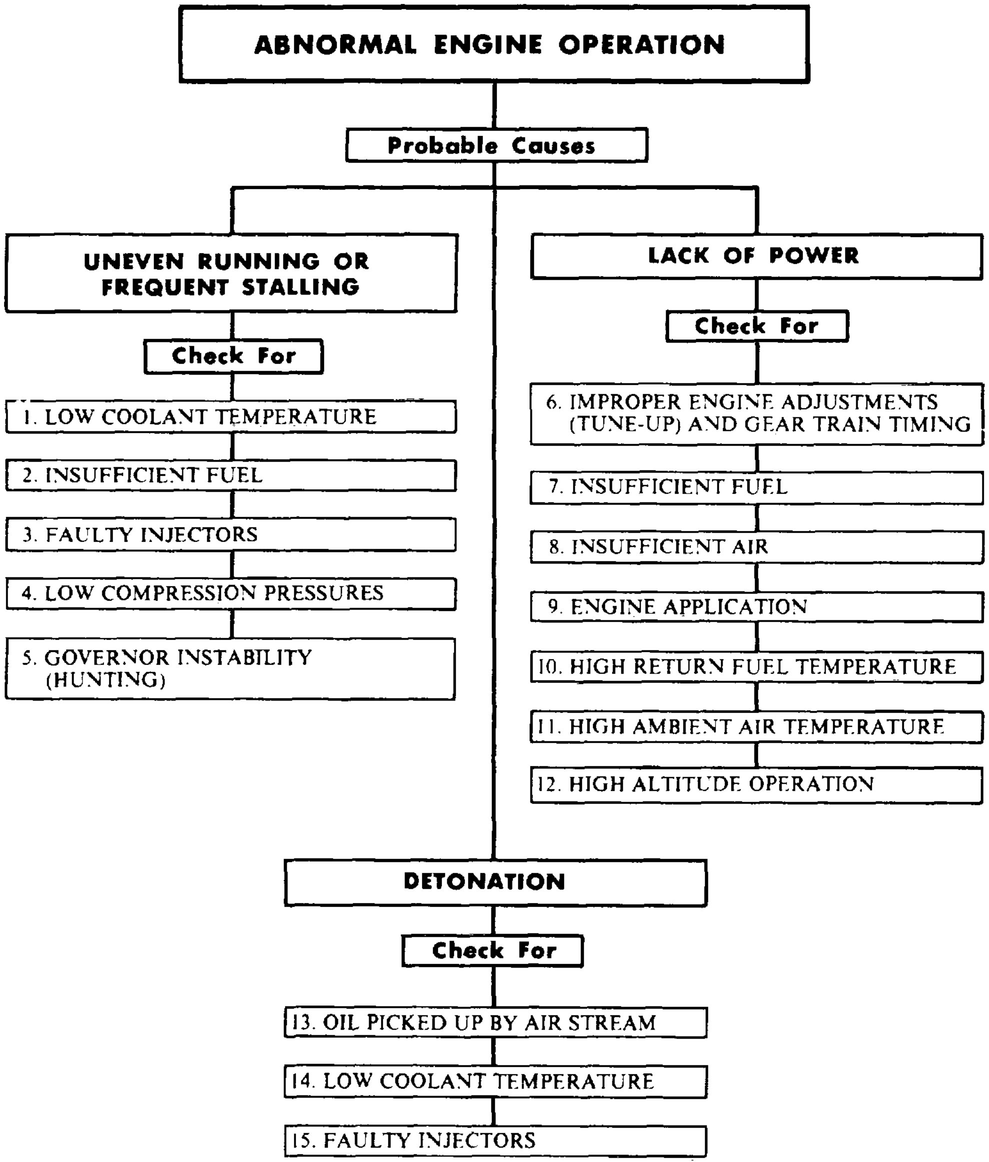
(10) Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.

(11) To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is dam- aged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.

(12) Adjust the exhaust valve clearance.

(13) Remove the flywheel housing cover at the blower drive support. Then remove the snap ring and withdraw the blower drive shaft from the blower. Inspect the blower drive shaft and drive coupling. Replace the damaged parts. Bar the engine over. If the blower does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If visual distress is noted, remove the blower (refer to SM6-5-44.0).

(14) Operate the starting aid according to the instructions under Cold Weather Starting Aids.


ABNORMAL ENGINE OPERATION
Probable Causes
UNEVEN RUNNING OR FREQUENT STALLING
Check For
1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)
LACK OF POWER
Check For
6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION
DETONATION
Check For
13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

## SUGGESTED REMEDY

(1) Check the engine coolant temperature gauge and, if the temperature does not reach 160-1850F (71- 850C) while the engine is operating, consult the Abnormal Engine Coolant Temperature chart.

(2) Check engine fuel spill back and if the return is less than specified, consult the No Fuel or In- sufficient Fuel chart.

(3) Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

(4) Check the compression pressures within the cylinders and consult the Hard Starting chart if compression pressures are low.

(5) Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

(6) If the engine is equipped with a throttle delay, check for the proper setting, binding or burrs on the piston or bracket, and a plugged discharge orifice.

Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

(7) Perform a Fuel Flow Test and, if less than the specified fuel is returning to the fuel tank, consult the No Fuel or Insufficient Fuel chart.

(8) Check for damaged or dirty air cleaners, and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the Hard Starting chart).

(9) Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

(10) Refer to Item 13 on Chart 5.

(11) Check the ambient air temperature. A power de-crease of .15 to .50 horsepower per cylinder, depending upon injector size for each 10°F (6°C) temperature rise above 900F (320C) will occur. Relocate the engine air intake to provide a cooler source of air.

(12) Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

(13) Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

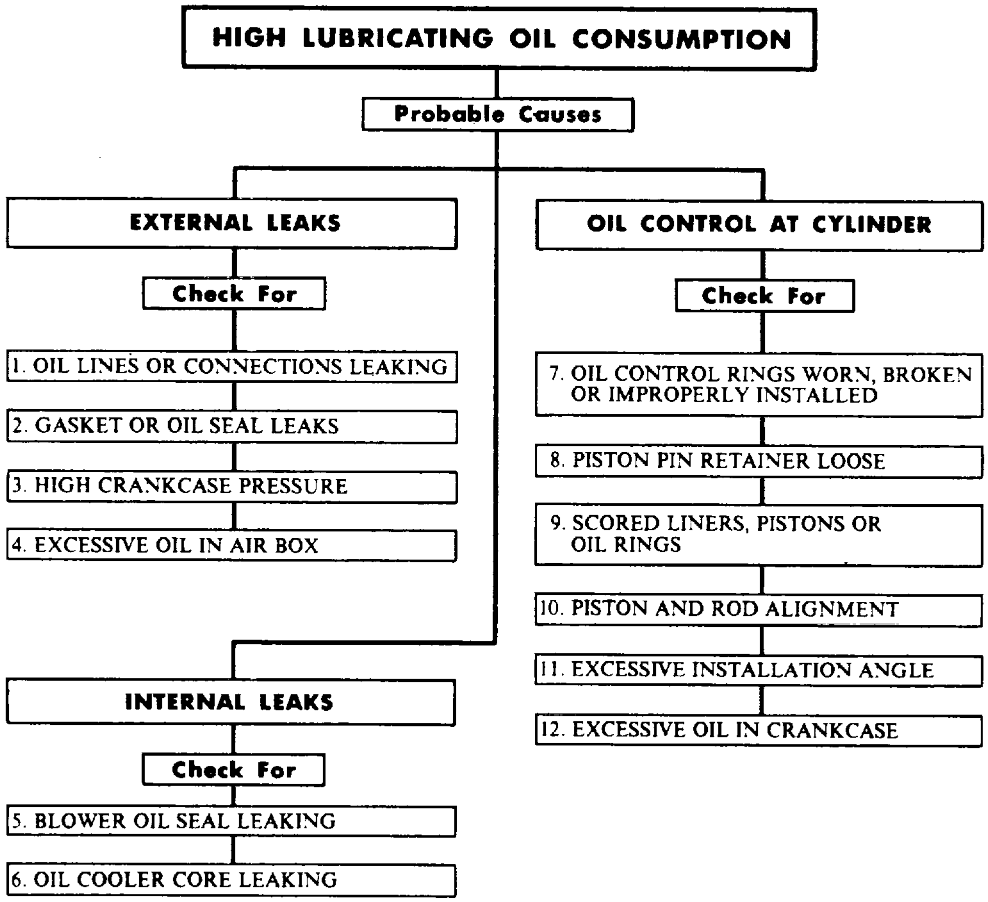
Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the blower oil seals by removing the air - inlet housing and watching through the blower in- 6 let for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Check for a defective blower-to-block gasket. Replace the gasket, if necessary.

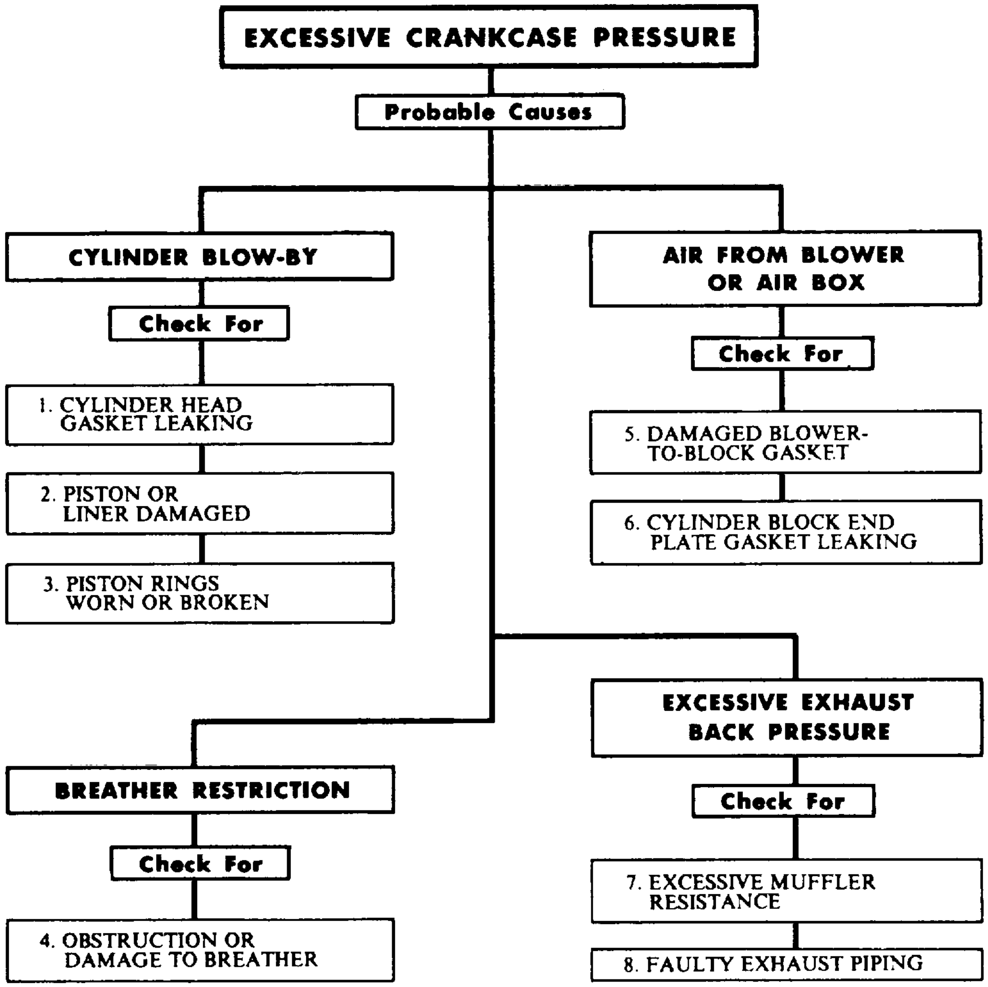
(14) Refer to Item 1 of this chart.

(15) Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.




## SUGGESTED REMEDY

(1) Tighten connections or replace defective parts.
(2) Replace defective gaskets or oil seals.
(3) Refer to the Excessive Crankcase Pressure chart.
(4) Refer to the Abnormal Engine Operation chart.
(5) Remove the air inlet housing and inspect the blower end plates while the engine is operating. If oil is seen on the end plate radiating away from the oil seal, overhaul the blower.
(6) Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.
(7) Replace the oil control rings.
(8) Replace the piston pin retainer and defective parts.
(9) Remove and replace the defective parts.
(10) Check the crankshaft thrust washers for wear. Replace worn and defective parts.
(11) Decrease the installation angle.
(12) Fill the crankcase to the proper level only.




## SUGGESTED REMEDY

(1) Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.
(2) Inspect the piston and liner and replace damaged parts.
(3) Install new piston rings.
(4) Clean and repair or replace the breather assembly.
(5) Replace the blower-to-block gasket.
(6) Replace the end plate gasket.
(7) Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.
(8) Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

## LOW OIL PRESSURE

**MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160 °F (71 °C)**

**Probable Causes**

### LUBRICATING OIL

**Check For**

1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY

### POOR CIRCULATION

**Check For**

3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING

### PRESSURE GAGE

**Check For**

8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY

### OIL PUMP

**Check For**

12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. FLANGE LEAK (PRESSURE SIDE)

**SUGGESTED REMEDY**

(1) Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

(2) Consult the Lubricating Oil Specifications in Operators Manual for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution. Refer to Fuel Leak Detection in SM6-5-72.0.

(3) A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

(4) Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

(5) Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

(6) Change the bearings. Consult the Lubricating Oil Specifications in Operators Manual for the proper grade and viscosity of oil. Change the oil filters.

(7) Replace missing plugs.

(8) Check the oil pressure with a reliable gauge and replace the gauge if found faulty.

(9) Remove and clean the gauge line; replace it, if necessary.

(10) Remove and clean the gauge orifice.

(11) Repair or replace defective electrical equipment.

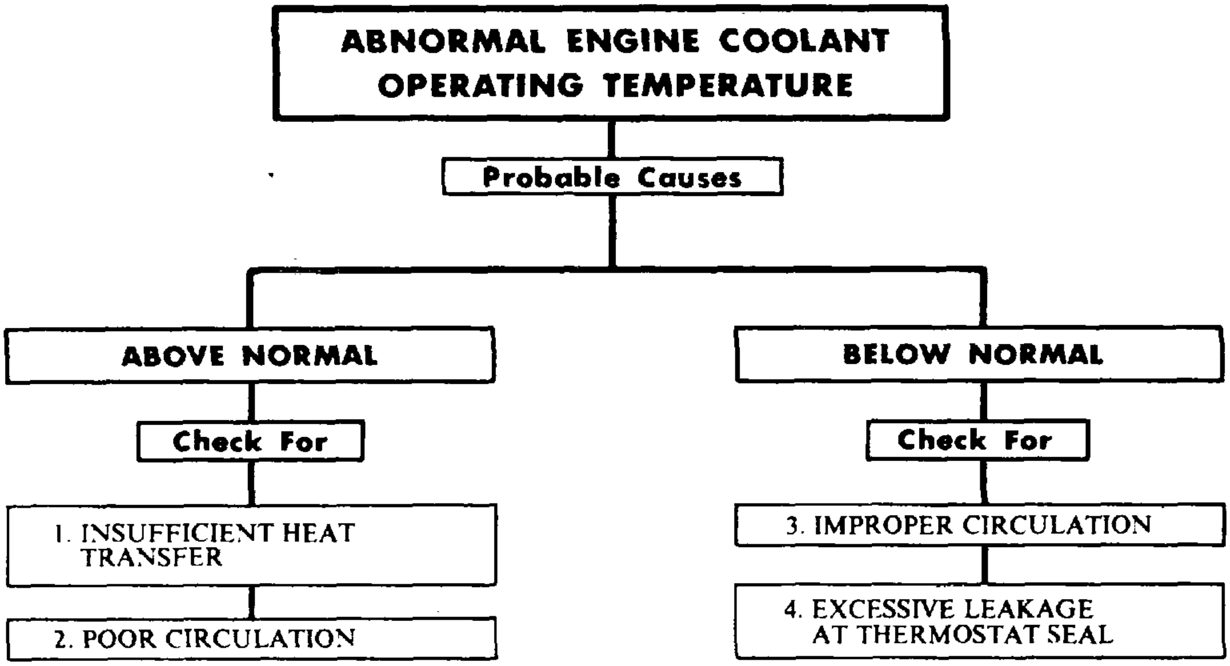
(12) Remove and clean the oil pan and oil intake screen. Consult the Lubricating Oil Specifications in Operators Manual for the proper grade and viscosity of oil. Change the oil filters.

(13) Remove and inspect the valve, valve bore and spring. Replace faulty parts.

(14) Disassemble the piping and install new gaskets.

(15) Remove the pump. Clean and replace defective parts.

(16) Remove the flange and replace the gasket.




**SUGGESTED REMEDY**

(1) Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow. Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature-controlled fan or inoperative shutters.

(2) Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate sup- ply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets re- placed if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

(3) The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

(4) Excessive leakage of coolant past the thermostat seal is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal.

| TOOL NAME | TOOL NO |
|---|---|
| Cylinder Checking Gauge and Master Ring Set | J 9353 |
| Cylinder Hone Set (2-1/2" to 5-3/4") | J 5902-01 |
| Dial Bore Gauge Master Setting Fixture | J 23059-01 |
| Dial Indicator Set | J 22273 |
| Diesel Engine Parts Dolly | J 6387 |
| Engine Overhaul Stand | J 6837-01 |
| Engine Overhaul Stand Adaptor Plate | J 8196 |
| Special Plug Remover | J 21996-01 |
| | |
| Cam Follower Service Fixture | J 5840-01 |
| Cylinder Head Holding Plate Set | J 3087-01 |
| Feeler Gauge Set (.0015" to .015") | J 3172 |
| Feeler Stock (.0015") | J 23185 |
| Guide Studs | J 9665 |
| Push Rod Remover (set of 3) | J 3092-01 |
| Slide Hammer | J 2619-01 |
| Socket (Fuel Line Nut) | J 8932-01 |
| Spring Tester | J 22738-02 |
| Valve Bridge Holding Fixture | J 21772 |
| Valve Bridge Guide Remover (Broken) | J 7453 |
| Valve Bridge Guide Remover Set (Press Fit) | J 7091-01 |
| Valve Bridge Guide Installer (Press Fit) | J 7482 |
| Valve Bridge Guide Remover and Installer (Threaded - 4-Valve Head | J 6846 |
| Valve Guide Cleaner | J 5437 |
| Valve Guide Installer (45° 4-Valve Head) | J 9729 |
| Valve Guide Installer (Machined 4-Valve Head) | J 21520 |
| Valve Guide Remover (4-Valve Head) | J 6569 |
| Valve Seat Dial Gauge | J 8165-2 |
| Valve Seat Grinder | J 8165-1 |
| Valve Seat Grinder Adaptor Set (4-Valve Head) | J 6390-02 |
| Valve Seat Insert Installer (4-Valve Head) | J 24357 |
| Valve Seat Insert Remover (45° 4-Valve Head) | J 3091-02 |
| Valve Seat Insert Remover (4-Valve Head) | J 6567-02 |
| Valve Spring Checking Gauge | J 25076-01 |
| Valve Spring Compressor | J 7455 |
| | |
| Crankshaft Front Oil Seal Installer | J 9783 |
| Crankshaft Oil Seal Expander | J 22425 |
| Crankshaft Pulley and Rubber Mounted Balancer Puller | J 5356 |
| Crankshaft Rear Oil Seal Installer | J 9727 |
| Crankshaft Rear Oil Seal Expander (Oversize Seal) | J 4195-01 |
| Crankshaft Rear Oil Seal Service Sleeve Installer | J 4194-01 |
| Dial Indicator Set | J 5959-01 |
| Driver Handle | J 3154-1 |
| Driver Handle | J 8092 |
| Micrometer Ball Attachment | J 4757 |
| Universal Bar Type Puller | J 24420 |
| | |
| Flywheel Lifting Fixture | J 25026 |
| Flywheel Lifting Tool | J 6361-01 |
| Oil Seal Removing and Replacing Tool Set | J 3154-04 |
| Slide Hammer Set | J 5901-01 |
| | |
| Crankshaft Oil Seal Expander | J 22425 |
| Crankshaft Oil Seal Expander (0.S. Seal) | J 4195-01 |
| Driver Handle | J 8092 |
| Flywheel Housing Aligning Studs (Set of 4) | J 1927-0 |
| Flywheel Housing Concentricity Gauge Set | J 9737-01 |

| TOOL NAME | TOOL NO. |
|---|---|
| **PISTON, CONNECTING ROD AND CYLINDER LINER** | |
| Connecting Rod Bolt Hole Reamer | J 28460 |
| Connecting Rod Bushing Reamer Set | J 1686-03 |
| Connecting Rod Holding Fixture | J 7632 |
| Connecting Rod Spray Nozzle Remover | J 8995 |
| Cylinder Checking Gauge and Master Ring Set | J 9353 |
| Cylinder Hone Set (2-1/2" to 5-3/4" range) | J 5902-01 |
| Cylinder Liner Hold-Down Clamp | J 21793-01 |
| Cylinder Liner Remover Set | J 1918-02 |
| Dial Bore Gauge Setting Fixture | J 23059-01 |
| Dial Indicator Set | J 22273 |
| Feeler Gauge Set | J 3172 |
| Micrometer Ball Attachment | J 4757 |
| Piston and Connecting Rod Bushing Installer and Remover Set | J 1513-02 |
| Piston Bushing Reamer Set | J 3071-01 |
| Piston Bushing Reaming Fixture | J 5273 |
| Piston Pin Alignment Tool | J 24285 |
| Piston Pin Retainer Installer (Trunk-Type Piston) | J 24107-01 |
| Piston Pin Retainer Leak Detector | J 23987-01 |
| Piston Ring Compressor | J 3272-03 |
| Piston Ring Remover and Installer | J 8128 |
| Piston to Liner Feeler Gauge Set | J 5438-01 |
| | |
| Accessory Drive Hub Oil Seal Aligning Tool | J 21166 |
| Blower )rive Cam Installer | J 1471 |
| Camshaft Gear Puller | J 1902-01 |
| Camshaft Gear Puller Adaptor Plate Set | J 6202-01 |
| Camshaft and Oil Pump Gear Replacer | J 1903 |
| Dial Indicator and Attachment Set | J 5959-01 |
| Slide Hammer Set | J 6471-02 |
| Spring Scale | J 8129 |
| | |
| Auxiliary Injector Tester ("N" injectors) | J 22640 |
| Fuel Pipe Socket | J 8932-01 |
| Fuel System Primer | J 5956 |
| Injector Body Reamer | J 21089 |
| Injector Body Thread Reconditioning Set | J 22690 |
| Injector Bushing Inspectalite | J 21471 |
| Injector Calibrator | J 22410 |
| Injector Service Set ("N" injectors): | J 23435-02 |
| Fuel Hole Brush | J 8152 |
| Injector Nut Socket Wrench | J 4983-01 |
| Injector Nut and Seat Carbon Remover Set | J 9418 |
| Injector Spray Tip Driver | J 1291-02 |
| Pin Vise | J 4298-1 |
| Rack Hole Brush | J 8150 |
| Spray Tip Carbon Remover | J 24838 |
| Spray Tip Wire (.0055") | J 21460-01 |
| Spray Tip Wire (.006") | J 21461-01 |
| Wire Sharpening Stone | J 8170 |
| +Injector Test Oil | J 26400 |
| Injector Tester | J 9787 |
| Injector Tip Concentricity Gauge | J 29584 |
| Injector Vise and Rack Freeness Tester | J 22396 |
| Injector Vise Jaws (Offset Body) | J 8912 |
| Injector Vise Jaws (Standard Body) | J 1261 |
| Lapping Block Set | J 22090 |
| Methyl Ethyl Ketone Cleaning Fluid | J 8257-01 |
| Polishing Compound ("N" injectors) | J 23038 |
| Polishing Stick Set ("N" injectors) | J 22964 |
| Spray Tip Flow Gauge | J 25600 |
| Spray Tip Gauge ("N" injectors) | J 9462-02 |
| Spring Tester | J 22738-02 |
| Wire Brush (brass) | J 7944 |

| TOOL NAME | TOOL NO. |
|---|---|
| **INJECTOR TUBE** | |
| Cylinder Head Holding Plates | J 3087-01 |
| Injector Tube Service Tool Set | J 22525 |
| Injector Tube Service Tool Set (for power equipment) | J 22515 |
| Injector Tube Swaging Tool | J 28611 |
| **FUEL PUMP** | |
| Fuel Pump Tool Set | J 1508-03 |
| Fuel Pump Wrench | J 4242 |
| Fuel System Primer | J 5956 |
| **MECHANICAL GOVERNOR** | |
| Adjustable Spanner Wrench | J 5345-5 |
| Governor Cover Bearing Installer | J 21068 |
| Governor Cover Bearing Remover/Installer | J 21967-01 |
| High-Speed Spring Retainer Nut Wrench | J 1652-01 |
| Variable Speed Spring Housing Bearing Installer Set | J 9196 |
| **BLOWER** | |
| Blower Clearance Feeler Set | J 1698-02 |
| Blower Rotor Shaft Remover and Installer Set | J 4254 |
| Blower Service Tool Set | J 6270-05 |
| Slide Hammer Set | J 6471-02 |
| Snap Ring Pliers (external type) | J 4880 |
| **SERVICE TOOLS** | |
| Spring Tester | J 9666 |
| Strap Wrench (spin-on filter) | J 24783 |
| Universal Puller (range 4" diam.) | J 24420 |
| Universal Puller (range 13" diam.) | J 8190 |
| Thermostat Seal Replacer | J 8550 |
| Water Pump and Fuel Pump Wrench | J 4242 |
| Water Pump Drive Coupling Remover | J 1930 |
| Water Pump Impeller Installer (.031" - .033") | J 22437 |
| Water Pump Impeller Installer (.052" - .072") | J 21971 |
| Water Pump Impeller Installer (.099" - .101") | J 9303 |
| Slide Hammer | J 2619-5 |
| Tachometer Alignment Tool Set | J 23068 |
| Tachometer Drive Shaft Remover | J 5901-3 |

## 74.1 General Information

## 74.2 Tools, Equipment

(1) Equipment Needed. Proper equipment should be available before overhaul is started a suitable hoist, proper hand tools, receptacles for small parts, an arbor press, and a converter teardown stand. Although convenient, the latter two are not necessary.

(2) Special Tools. Paragraph 74.6 has a chart listing special tools and their part numbers, their use, and references to the figures and paragraphs where they are used. Special tools for the Allison torque converter are available through the Kent-Moore Tool Division, 1501 5S. Jackson St., Jackson, Michigan 49203. Refer to Fig. 1 for these tools. Refer to Fig. 2 through 5 for other special tools that can be fabricated locally.

## 74.3 Parts Care

(1) Handling. Handle the converter parts with care. Nicks, scratches or dents caused by careless handling of parts can cause subsequent converter failure.

(2) New Parts Needed. Replace all gaskets, worn seal rinqs, and cotter pins. If the converter has been subjected to excessive heat, replace all springs and rubber seals. Handle rubber and metal seal rinqs with care to prevent damage.

## 74.4 Cleaning, Inspection

(1) Dirt, Abrasives Harmful. Whenever the converter contains dirt or other abrasive matter, unnecessary wear will result. Inspect all parts for abrasive material any time the converter is disassembled. Metallic contamination of oil is evidence of the failure of some part in either the converter (or the transmission). When metal particles are found the converter (and transmission) must be thoroughly cleaned. All oil lines and cooler passages should be cleaned.

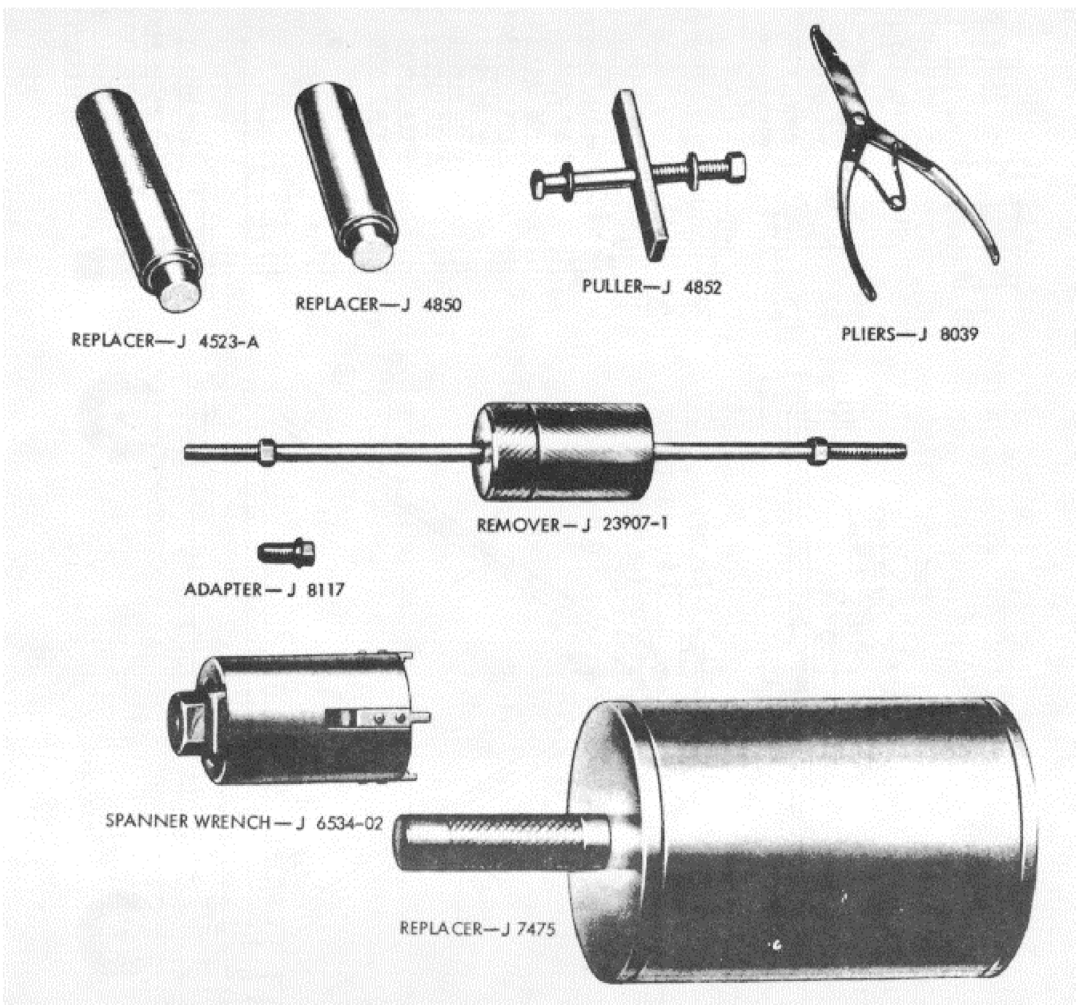



*Fig. 1 Special Tools For Torqmatic Converter Overhaul*

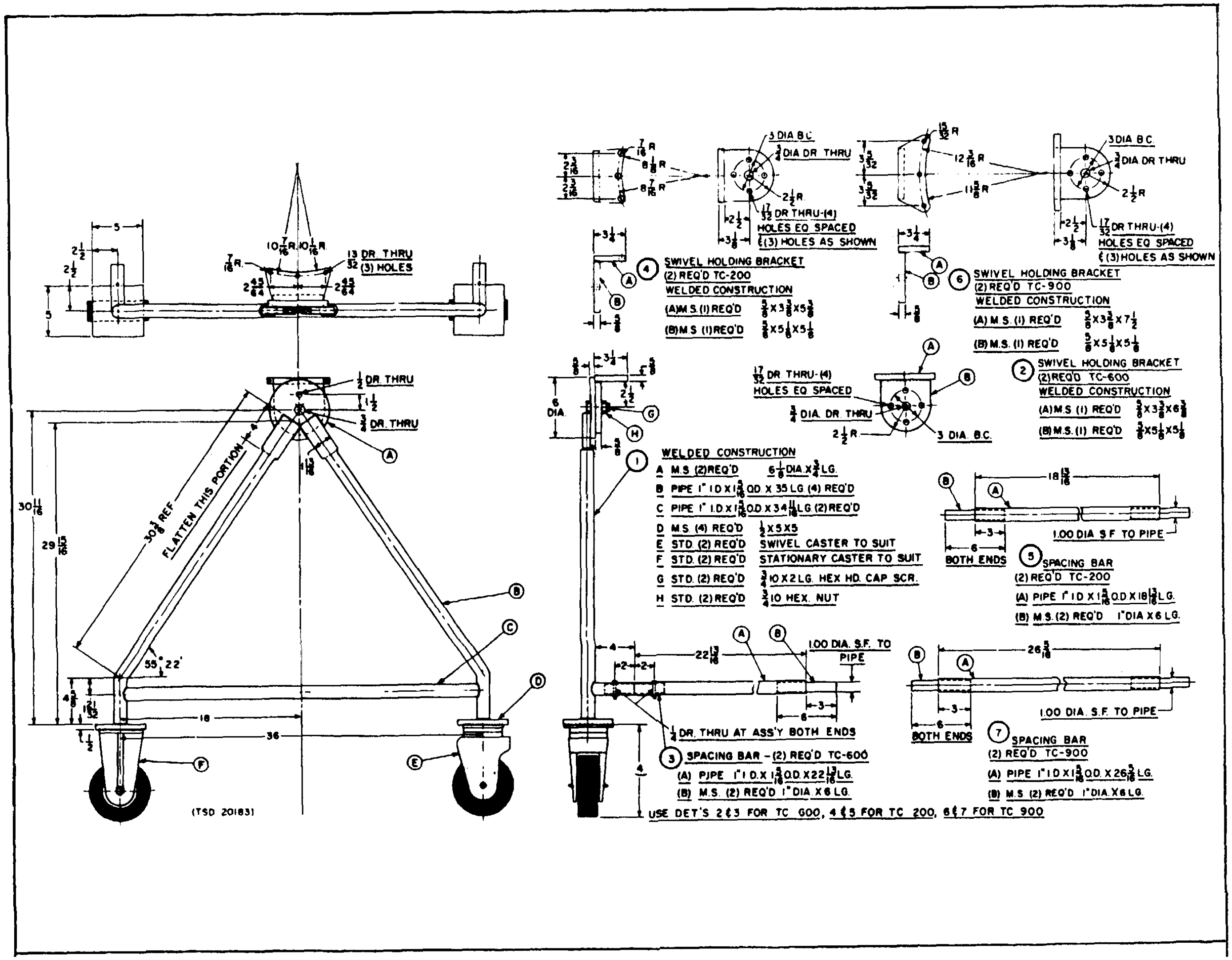



*Fig. 2 Special Tool - Converter Overhaul Stand*

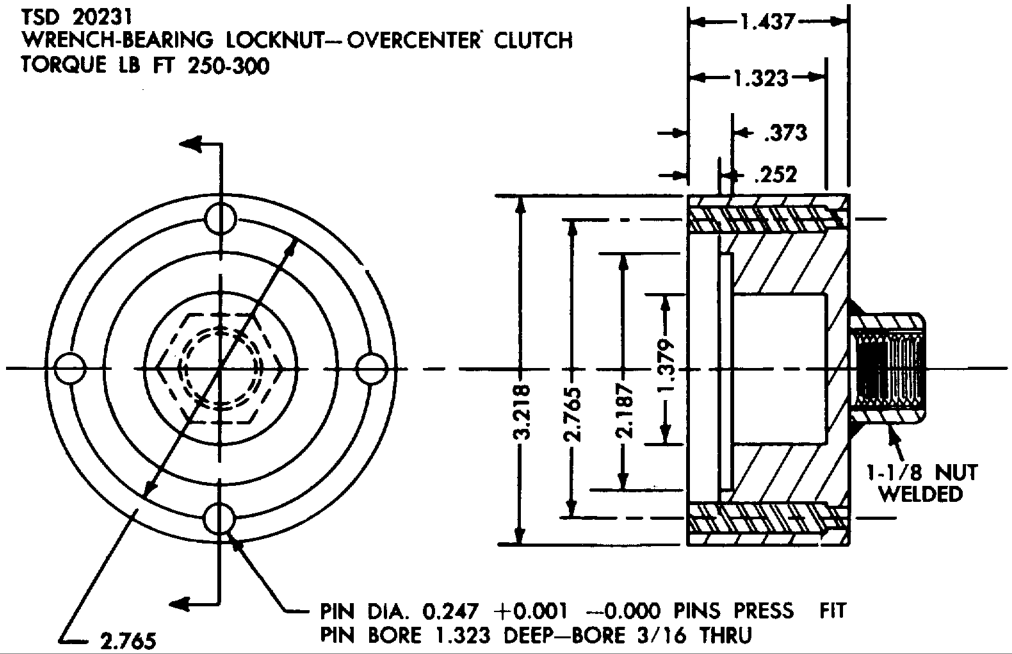



*Fig. 3*
*Special Tool - Spanner Wrench For Manual Overcenter, Input Disconnect Clutch Locknut*

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(2) Cleaning Parts
- (a) All metallic parts except bearings should be cleaned thoroughly with dry-cleaning solvent, volatile mineral spirits, paint thinner, or by the steam-cleaning method.
- (b) Parts should be dried with compressed air. Steam-cleaned parts should be oiled immediately after drying.
- (c) Clean oil passages by working a piece of wire back and forth through the passages and flushing them with cleaning solvent or paint thinner. Dry the passages with compressed air.
- (d) Examine parts, especially oil passages, after cleaning to make certain they are entirely clean. Reclean them if necessary.

(3) Cleaning Bearings
- (a) Thoroughly wash bearings that have been in service in dry-cleaning solvent, volatile mineral spirits, or paint thinner.
- (b) If the bearings are particularly dirty or filled with hardened grease, soak them in solvent before trying to clean them.
- (c) Before inspection, oil bearings with the same type of oil that will be used in the transmission.

Note: <u>Never dry bearings with compressed air. Do not spin bearings while they are not lubricated.</u>

(4) Keeping Bearings Clean. Since dirt or grit in ball bearings is usually responsible for bearing failures, it Is important to keep bearings clean during installation and removal. Observance of the following rules will do much to insure maximum bearing life.
- (a) Do not remove the wrapper from new bearings until ready to install them.
- (b) Do not remove the grease in which new bearings are packed.
- (c) Do not lay bearings on a dirty bench; place them on clean paper.

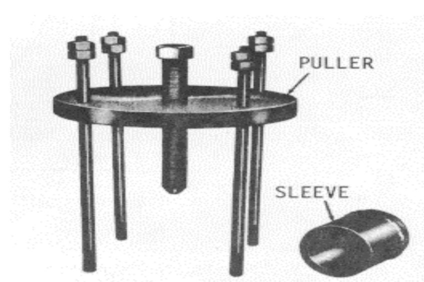



*Fig. 4*
*Special Tool - Puller And Sleeve For Converter Pump Bearing*

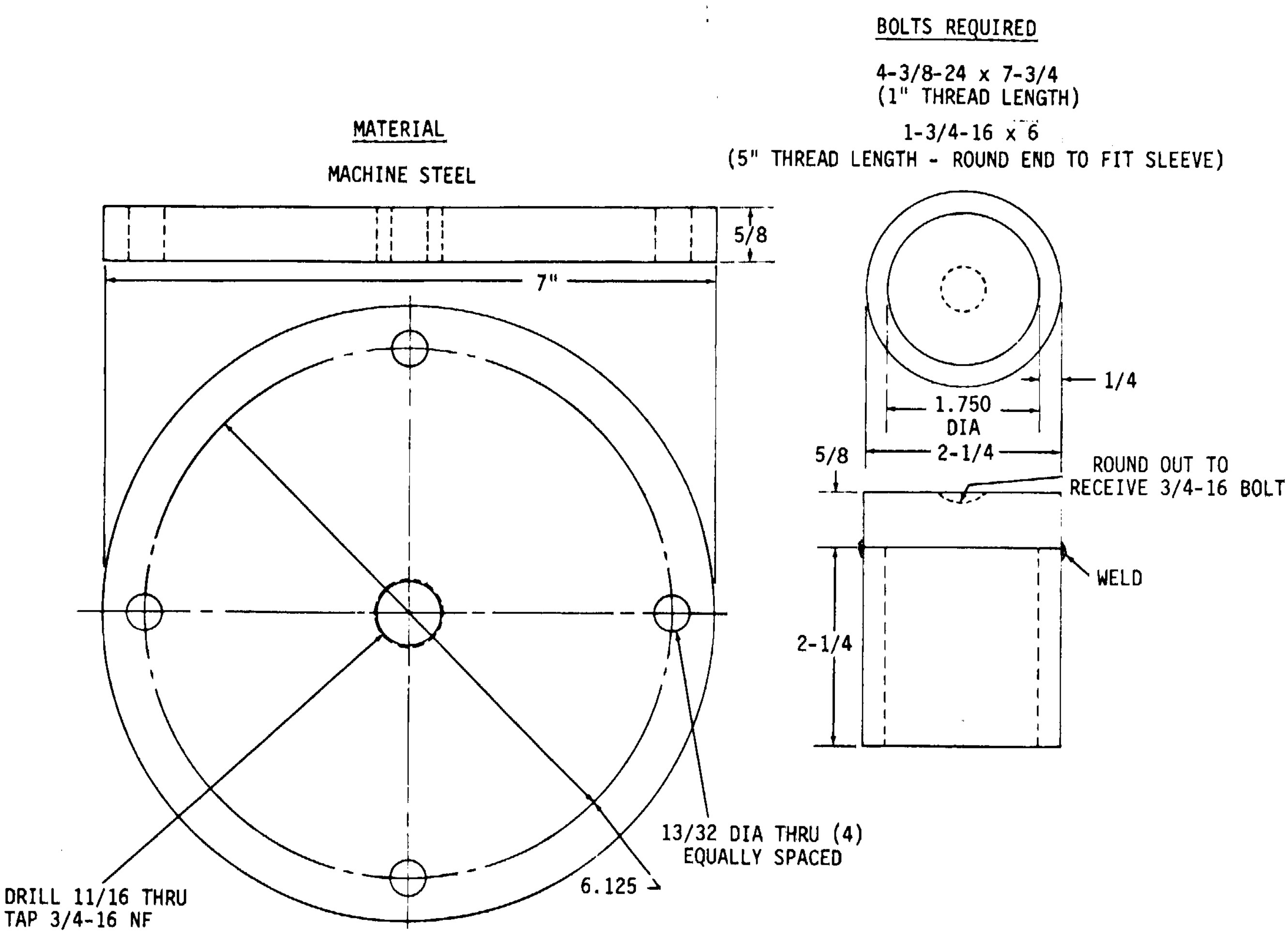



*Fig. 5*
*Special Tool-Puller And Sleeve For Converter Pump Bearing-Sketch*

(d) If assembly is not to be completed at once, wrap or cover the exposed bearings with clean paper or cloth to keep out dust.

(5) Inspecting Case Parts, Machined Surfaces

(a) Inspect bores for wear, grooves, dirt and scratches. Remove all scratches and burrs with crocus cloth. Remove foreign matter. Replace parts that are deeply grooved or scratched.

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.
Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compress Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

(b) Inspect all oil passages for obstructions. If an obstruction is found, remove it with compressed air or by working wire back and forth through the passage and flushing it out with cleaning solvent.

(c) Inspect mounting faces for nicks, burrs, scratches, and foreign matter. Remove such defects with crocus cloth or a soft stone. If scratches are deep, replace the defective part.

(d) Inspect threaded openings for damaged threads. Chase damaged threads with the correct size used tap.

**CAUTION**

A New Tap Can Cut Oversize.

(e) Replace housings or other case parts that are cracked.

(f) Inspect all machined surfaces for damage that could cause oil leakage or other malfunction of the part. Rework or replace the defective parts.

(6) Inspecting Bearings

(a) Inspect bearings for roughness of rotation. Replace a bearing if its rotation is still rough after cleaning and oiling.

(b) Inspect bearings for scored, pitted, scratched, cracked, or chipped races and for indication of excessive wear of rollers or balls. If one of these defects is found, replace the bearing.

(c) Inspect a defective bearing's housing and shaft for grooved, burred or galled conditions that would indicate that the bearing has been turning on its housing or on its shaft. If the damage cannot be repaired with crocus cloth, replace the defective part.

(d) When installing a bearing on a shaft, heat the bearing to 3000 F (1490C) on an electric hot plate or in an oil bath. Coat the mating surfaces with white lead and use the proper size installation sleeve and an arbor press to seat the bearing.

(e) If a bearing must be removed or installed without a sleeve, be careful to press only on the race which is adjacent to the mounting surface. If an arbor press is not available, seat the bearing with a drift and a hammer, driving against the supported race.

(7) Inspecting Bushings, Thrust Washers

(a) Inspect bushings for scores, burrs, roundness, sharp edges, and evidence of overheating. Remove scores with crocus cloth. Remove burrs and sharp edges with a scraper or knife blade. If the bushing is out of round, deeply scored, or excessively worn, replace it using the proper size replacer.

Note: Sometimes it is necessary to cut out a defective bushing. Be careful not to damage the bore into which the bushing fits.

(b) Inspect thrust washers for distortion, scores, burrs, and wear. Replace the thrust washer, if it is defective or worn. It is much less expensive to replace such parts than to replace converter elements, which can fail due to defective bearings, bushings, or thrust washers.

(8) Inspecting Oil Seal, Gaskets

(a) Inspect seal rings for cuts, hardness, or other indications of deterioration. Replace the seal rings if these defects are found.

(b) When replacing lip-type seal rings, make sure the spring-loaded side is toward the oil to be sealed in (toward the inside of the unit). Use a nonhardening sealing compound on the outside diameter of the seal to help prevent oil leaks.

(c) Replace all composition gaskets. d) Inspect hook-type seal rings for wear, broken hooks, and distortion.

(e) Install a new hook-type seal ring if it is worn so much that there is no gap between the hooks of the seal ring when it is installed.

(f) The sides of the seal ring should be smooth (0.005 inch (O.127mm) maximum side wear). The sides of the shaft groove (or the bore) in which the seal ring fits should be smooth (50 micro-inches (1.25 micron) equivalent) and square with the axis of rotation within 0.002 of an inch (0.0508 mm). If the sides of the ring grooves have to be reworked (0.020-inch (0.508mm) maximum side wear), install a new seal ring.

(9) Inspecting Gears

(a) Inspect gears for scuffed, nicked, burred or broken teeth. If the defect can not be removed with a soft stone, replace the gear.

(b) Inspect gear teeth for wear that may have destroyed the original tooth shape. If this condition is found, replace the gear.

(c) Inspect the thrust faces of gears for scores, scratches, and burrs. Remove such defects with a soft stone. If scratches and scores cannot be removed with a soft stone, replace the gear.

(10) Inspecting Splined Parts. Inspect splined parts for stripped, twisted, chipped or burred splines. Remove burrs with a soft stone. Replace the part if other defects are found. Spline wear is not considered detrimental except where it affects tightness of fit of the splined parts.

(11) Inspecting Threaded Parts. Inspect parts for burred or damaged threads. Remove burrs with a soft stone or fine file. Replace damaged parts.

(12) Inspecting Snap Rings. Inspect all snap rings for nicks, distortion, and excessive wear. Replace the part if one of these defects is found. The snap ring must snap right in its groove for proper functioning.

(13) Inspecting Springs Inspect all springs for signs of overheating, permanent set or wear due to rubbing adjacent parts. Replace the spring if any one of these defects is found.

74.5 Torque Specifications

The following general torque specifications are recommended for use in all cases where specific requirements are not set forth. Refer to Fig. 6 for a cross-section view of the torque converter, indicating the torque specification for all bolts shown.

GENERAL TORQUE SPECIFICATIONS - BOLTS AND SCREWS

(All torque values are given in pound feet and Newton meters)

| Size | Threads per inch | Standard heat-treated bolts and screws lb ft | (N·m) | Special heat-treated bolts, screws, Allen-head screws, and self-locking capscrews lb ft | (N.m) |
|---|---|---|---|---|---|
| 1/4 | 20 | 6-8 | (8-11) | 9-11 | (12-15) |
| | 28 | 8-10 | (11-14) | 10-12 | (14-16) |
| 5/16 | 18 | 15-18 | (20-24) | 17-20 | (23-27) |
| | 24 | 17-20 | (23-27) | 19-23 | (26-31) |
| 3/8 | 16 | 26-32 | (35-43) | 36-43 | (49-58) |
| | 24 | 33-40 | (45-54) | 41-49 | (56-66) |
| 7/16 | 14 | 42-50 | (57-68) | 54-65 | (73-88) |
| | 20 | 50-60 | (68-81) | 64-77 | (87-104) |
| 1/2 | 13 | 67-80 | (91-108) | 81-97 | (110-132) |
| | 20 | 83-100 | (113-136) | 96-115 | (130-156) |
| 9/16 | 12 | 85-100 | (115-136) | 103-123 | (140-167) |
| | 18 | 100-120 | (136-163) | 122-146 | (165-198) |
| 5/8 | 11 | 117-140 | (159-190) | 164-192 | (222-260) |
| | 18 | 134-160 | (182-217) | 193-225 | (262-305) |
| 3/4 | 10 | 180-210 | (244-285) | 284-325 | (385-441) |
| | 16 | 215-250 | (292-339) | 337-385 | (457-522) |
| 7/8 | 9 | 315-360 | (427-488) | 490-550 | (664-746) |
| | 14 | 372-425 | (504-576) | 575-650 | (780-881) |

Note: Any special torque requirements different from the standard torques listed above will be specified in the text or illustrations.

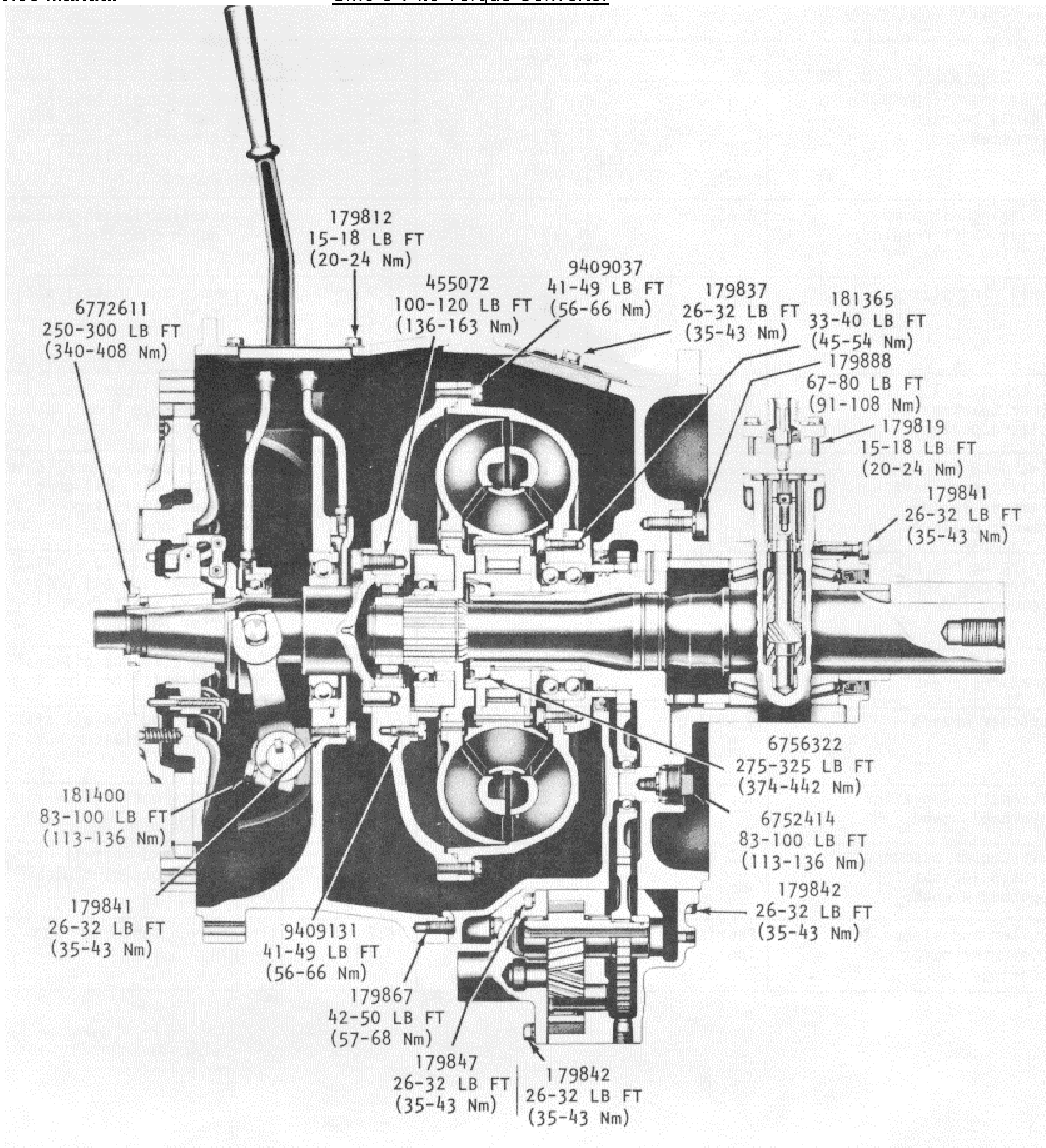



*Fig. 6*
*Torque Specifications - Cross Section View*

### 74.6 Special Tools Chart

| Name | Number | Figure | Para. | Use |
|---|---|---|---|---|
| Charging oil pump needle bearing replacer. | J 4850 | 1<br>26<br>31 | 74.2<br>74.18<br>74.18 | To remove needle bearing from pump body; to install needle bearing in pump driven gear; to install sleeve into pump body. |
| Charging oil pump drive shaft needle bearing replacer | J 4523-A | 1<br>29 | 74.2<br>74.18 | To install drive shaft needle bearing in pump body. |
| Snap ring pliers | J 8039 | 1<br>24<br>20 | 74.2<br>74.10<br>74.16 | To remove and install all snap rings. |
| Charging oil pump rear bearing sleeve puller. | J 4852 | 1<br>26 | 74.2<br>74.18 | To remove oil pump rear bearing sleeve from charging oil pump. |
| Charging oil pump idler gear shaft remover (slide hammer puller). | J 23907-1 | 1<br>16 | 74.2<br>74.13 | Used with adapter J 8116 to remove charging oil pump idler gear shaft from converter housing. |
| Charging oil pump idler gear shaft remover (adapter). | J 8117 | 1<br>16 | 74.2<br>74.13 | Used with puller J 23907-1 remove charging oil pump idler gear shaft from |
| Converter pump hub seal replacer. | J 7475 | 1<br>14 | 74.2<br>74.13 | To press pump hub oil seal into converter housing. |
| Spanner wrench. | J 6534-02 | 1<br>8<br>8 | 74.2<br>74.10<br>74.25 | To remove and install stator roller race retainer nut. |
| Torqmatic converter overhaul stand. | TSD 20183 | 2 | 74.2 | To support converter during overhaul. |
| Overcenter disconnect clutch locknut spanner wrench. | TSD 20231 | 3<br>33 | 74.2<br>74.19 | To remove and install over-center disconnect clutch locknut. |
| Puller and sleeve for converter pump bearing. | Fabricated Tool | 4<br>10 | 74.2<br>74.10 | To remover converter pump bearing. |

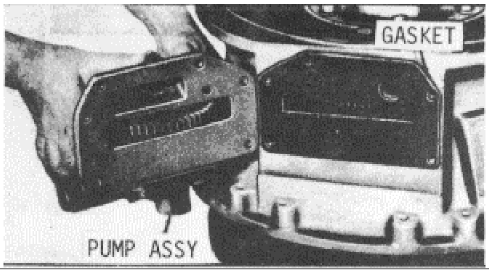



*Fig. 7*
*Removing (Or Installing) Charging Oil Pump Assembly*

74.7 Torque Converter Disassembly

74.8 Removal of Charging Oil Pump Assembly

(1) Position the converter, on the disconnect clutch end, on the disassembly table.
(2) Remove six bolts and lock washers from the pump assembly. Remove the assembly and gasket (Fig. 7).

74.9 Removal of Overcenter Disconnect Clutch Assembly

(1) Remove two bolts (5) (Fig. 14) and lockwashers (6) that retains converter housing access cover (4).
(2) Remove cover (4) and gasket (3).
(3) Remove 36 converter pump-to-converter drive housing bolts (item 7 of Fig. 20).
(4) Remove eleven converter housing-to-disconnect clutch housing bolts (23) (Fig. 1 and lockwashers (24).
(5) Using an eyebolt in the end of the output shaft or a sling attached to the converter housing, lift the converter up, leaving the disconnect clutch housing assembly on the table.

74.10 Removal of Converter Elements

(1) Remove snap ring (9) (Fig. 24) from converter output shaft (33) (Fig. 25).
(2) Remove the inner race of bearing (10) (Fig. 24) and turbine assembly with overrunning clutch, items (14) thru (18).

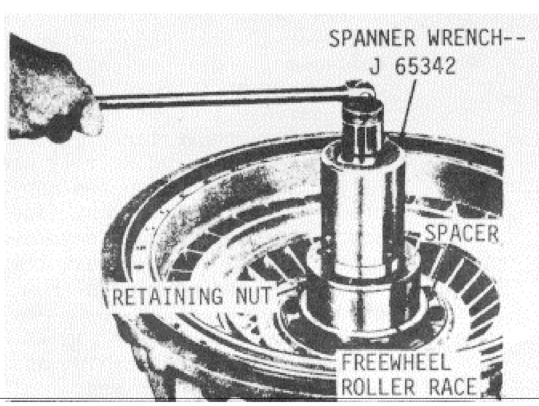



*Fig. 8*
*Removing (Or Installing) Freewheel Roller Race Retaining Nut*

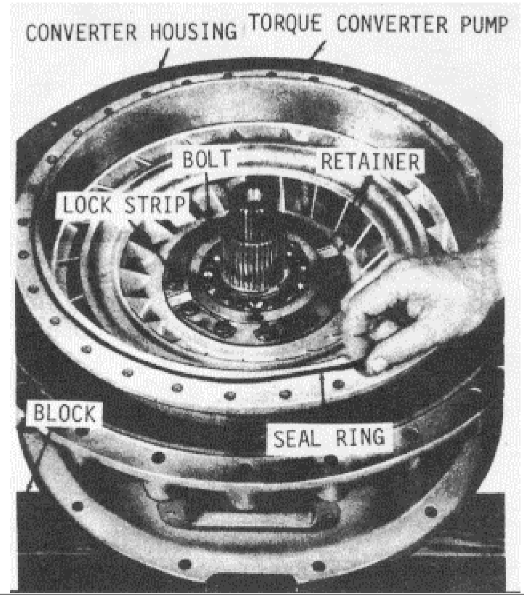



*Fig. 9*
*Removing (Or Installing) Seal Ring From Converter Pump Flange*

(3) Remove snap ring (15) from converter output shaft (33) (Fig.25)
(4) Remove stator assembly, items (3) through (5) (Fig. 20 ).
(5) Straighten the staked section of the freewheel roller race retaining nut (20).
(6) Using the spanner wrench J 65342, remove the retaining nut (Fig. 8).
(7) Remove freewheel roller race and spacer (Fig. 8).
(8) Remove 12 bolts, six lock strips and the split retainer that retains the converter pump (Fig. 9).
(9) Remove the converter pump (Fig. 9).
(10) The converter pump hub and bearing may come off with the converter pump. If not, remove the hub with bearing (Fig. 10).
(11) Remove the bearing from the converter pump hub.

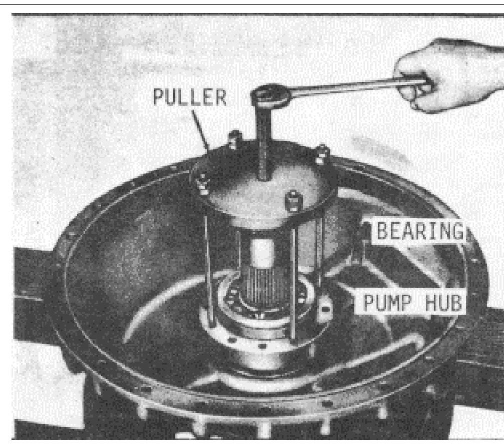



*Fig. 10*
*Removing Converter Pump Hub and Bearing*

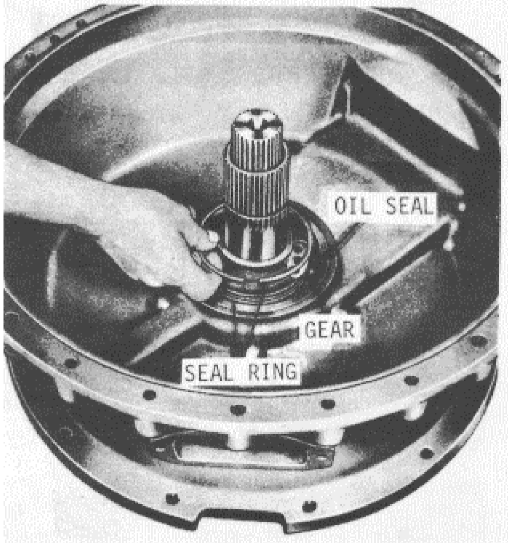



*Fig. 11*
*Removing (Or Installing) Seal Rings From Converter Ground Sleeve*

### 74.11 Removal of Torque Converter Output Shaft

(1) Position the converter housing with the output shaft up (Fig. 12).
(2) Remove six bolts and lockwashers retaining the bearing retainer.
(3) Using jackscrews, remove the bearing retainer and gasket from the converter housing (Fig. 12).
(4) Remove the converter output shaft (Fig.13). A bearing and two seal rings will come out with the shaft.

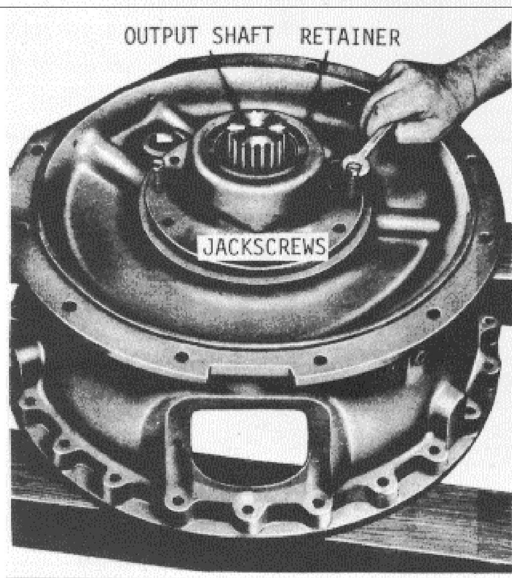



*Fig. 12*
*Removing Bearing Retainer*

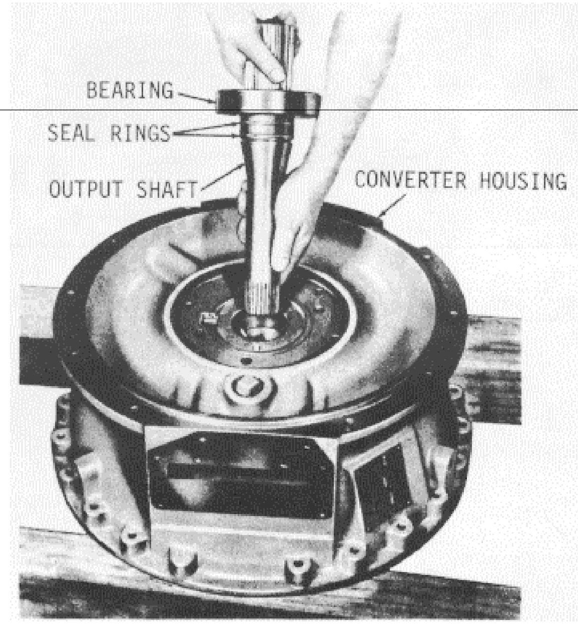



*Fig. 13*
*Removing (Or Installing) Output Shaft*

### 74.12 Rebuild of Subassemblies
### 74.13 Converter Housing

(1) Disassembly (Fig. 14)
  (a) Remove the square-head plug, seal ring, and lock washer from the rear of the converter housing (Fig. 15).
  (b) Install the slide hammer remover J 3187 and adapter J 4857 (Fig. 1) in the threaded hole in the oil pump idler gear shaft (Fig. 16).
  (c) Remove the shaft, being careful that the oil pump idler gear does not drop out of the housing (Fig. 16).
  (d) Remove the oil pump idler gear assembly (Fig. 17). Refer to paragraph 74.20 for gear assembly rebuild instructions,
  (e) Oil pump drive gear (2) (Fig. 14) and converter pump hub oil seal (1) generally are not removed. If either the gear or seal needs to be replaced, collapse the oil seal with a drift and hammer and remove the oil seal. The gear can then be removed.
  (f) Ordinarily, converter ground sleeve (18) is not removed. If it needs to be replaced, position the converter housing in a press, front side up, and press the ground sleeve out of the housing (Fig. 18). Remove the ground sleeve key and dowel pin from the ground sleeve.

(2) Cleaning, Inspection, Wear Limits. Refer to paragraph 74.4 for cleaning and inspection procedures, and for wear limits information.

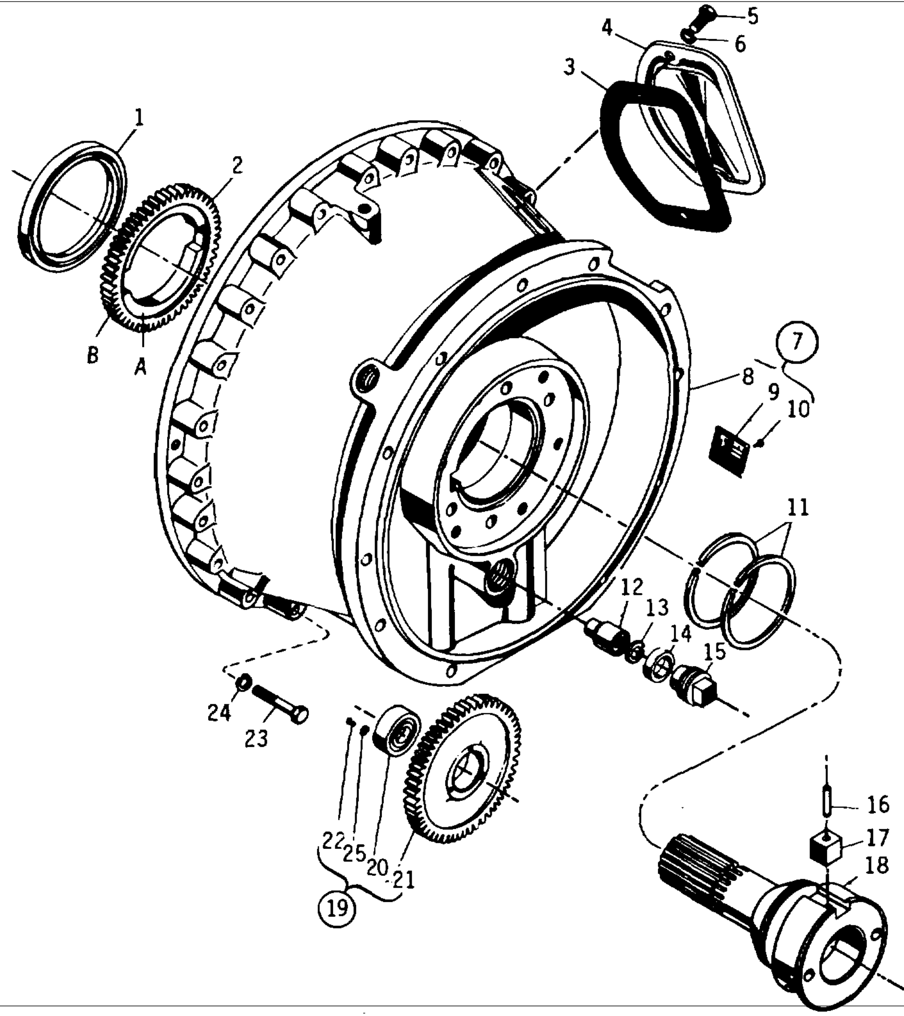



*Fig. 14*
*Torqmatic Converter Housing - Exploded View*

1. Oil Seal
2. Charging Oil Pump Drive Gear
3. Gasket
4. Converter Housing Cover
5. Hexagon-head Bolt, 3/8-16 x 3/4
6. Lock Washer, 3/8
7. Converter Housing Assembly
8. Converter Housing
9. Name Plate
10. Drive Screw, 4 x 1/4
11. Hook-type Seal Ring
12. Pump Idler Gear Shaft
13. Lock Washer, 1/2
14. Seal Ring
15. Plug, 1 in.
16. Dowel Pin
17. Key
18. Converter Ground Sleeve
19. Oil Pump Idler Gear Assembly
20. Single-row Ball Bearing Assembly
21. Oil Pump Idler Gear
22. Rivet
23. Hexagon-head Bolt, 7/16-14 x 2-1/4
24. Washer
25. Lock Washer, 7/16

(3) Assembly (Fig. 14)

(a) If the ground sleeve was removed, install dowel pin (16) (Fig. 14) in ground sleeve key (17) and install the key on the new ground sleeve (18) so that the end of the key is flush with the face of the ground sleeve. Notice that the dowel pin hole in the key is off center. Press the ground sleeve and the key into the housing (Fig. 19).

(b) If oil pump drive gear (2)(Fig.14) and converter pump hub oil seal (1) were removed, install the gear. Install the oil seal with the spring side toward the gear, using replacer J 7475 (Fig. 14).

(c) Position the converter on the table with the rear end up.

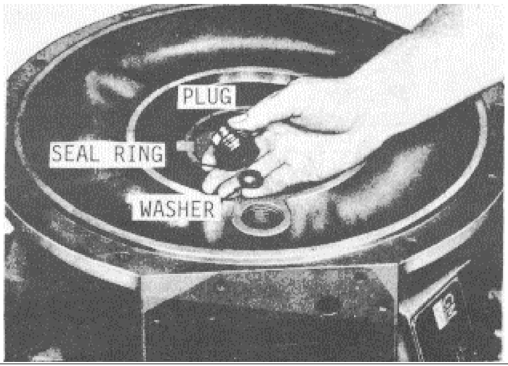



*Fig. 15*
*Removing (Or Installing) Square-head Plug, Seal Ring, and Lock Washer From Converter Housing*

(d) Install the charging oil pump idler gear assembly by positioning the gear in the housing bore (Fig. 17) and installing oil pump idler gear shaft (12) (Fig. 14) in its bore. Use a soft drift or a bolt of the proper size threaded into the shaft and tap the shaft into place.

(e) Install the lock washer, seal ring, and square-head plug (Fig. 15) into the oil pump idler gear shaft bore. Torque the plug 80-100 ft/lb.

## 74.14 Converter Pump and Hub Assembly

(1) Disassembly (Fig. 20)

(a) The converter pump was removed when the converter was disassembled into subassemblies (paragraph 74.10). No further disassembly is necessary.

(b) Remove seal ring (23) (Fig. 20) from converter pump hub (24).

(c) Press double-row ball bearing assembly (13) from converter pump hub (24).

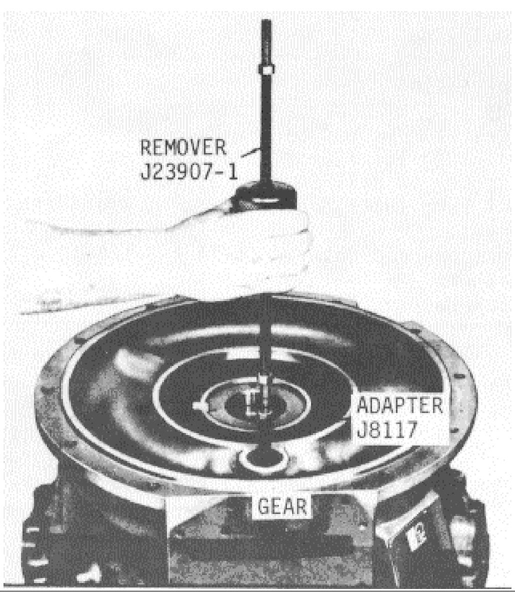



*Fig. 16*
*Removing Charging Oil Pump Idler Gear Shaft*

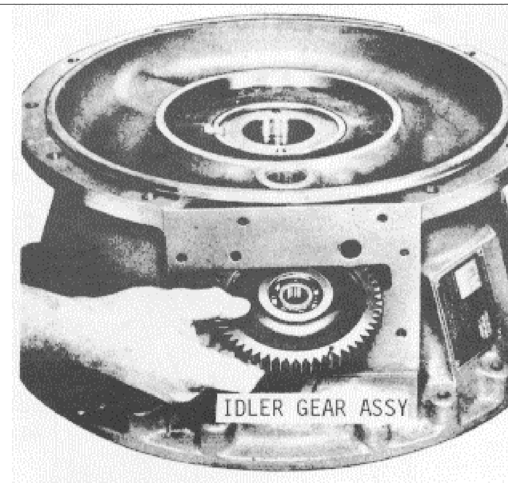



*Fig. 17*
*Removing (Or Installing) Oil Pump Idler Gear Assembly*

(2) Cleaning, Inspection. Refer to paragraph 74.4 for cleaning and inspection procedures.

(3) Assembly (Fig. 20)

(a) Install double-row ball bearing assembly (13) (Fig. 20), seal ring, groove side up, into converter pump hub (24). Press the bearing until it is firmly seated in the hub.

(b) Install seal ring (23) onto pump hub (24).

## 74.15 Stator

(1) Disassembly (Fig. 20)

(a) Remove rollers (5) and springs (4) from stator (3).

(b) Remove bearing (7) and washer (6) from the stator.

(c) Do not remove the rivets from the stator assembly. If any part of a stator assembly is worn or damaged, the assembly must be replaced.

(2) Cleaning, Inspection, Wear Limits. Refer to paragraph 74.4 for cleaning,

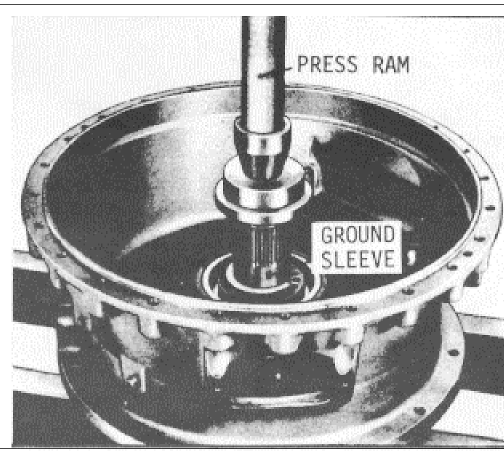



*Fig. 18*
*Removing Ground Sleeve From Housing*

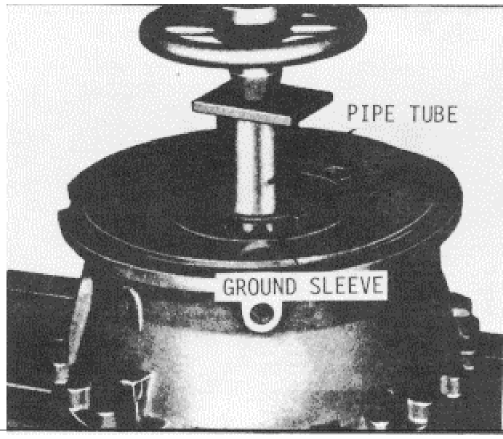



*Fig. 19*
*Installing Ground Sleeve*

inspection procedures, and to for wear limits information.

(3) Assembly
  - (a) Install the freewheel rollers and springs into the stator cam (Fig. 21). Rollers and springs may be retained with a heavy coating of oil soluble grease.
  - (b) Install the springs in the deep end of the stator pocket, with the end of the spring contacting the roller toward the bore of the stator.(Fig. 22).
  - (c) Install washer and bearing, roller side up, into stator. Install stator race into stator (Fig. 23).

## 74.16 Converter Turbine Assembly

(1) Disassembly
  - (a) Remove snap ring (14) (Fig. 24) from converter turbine (2) (Fig. 20).
  - (b) Remove sprag clutch race (17) (Fig. 24) with bearing assembly (15) and retainer (16).
  - (c) Press bearing assembly (15) from race (17) and remove retainer (16).
  - (d) Remove sprag assembly (18) from converter turbine (2) (Fig. 20).
  - (e) Do not remove the rivets from the turbine. If the turbine assembly is worn or damaged, the assembly must be replaced.

(2) Cleaning, Inspection, Wear Limits. Refer to paragraph 74.4 for cleaning and inspection procedures, and to 74.28-.34 for wear limits information.

(3) Assembly
  - (a) Install retainer (16) (Fig. 24) in sprag race (17).
  - (b) Install bearing assembly (15) in sprag race (17). Press the bearing until it is firmly seated against the retainer in the race.
  - (c) Install sprag clutch assembly (18), flanged side out, onto converter turbine (2) (Fig. 20).
  - (d) Install the bearing with the race and retainer onto the turbine assembly. Press the bearing until it is firmly seated against the shoulder on the turbine assembly.
  - (e) Install snap ring (14) (Fig. 24).

## 74.17 Output Shaft and Bearing Retainer

(1) Disassembly (Fig. 25)
  - (a) Remove two hook-type seal rings (17) from the output shaft (18).
  - (b) When it is necessary to replace roller bearing assemblies (16) and (22), support the shaft and bearing assembly, small end up, on two steel plates in an arbor press. The plates must be placed between the two bearings, making certain that only the inner race of the bearing rests on the plates. Press the shaft out of the front roller bearing.
  - (c) If the rear bearing must be removed, use a hammer and chisel to crack sleeve (23) over the keyway slot. This will loosen the sleeve so that it can be removed. Then place the shaft, rear end up, in a press Place the bearing inner race on the plates and press the shaft out of the sleeve and the rear output bearing.
  - (d) Do not remove lip-type oil seal (28) from bearing retainer (29) unless replacement is necessary. If necessary, remove the seal.

(2) Cleaning, Inspection, Wear Limits. Refer to paragraph 74.4 for cleaning and inspection procedures, and to 74.28-.34 for wear limits information.

(3) Assembly (Fig. 25)
  - (a) If oil seal (28) was removed from bearing retainer (29), install new replacement. Press the new seal from the chamfered end of the retainer, spring side of seal toward the chamfered end of the retainer, flush to 1/16 inch (1.5875 mm) below the bottom of the chamfer.
  - (b) If roller bearings (16) and (22) were removed, support the shaft (18), small end up, in an arbor press. Install a roller bearing on the shaft so that the thick side of the inner race is down. Press the bearing onto the shaft until it firmly seats against the shoulder on the shaft.
  - (c) Turn the shaft end for end and press the other roller bearing onto the shaft in the same manner.
  - (d) Heat sleeve (23) to approximately 350°F and press it onto the shaft until it is seated against the bearing.
  - (e) Install two hook-type seal rings (17) on the output shaft.

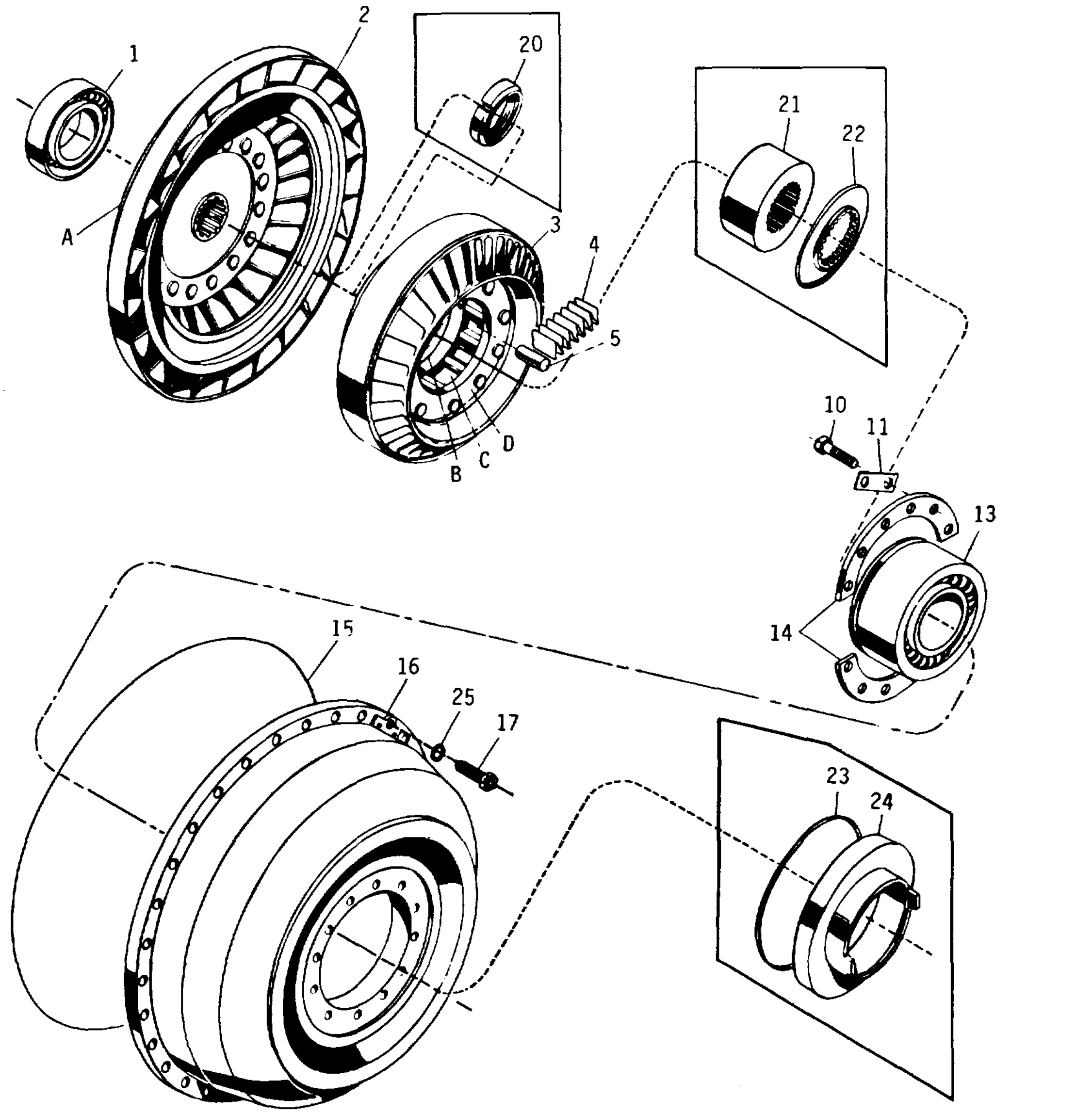



*Fig. 20*
*Torqmatic Converter - Exploded View*

1. Roller Bearing Assembly
2. Torque Converter Turbine
3. Stator
4. Freewheel Roller Spring
5. Freewheel Roller
10. Hexagon-head Bolt, 3/8-24 x 1-3/8
11. Lock Strip
13. Double-row Ball Bearing Assembly
14. Retainer
15. Seal Ring
16. Converter Pump
17. Hexagon-head, Self-locking Bolt, 3/8-24 x 1-1/4
20. Nut
21. Stator Freewheel Roller Race
22. Stator Back Plate
23. Seal Ring
24. Converter Pump Hub
25. Washer

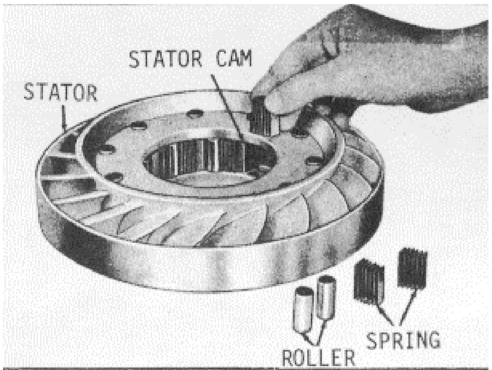



*Fig. 21*
*Installing Stator Springs and Rollers Into Stator Cam*

### 74.18 Charging Oil Pump

(1) Disassembly (Fig. 26)

(a) Remove the converter pressure regulator valve plug, gasket, spring and valve from the pump cover (Fig. 27).

(b) Remove 6 bolts and lock washers retaining the pump cover (Fig. 27).

(c) Remove the pump cover and gasket (Fig. 27).

(d) Remove the snap ring, clutch pressure regulator valve and spring from the pump cover (Fig. 28).

(e) Do not remove the needle roller bearing from the pump cover unless replacement is necessary (Fig. 28). If necessary, collapse the bearing, being careful not to damage the bearing bore in the cover and remove the bearing.

(f) Remove the oil pump driven gear and bearing as an assembly (Fig. 29). Do not remove the bearing from the gear unless replacement is necessary. If necessary, remove the bearing.

(g) Remove the charging pump driving gear shaft and driving gear (Fig. 30)

(h) Remove the hook-type seal ring from the shaft gear (Fig. 30).

(i) Do not remove the O-ring seal or needle roller bearing from the oil pump housing unless replacement is necessary (Fig. 30). If necessary,

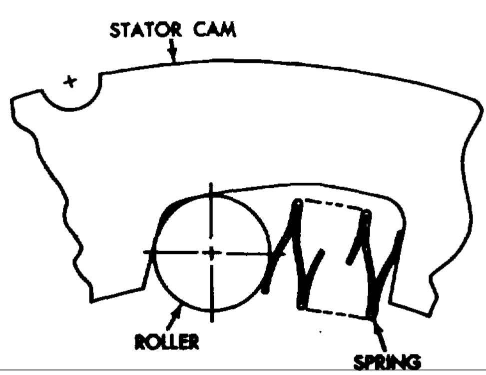



*Fig. 22*
*Spring and Roller Installed in Stator Cam*

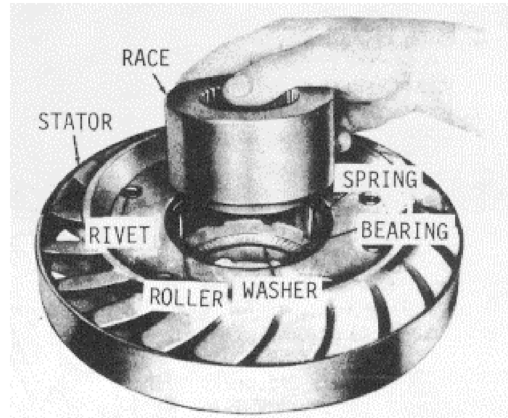



*Fig. 23*
*Installing Stator Freewheel Roller Race*

remove seal and bearing, using replacer J 4850. Press or drive the seal and bearing out of their bore into the pocket of the pump body (Fig. 31).

(j) Do not remove sleeve (25) (Fig. 26) from the oil pump body unless replacement is necessary. If necessary, drive the sleeve out of the pump body (Fig. 32). Use puller J 4852 (Fig. 1) or a steel disk ¼ by 1.370 inch (6.35 x 34.798 mm) in diameter. Remove the pipe plug from the rear of the pump body. Place the disk in the slot behind the sleeve, aligning the disk with the sleeve. Insert a drift through the pipe plug hole in the rear of the pump body and place the drift against the disk. Press or drive the sleeve out of its bore.

(k) Do not remove plugs (28), (29), (30), and (31) (Fig. 26) from body (27) unless replacement is necessary or for cleaning purposes. If necessary, remove the plugs.

(2) Cleaning, Inspection, Wear Limits. Refer to paragraph 74.4 for cleaning and inspection procedures, and to 74.28-.34 for wear limits information.

(3) Assembly (Fig. 26)

(a) If sleeve (25) was removed from the oil pump body, install a new replacement. Press the new sleeve, with the chamfer on the inside diameter facing up, into the body until it is firmly seated. Use tool J 4850 (Fig. 1) for installing the sleeve.

(b) If bearing assembly (23) (Fig. 26) and seal ring (22) were removed from oil pump body (27), install new replacements. Install the bearing, pressing against the numbered end of the bearing cage, flush to 0.090 to 0.100 inch (2.286 to 2.540 mm) below the edge of the bearing bore.

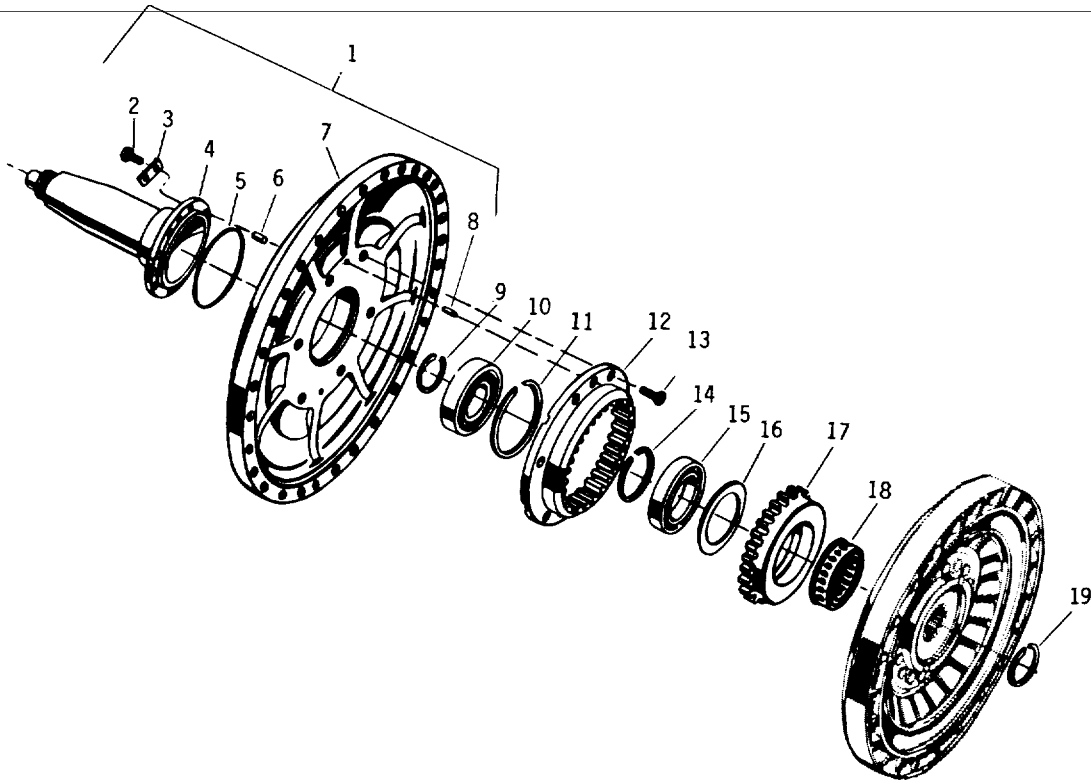



*Fig. 24*
*Converter Drive Housing and Sprag Clutch - Exploded View*

1. Converter Drive Housing Assembly
2. Hexagon-head Bolt, 9/16-18 x 1-3/8
3. Lock Strip
4. Shaft
5. Seal Ring
6. Dowel Pin
7. Converter Drive Housing
8. Dowel Pin
9. Snap Ring
10. Roller Bearing Assembly
11. Snap Ring
12. Drive Hub
13. Hexagon-head, Self-locking Bolt, 3/8-24 x 3/4
14. Snap Ring
15. Single-row Ball Bearing Assembly
16. Retainer
17. Sprag Clutch Outer Race
18. Sprag Assembly
19. Snap Ring

Install the seal ring, flush to 0.020 to 0.030 inch (0.508 to 0.762 mm) below the edge of the bearing bore.

(c) Install the hook-type seal ring onto the pump drive shaft gear (Fig. 30).

(d) Install oil pump driving gear and while holding it in position, install the driving gear shaft (Fig. 30).

(e) If needle roller bearing (Fig. 29) was removed from the pump driven gear, install new replacement. Install bearing, pressing on the numbered end of the bearing cage and into the chamfered end of the gear, flush with the bottom of the chamfer in the gear.

(f) Install the assembled gear and bearing into the oil pump body (Fig. 29).

(g) If the needle roller bearing (Fig. 28) was removed from the oil pump body cover, install new replacement.

Install the bearing, pressing on the numbered end of bearing cage, until the bearing is firmly seated in the pump cover.

(h) Install the clutch pressure regulator valve spring, valve and snap ring in the oil pump body cover (Fig. 28).

(i) Install the oil pump body cover gasket and assembled cover onto the oil pump body and secure with six bolts and lock washers (Fig. 29).

(j) Install converter pressure regulator valve, spring, gasket and plug in oil pump cover (Fig. 27).

(k) Install plugs (28), (29), (30) and (31) (Fig. 26).

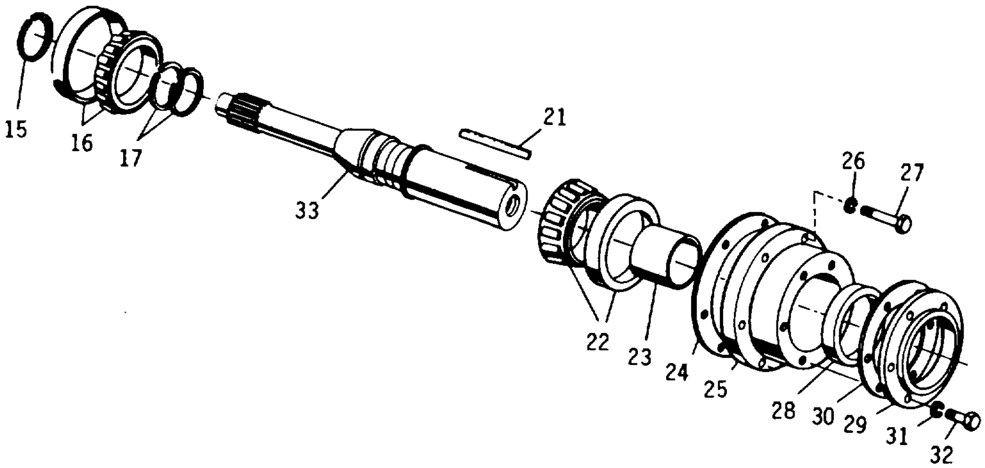



*Fig. 25*
*Converter Output Shaft and Flange - Exploded View*

15. Snap Ring
16. Separable Outer Race Roller Bearing
17. Hook-type Seal Rings
21. Key
22. Separable Outer Race Roller Bearing Assembly
23. Sleeve
24. Gasket
25. Bearing Retainer Housing
26. Lock Washer, 1/2
27. Hexagon-head Bolt, 1/2-13 x 1-7/8
28. Dual Oil Seal
29. Bearing Retainer
30. Gasket
31. Lock Washer, 3/8
32. Hexagon-head Bolt, 3/8-16 x 1-1/4
33. Converter Output Shaft

74.19 Manual Overcenter, Input Disconnect Clutch

(1) Disassembly (Fig. 33)

(a) Using a bearing puller, remove ball bearing assembly (56) (Fig. 33) from the end of converter drive shaft (4) (Fig. 24).

(b) Remove four bolts (32) (Fig. 33) and lock washer (33) securing access cover (34).

(c) Disconnect two grease fittings (25) and (36) and nuts (26) and (37) from the bearing lube tubes (27) and (38) and remove access cover (34).

(d) Using wrench TSD 20231 (Fig. 3), remove spanner lock nut (1) (Fig. 33) from the front end of the converter drive shaft.

(e) Using caution not to damage the bearing diameter, drive or press converter drive shaft (4) (Fig. 24) rear-ward out of clutch assembly (4) (Fig. 33) and ball bearing (35). Remove converter drive housing assembly (7) (Fig. 24), but DO NOT disassemble ' the drive shaft from the drive housing since it was partially machined after assembly.

(f) Remove key (2) (Fig. 33), clutch assembly (4), and attached bearing lube tube (27).

(g) If necessary for parts replacement, remove elbow (28) and bearing lube tube (27) from shift collar (18).

(h) Remove eight bolts (40) and lock-washers (41) from bearing retainer (39).

(i) Remove bearing retainer (39) and attached bearing lube tube (38).

(j) Remove ball bearing (35) from clutch housing (30).

(k) Remove bearing lube tube (38) from bearing retainer (39).

(l) Remove clutch shifter control linkage from shifter shaft (44).

(m) Loosen two bolts (52) and lockwashers (53) in clutch shifter yoke.

(n) Tap shifter shaft (44) out of shifter yoke (51), and remove two keys (50). Remove shifter shaft (44) and yoke (51) from housing (30).

(2) Cleaning, Inspection, Wear Limits Refer to paragraph 74.4 for cleaning and inspection procedures, and to 74.28-74.34 for wear limits information.

(3) Assembly (Fig. 33)

(a) Hold clutch shifter yoke (51) (Fig. 33) in position inside housing (30). Slide shaft (44) into housing (30) and insert two Woodruff keys (50) in their slots in shaft (44). Slide the shaft into yoke (51) and into position in housing.

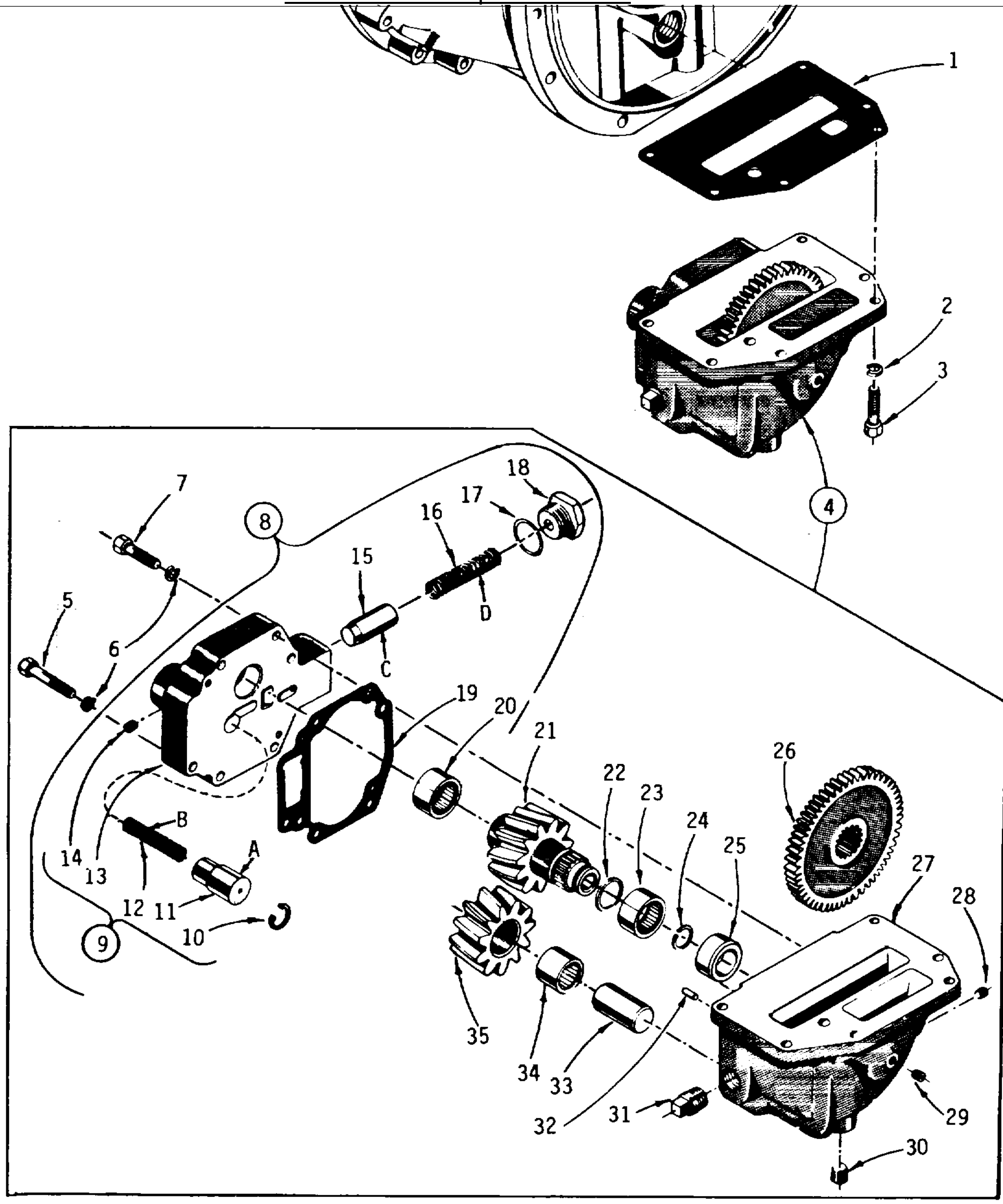



*Fig. 26*
*Changing Oil Pump-Exploded View*

1. Charging Oil Pump Gasket
2. Lock Washer, 3/d
3. Hexagon-head Bolt, 3/8-16x1-3/8
4. Charging Oil Pump Assembly
5. Hexagon-head Bolt, 3/8-16x1-3/8
6. Lock Washer, 3/8
7. Hexagon-head Bolt, 3/8-16 x 2
8. Charging Oil Pump Cover Assy.
9. Charging Pump Cover Assembly
10. Snap Ring
11. Clutch Pressure Regulator Valve
12. Clutch Pressure Regulator Valve Spring (6770417, standard)
13. Pump Cover
14. Plug
15. Converter Pressure Regulator Valve
16. Converter Pressure Regulator Valve Spring
17. Gasket
18. Hexagon-head Plug
19. Gasket
20. Needle Roller Bearing Assembly
21. Oil Pump Driving Shaft Gear
22. Seal Ring
23. Needle Roller Bearing Assembly
24. Hook-type Seal Ring
25. Sleeve
26. Pump Driving Gear
27. Charging Oil Pump Body
28. Pipe Plug, 1/3
29. Pipe Plug, 1/8
30. Pipe Plug, 3/8
31. Pipe Plug, 3/4
32. Dowel Pin
33. Pump Driven Gear Shaft
34. Needle Roller Bearing Assembly
35. Pump Driven Gear

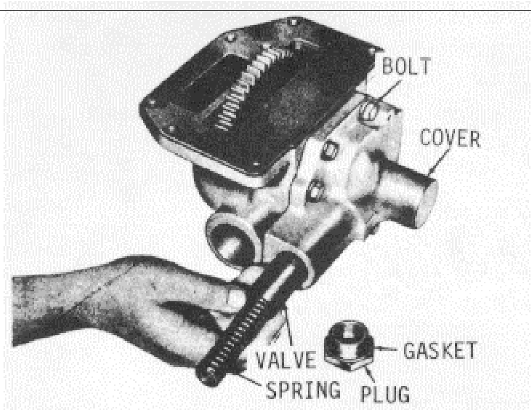



*Fig. 27*
*Removing (Or Installing) Converter-In Pressure Regulator Valve*

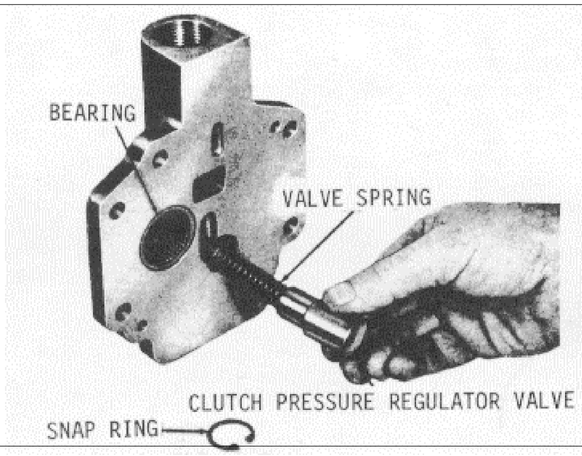



*Fig. 28*
*Removing (Or Installing) Clutch Pressure Regulator Valve*

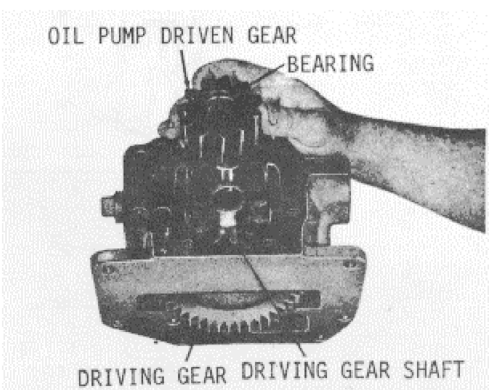



*Fig. 29*
*Removing (Or Installing) Oil Pump Driven Gear*

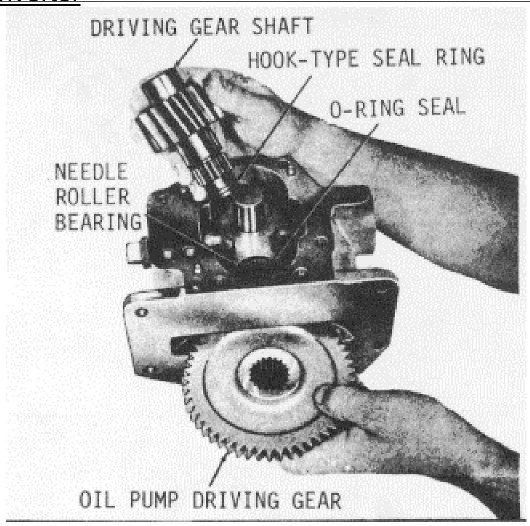



*Fig. 30*
*Removing (Or Installing) Oil Pump Driving Gear Shaft*

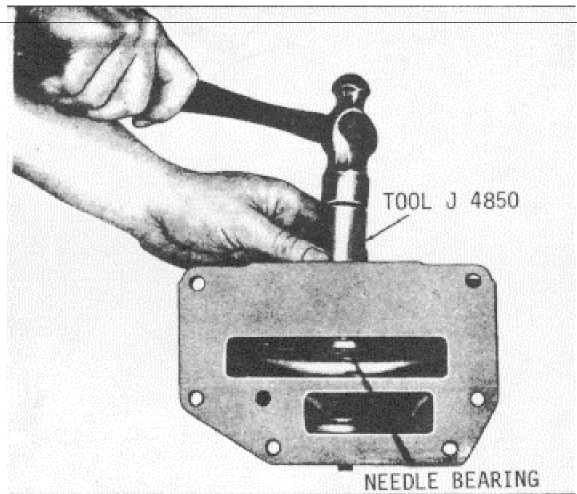



*Fig. 31*
*Removing Needle Bearing From Pump Body*

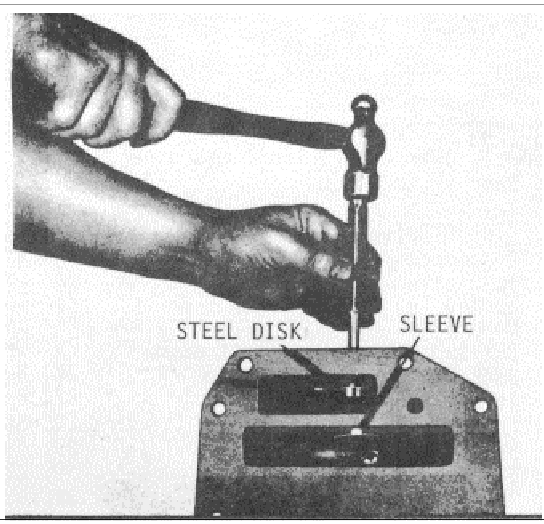



*Fig. 32*
*Removing Oil Pump Bearing Sleeve From Pump Body*

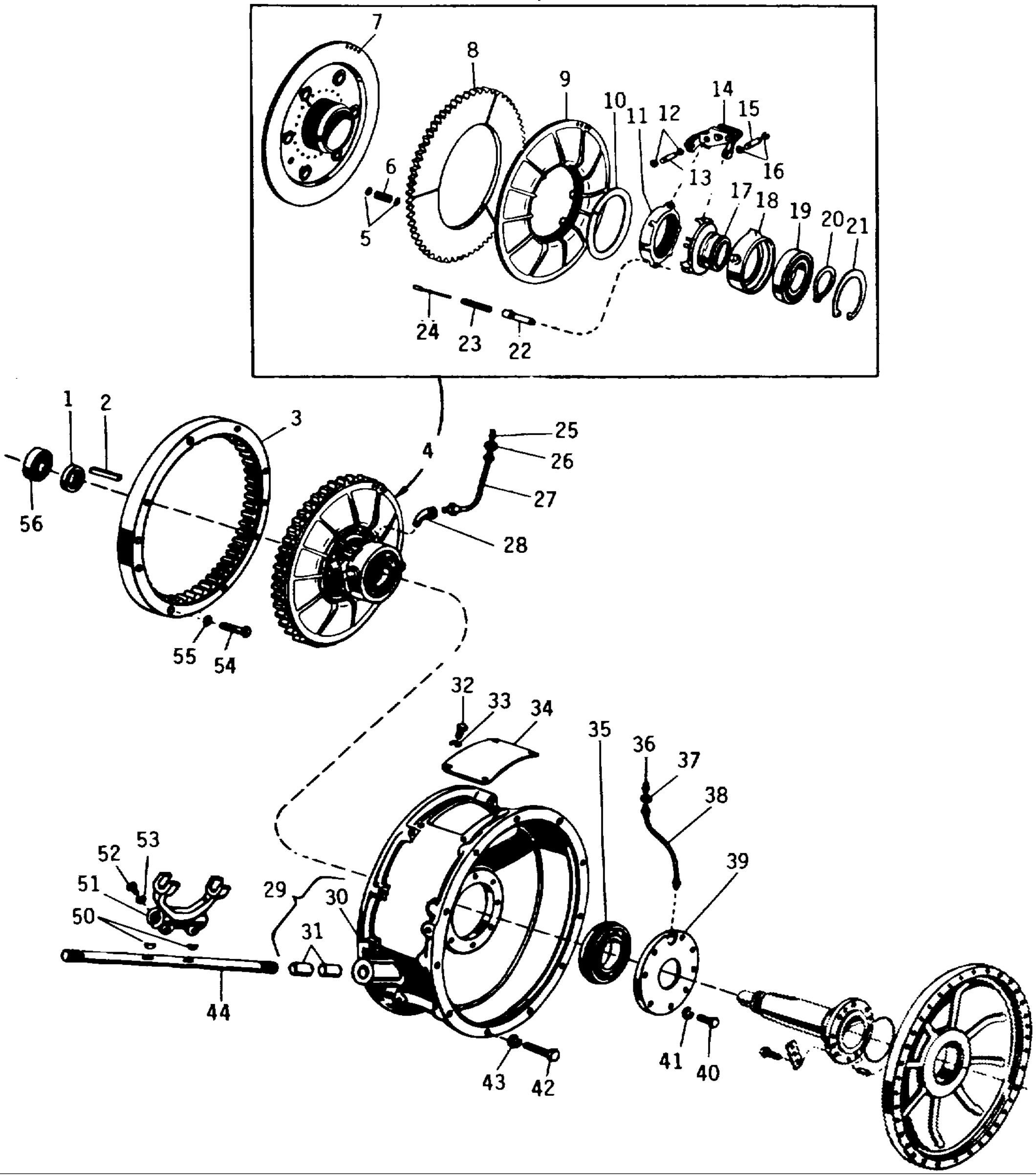



*Fig. 33*

*Manual, Overcenter, Input Disconnect Clutch Assembly - Exploded View*

1. Spanner Lock Nut
2. Key
3. Clutch Drive Gear
4. Disconnect Clutch Assembly
5. Insulating Washer (8)
6. Spring (4)
7. Hub Pate
8. Driving Clutch Disk (set of 3)
9. Back Plate
10. Thrust Ring
11. Adjust Collar
12. Snap Ring (10)
13. Toggle Strap Pin (5)
14. Toggle Assembly (set of 5)
15. Toggle Liner Pin (5)
16. Snap Ring (10)
17. Shift Sleeve
18. Shift Collar
19. Ball Bearing
20. External Snap Ring
21. Internal Snap Ring
22. Lock Pin Sleeve
23. Lock Spring
24. Lock Pin
25. Grease Fitting
26. Nut, 5/8-18 -
27. Bearing Lube Tube
28. Street Elbow
29. Clutch Housing Assembly
30. Clutch Housing
31. Bushing (4)
32. Bolt, 5/16-18 x 1/214)
33. Lock Washer, 5/16-(4)
34. Access Cover
35. Ball Bearing
36. Grease Fitting
37. Nut, 5/8-18
38. Bearing Lube Tube
39. Bearing Retainer
40. Bolt, 3/8-16 x 1-1/4 (8)
41. Lock Washer 3/8 (8)
42. Bolt, 7/16-14 x 2-1/4 (11)
43. Washer, 7/16 (11)
44. Clutch Shifter Shaft
50. Woodruff Key (2)
51. Clutch Shifter Yoke
52. Bolt, 7/16-20 x 1-1/2 (2)
53. Lock Washer, 7/16 (2)
54. Bolt, 1/2-13 x 2-3/4 (8)
55. Lock Washer (8)
56. Ball Bearing Assembly

(b) Position yoke (51) centrally over Woodruff keys 50) and tighten retaining bolts (52) and lock washers (53) on yoke (51).

(c) Place clutch shifter control linkage in position on shaft (44).

(d) Install bearing lube tube (38) on bearing retainer (39).

(e) Install ball bearing (35) in housing (30).

(f) Secure bearing retainer (39) to housing (30) with eight bolts (40) and lock washers (41).

(g) Press or drive converter drive shaft (4) (Fig. 24) into the retainer side of ball bearing (35) (Fig. 33) until the shoulder of the shaft protrudes through the bearing approximately 1/8 inch (3.175 mm). Be careful not to damage the bearing diameter on the shaft.

(h) If elbow (28) and bearing lube tube were removed, install the elbow into shift collar (18) so that it is parallel with clutch back plate (9) and points toward the right (when viewed from the converter side of the clutch assembly). Install bearing lube tube (27) into elbow (28).

(i) Install clutch assembly (4), engaging the two pins on the throw-out bearing in the yoke (51) as the clutch assembly is slid into place. Be sure to place tube (27) toward clutch housing access cover opening.

(j) Install key (2) between clutch assembly (4) and converter drive shaft (4) (Fig. 24).

(k) Install spanner lock nut (1) (Fig. 33) and torque to 250-300 ft/lb. (340-408 N.m), using spanner wrench TSD 20231 (Fig. 3). Bend a section of the lock nut into the shaft groove.

(l) Install grease fittings (25) and (36) into tubes (27) and (38). Push the upper ends of the tubes through holes in housing (30). Install nuts (26) and (37) onto tubes (27) and (38).

(m) Secure access cover (34) with four bolts (32) and lock washers (33).

(n) Press single-row ball bearing assembly (56), with numbered side out, onto the converter drive shaft.

## 74.20 Oil Pump Idler Gear

(1) Disassembly (Fig. 14)

(a) To remove ball bearing (20) from hub of idler gear (21), grind the head from three rivets (22). (The head end of the rivets rests against washers (25),) Drive the rivets from the gear and remove the washers and bearing.

(2) Cleaning, Inspection. Refer to paragraph 74.4 for cleaning and inspection procedures.

(3) Assembly (Fig. 34)

(a) Install the bearing into the idler gear hub. Assemble the washer onto

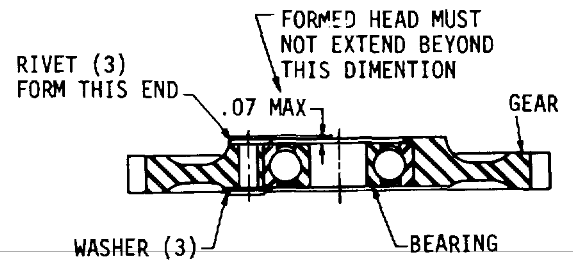



*Fig. 34*

*Idler Gear and Bearing Assembly*

the rivet, and install them into the flat side of the gear hub. Support the rivet head (washer side) on a suitable hard surface, and peen the rivet shank against the spotface. Repeat the procedure for the remaining two washers and rivets. Make sure that the formed head does not extend beyond the 0.07 inch (1.778 mm) dimension indicated in Figure 34.

## 74.21 Torque Converter Assembly

## 74.22 Installing Torque Converter Output Shaft

(1) Position the converter housing assembly, rear end up, on the assembly table (Fig. 35).

(2) Install the outer race of the front roller bearing, with the thick end down, so that it rests against the end of the ground sleeve (Fig. 35).

(3) Install the output shaft so that the front roller bearing engages with its outer race (Fig. 35).

(4) Install the bearing retainer housing gasket, making sure that any oil drain holes in the bearing housing align with the holes in the converter housing.

(5) Secure the bearing retainer housing with six 1/2-13 x 1-7/8 inch bolts and lock washers. Tighten bolts to 67-80 ft/lb. (91-108 N'm) torque.

(6) If the outer race of the rear roller bearing was removed, install it, thin edge down, in bearing retainer housing.

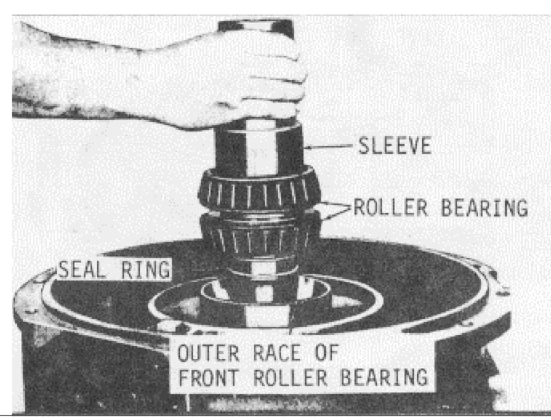



*Fig. 35*

*Removing (Or Installing) Output Shaft*

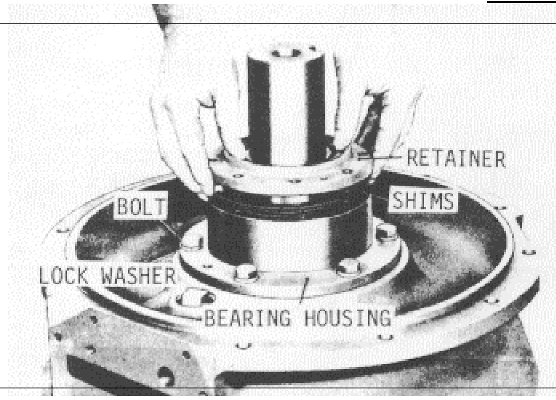



*Fig. 36*
*Removing (Or Installing) Bearing Retainer and Shims*

### 74.23 Installing Bearing Retainer

(1) Install the bearing retainer on the out-put shaft and seat it against the rear bearing by tapping it lightly with a soft hammer (Fig. 36).

(2) Using a feeler gage inserted between bearing retainer housing, measure the space between those two parts.

(3) Add 0.006 inch (0.1524 mm) to the measurement obtained in (2) above. This is the calculated shim thickness. Make up a shim pack and install it between the retainer and housing (Fig. 36).

(4) Secure the retainer with eight 3/8-16 by 1-1/4 inch bolts and lock washers. Tighten bolts to 26-32 ft/lb. (35-43 N-m) torque.

### 74.24 Checking End Play of Output Shaft

(1) To check the end play in the output shaft, position the converter, rear end up, on the assembly table. Support the converter by the converter housing only. Make sure the shaft does not touch the table.

(2) Attach a dial indicator to the converter housing so that the indicator touches

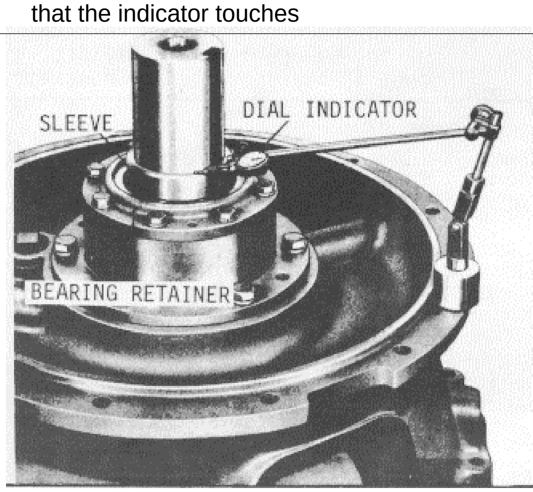



*Fig. 37*
*Checking End Play - Weight Resting On Housing*

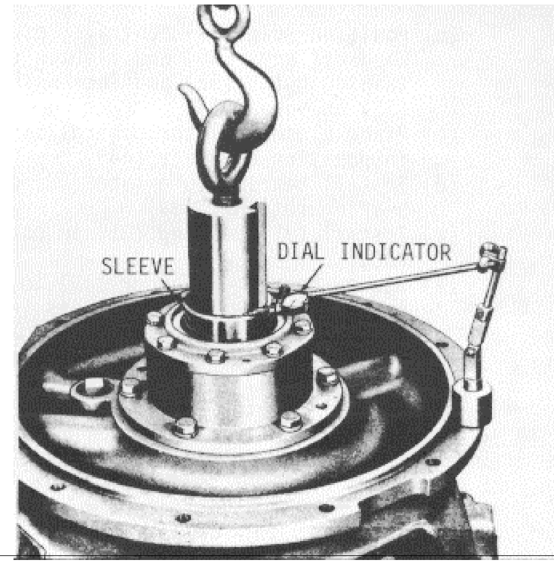



*Fig. 38*
*Checking End Play - Weight Suspended by Output Shaft*

the rear end of the oil seal sleeve on the output sleeve (Fig. 37).

(3) Install an eyebolt in the rear end of the output shaft. Using a hoist, raise the converter high enough to be sure that all the weight of the converter is on the output shaft (Fig. 38).

(4) The indicator reading is the end play of the output shaft (Fig. 38). The end play must be at least 0.004 inch (0.1016 mm) but not over 0.006 inch (0.1524 mm).

(5) If the end play is less than 0.004 inch (0.1016 nmm), remove the bearing retainer and add a sufficient amount of shims to the shim pack to bring the end play within the required limits. If the end play exceeds 0.006 inch (0.1524 mm), remove a sufficient amount of shims from the shim pack to bring the end play within the required limits.

### 74.25 Installing Torque Converter Elements

(1) Install the seal rings on the converter ground sleeve (Fig. 11).

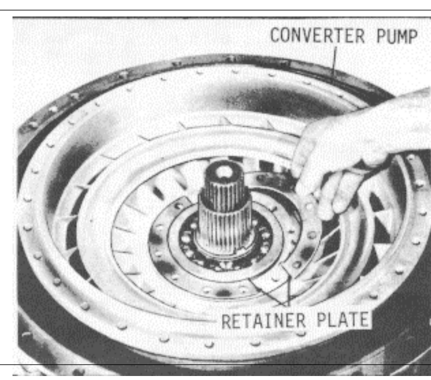



*Fig. 39*
*Removing (Or Installing) Split Retainer Plate*

(2) Install converter pump hub (24) (Fig. 20), double-row ball bearing assembly (13), and seal ring **(23)** as an assembly onto the converter ground sleeve.

**CAUTION**

Index Tangs On Pump Hub (24) With The Slots In The Charging Oil Pump Drive Gear (2) (Fig. 14).

(3) Install the converter pump assembly (Fig. 39).
(4) Install the split retainer (Fig. 39).
(5) Secure the converter pump with six lock strips and 12 3/8-24 x 1-3/8 inch bolts (Fig. 9). Tighten bolts to 33-40 ft/lb. (45-54 N.m) torque. Bend a corner of lock strip against each of the bolt heads.
(6) Install plate (22) (Fig. 20) onto the converter output shaft.
(7) Place stator (3) on the assembly table, thick-edge vane side up.
(8) Install ten rollers (5) and ten springs (4) in stator (3). Retain the rollers and springs in the stator with a heavy coating of oil soluble grease.

Note: <u>Springs should be in the deep end of the cam pocket and the roller in the shallow end (Fig. 23). Note that the open end of the spring next to the roller is toward the bore of the stator</u>.

(9) Install freewheel roller race (21) (Fig. *LO)* into stator (3), splined end of the race first.
(10) Install assembled stator with roller race onto the converter output shaft, splined end of the race first.

Note: <u>Stator should rotate freely in a clockwise direction, but lock up when attempt is made to rotate it in the opposite direction</u>.

(11) Using spanner wrench J 6534, install freewheel roller race retainer nut. Tighten nut to 275-325 ft/lb. (374-442 N.m) torque and stake securely (Fig. 8).
(12) Install snap ring (19) (Fig. 24) onto converter output shaft (19) (Fig. 25).
(13) Install the assembled turbine, sprag and bearing assembly onto the converter output shaft.
(14) Install inner race of roller bearing (10) (Fig. 24) onto the converter output shaft and secure with snap ring (9).

## 74.26 Installing Overcenter Disconnect Clutch

(1) Position the converter housing on its output end.
(2) Install a headless guide bolt in the converter drive shaft housing (7) (Fig. 24).
(3) Using a sling, install the disconnect clutch assembly onto the converter, using the headless guide bolt to align the drive shaft housing (7) bolt holes with holes in converter pump(16) (Fig 20). Also align the disconnect housing-to-converter housing mounting bolt holes.
(4) Working through the converter cover access opening, remove the headless guide bolt, and install 30 converter driven shaft housing-to-converter pump 3/8-24 x1-1/4 inch bolts (17). Tighten bolts to 41-49 ft/lb. (56-66 N-m) torque.
(5) Install 11 converter housing-to-disconnect clutch housing bolts (23) (Fig. 14) with lock washers (24).
(6) Install converter housing access cover (4) and gasket (3) and secure with two 3/8-16 x 3/4 inch bolts (5) and lock washers (6). Tighten bolts to 26-32 ft/lb. (35-43 N.m) torque.

## 74.27 Installing Charging Oil Pump Assembly

(1) Install the oil pump body gasket and oil pump on the converter housing (Fig. 7).
(2) Secure the pump to the converter housing with six 3/8-16 x 1-3/8 inch bolts and lock washers. Tighten bolts to 26-32 ft/lb ft/lb. (35-43 N-m) torque.

**CAUTION**

Be Sure The Oil Pump Turns Freely After It Is Bolted To The Converter Housing.

(3) Install the converter housing access cover gasket (3) (Fig. 14) and cover (4) onto the converter housing. Secure the cover to the housing with two 3/8-16 x 3/4 inch bolts and lock washers. Tighten bolts to 26-32 ft/lb. (35-43 N-m) torque.

## 74.28 Wear Limits Data

The Wear Limits Chart at the end of this SM lists the maximum variations from the original dimensions at which the converter can be expected to function satisfactorily. It is possible that in individual cases, parts may give satisfactory service beyond the limits specified. The chart is based on field service experience and is intended only as a guide to parts replacement. Use this chart in conjunction with paragraph 74.4 on Cleaning and Inspection. Wear limits are illustrated in the exploded views and may be located by referring to the figure numbers and reference letters in the chart.

### 74.29 Bearings and Bearing Journals and Bores

The application of bearings to any product is based on the recommendation of the bearing manufacturer and, therefore, no diametral dimensional deviation should be permitted on the bearing or mating pieces. Bearings should be carefully checked for signs of distress before reinstalling in the product.

### 74.30 Gears

Gears should be inspected for load pattern and signs of distress. Any distress indicates a possible future failure and the re-using of such gears should be the decision of the individual customer based on previous experience. Backlash cannot be used to establish critical wear of a gear, since production backlash tolerances are of such nature that a gear usually pits, scuffs, scores, or galls long before the gear wears sufficiently that such wear could be determined by backlash measurements.

### 74.31 Splines

Unless severe, spline wear is not considered detrimental except where it affects tightness of an assembly such as drive line flanges. Here again, backlash cannot be used to establish critical wear of splines since both parts (male and female) must be centrally located in respect to each other in order to obtain a correct measurement.

### 74.32 Oil Seals

Seals should be replaced if there are signs of excessive hardening, scoring, or other indications of deterioration.

### 74.33 Springs

Springs should be replaced if they show signs of overheating, permanent set (see individual part wear limits for load versus height dimensions) or wear due to rubbing adjacent parts.

### 74.34 Piston Type Seal Rings

Sides of the seal ring should be smooth; maximum side wear 0.005 inch (0.127 mm). The sides of the shaft groove in which the seal ring runs should be smooth [50 micro-inch (1.25 micron) equivalent], and square with the axis of rotation within 0.002 inch (0.051 N.m). A new seal ring should be installed if shaft grooves are reworked, or seal ring outside diameter wear causes the possibility of the gap closing between the seal ring hooks when the ring is installed.

### 74.35 Troubleshooting

Following is a Troubleshooting Chart, which will help you locate the source of converter trouble. This chart is organized to cover troubles that may occur first -- due to improper maintenance. Remember that the Torqmatic converter is part of the power package, and, therefore, the whole package must be considered when running down the source of trouble.

| REFERENCE | DESCRIPTION | PART NUMBER | DIMENSION Inches | DIMENSION Millimeters | WEAR LIMIT Inches | WEAR LIMIT Millimeters |
|---|---|---|---|---|---|---|
| Fig. 14 | TORQUE CONVERTER HOUSING ASSEMBLY | | | | | |
| A | Oil pump drive gear | 6751502 | 4.162 | 105.715 | 4.172 | 105.969 |
| B | Oil pump drive gear thickness (gear may be reversed to equalize wear) | | Each face | | 0.006 | 0.152 |
| Fig. 20 | TORQUE CONVERTER TURBINE AND STATOR ASSEMBLY | | | | | |
| A | Turbine hub depth | 6772215 | 0.650/0.652 | 16.51/16.56 | 0.641 | 16.281 |
| B | Stator thrust washer | 6772295 | 0.478/0.486 | 12.141/12.345 | 0.460 | 11.684 |
| C | Roller thrust washer, thick | 6771017 | 0.023/0.027 | 0.584/0.686 | 0.022 | 0.559 |
| D&B | Stator side washer, thick | 6774117 | 0.340/0.360 | 8.636/9.144 | 0.032 | 8.128 |
| | All stator washers bore | | 4.010/4.014 | 101.854/101.956 | 4.016 | 102.006 |
| G | Stator back plate, thick | 6772199 | 0.334/0.338 | 8.4834/8.5854 | 0.324 | 8.230 |
| A | Clutch pressure. regulating valve, | 6770418 | | | 0.004 | 0.102 |
| Fig. 26 | CHARGING OIL PUMP | | | | | |
| | Gear end clearance clearance with oil pump cover | | | | 0.010 | 0.254 |
| B | Clutch pressure spring, free height | 6770417 | 2.397 | 60.884 | | |
| | (Length under force of 24 to 28 pounds or 106.78 to 124.55 N is 1.75 inches of 79.9 mm) | | | | | |
| | Clutch pressure spring, free height | 6773896 | 2.496 | 63.398 | | |
| | (Length under force of 29 to 31 pounds or 129.0 to 137.9 N is 1.75 inches or 79.9 mm) | | | | | |
| C | Converter pressure regulating valve, clearance with oil pump cover | 6756527 | | | 0.006 | 0.152 |
| | Converter pressure spring, free height | 6756484 | 4.72 | 119.888 | | |
| | (Length under force of 91.2 to 100.8 pounds or 408.35 to 448.38 N is 3.420 inches or 86.868 mm) | | | | | |

**TROUBLESHOOTING CHART**

A. LOW CONVERTER CHARGING PRESSURE

| CAUSE | REMEDY |
|---|---|
| 1. Low oil supply | 1. Add oil. |
| 2. Oil line leakage | 2. Check for air leaks in suction lines and oil leaks in pressure lines. |
| 3. Excessive oil flow to transmission | 3. Check operation of clutch pressure valve, converter bypass valve and transmission driven pump. |
| 4. Plugged inlet line or screen | 4. Check inlet line and screen; clean if necessary. |
| 5. Defective oil pump | 5. Check for wear in oil pump. |
| 6. Suction screen uncovered | 6. Low oil level or improper installation of screen. Correct as required. |
| ,7. Oil foaming | 7. Oil return line not below oil level in sump. |

B. HIGH OIL TEMPERATURE

| | |
|---|---|
| 1. Low oil level (low flow rate) | 1. Add oil. |
| 2. High oil level | 2. Drain oil to full mark. |
| 3. Low water level in cooling system | 3. Add water. Check for leaks. |
| 4. Low converter charging pressure | 4. Refer to 'A' above. |
| 5.. Clogged or dirty heat exchanger or filter | 5. Clean or replace as necessary. |
| 6. Operating too long in an inefficient converter range. | 6. Readjust work cycle to allow converter operation in an efficient converter range. |
| 7. Stator locked | 7. Check for low top speed of vehicle or other equipment. |
| 8. Stator installed without rollers or springs (low stall speed) | 8. Disassemble converter and install rollers or springs. |

C. HIGH ENGINE SPEED AT CONVERTER STALL

| | |
|---|---|
| 1. Low oil supply | 1. Add oil. |
| 2. Low converter charging pressure | 2. Refer to 'A' above. |
| 3. High oil temperature | 3. Refer to 'B' above. |

D. LOW ENGINE SPEED AT CONVERTER STALL

| | |
|---|---|
| 1. Low engine output torque | 1. Tune engine and check output. |
| 2. Converter element interference | 2. Check for noise at stall. Overhaul converter if necessary. |
| 3. Stator installed without rollers | 3. Disassemble converter and install rollers |

E. LOSS OF POWER

| | |
|---|---|
| 1. Stator installed without rollers (low | 1. Disassemble converter and install rollers. |
| 2. Low converter charging pressure | 2. Refer to 'A' above. |
| 3. Low engine speed, at converter stall | 3. Refer to 'D' above. |

F. MANUAL INPUT DISCONNECT CLUTCH SLIPPAGE

| | |
|---|---|
| 1. Clutch facing wear | 1. Adjust clutch. |
| 2. Grease on faces | 2. Clean parts. |

## 75.1 General Information

The diesel engine has no carburetor or ignition system. Air is drawn into the combustion chamber on the intake stroke and heated to about 1000°F by compression of the air on the compression stroke. Near top dead center diesel fuel is injected under pressure into the heated air in the combustion chamber. The diesel fuel ignites and burns, forcing the piston down on the power stroke. The burned gases (exhaust) are forced out through the exhaust valves on the next, or exhaust, stroke.

Starting a diesel engine above 50° F is no problem. But as the temperature drops, it becomes increasingly hard to start the engine because the temperature at the end of the compression stroke is directly proportional to the inlet air temperature and because some of the heat of compression is absorbed by the piston, cylinder walls, and cylinder head. This heat loss can be great enough to lower the air temperature in the combustion chamber below 725° F, which is the approximate ignition temperature of diesel fuel.

Starting fluid has an ignition point of approximately 350° F, and when drawn into the cylinder with the intake air, it will ignite and burn as it is compressed. The burning of the starting fluid raises the temperature in the combustion chamber high enough to ignite and burn the diesel fuel when it is injected. Using too little starting fluid will not start the engine, and too much causes "pinging" and possible engine damage or even engine "lock-up". A "measured shot" of starting fluid is sprayed through an orifice into the air intake stream will obtain a quick start. The fluid is injected during a 3 to 5 second period.

The high pressure cylinder is designed to disperse starting fluid through a "measured shot" system and give good atomization at -650 F. 75.2 Trouble Shooting

**WARNING**

When Maintaining Or Troubleshooting These Systems, Always Make Sure That You Are In A Well-Ventilated Area Away From Heat, Open Flames, Or Sparks. Wear Goggles When Testing To Avoid Eye Injury. Make Sure That Openings Of The Valve, Tube, Or Atomizer Are Pointed Away From Yourself While Testing.

The Ethyl Ether Used In This Starting Fuel For These Systems Is Extremely Flammable, Toxic, Harmful, Or Fatal If Swallowed. Avoid Contact With The Skin Or Eyes And Breathing The Fumes. If Swallowed, DO NOT INDUCE VOMITING. Call Physician Immediately.

If Fuel Enters Eyes Or Fumes Irritate Eyes, They Should Be Washed With Large Quantities Of Clean Water For 15 Minutes. A Physician, Preferably An Eye Specialist, Should Be Contacted.

Do Not Store Cylinders In Temperatures Above 160° F Contents Are Under Pressure. Do Not Incinerate, Puncture, Or Attempt To Remove Center Core Valve Or Side Safety Valve From Cylinder.

Check These Points When The Unit Does Not Operate Correctly.

(a) Fuel Cylinder: Check to see if cylinder is handtight and screwed all the way down. Check starting fluid supply (empty cylinder weight is approximately 16 oz/453.6g; a FULL cylinder is approximately 33 oz/935.6g).

If the cylinder is empty - replace.

Important: Always check valve gasket under cylinder (it is suggested to replace gasket when changing fuel cylinders). If gasket is damaged or missing, the valve will leak when operated. Replace with new gasket. If two gaskets are used. The valve may not operate. (Gasket No. 111025).

Always clean dirt away from the top and exterior of the valve before removing cylinders and clean out valve area where cylinder is installed since any dirt or foreign matter can clog the valve or atomizer of your system.

After checking all other components of the system in accordance with the listed trouble shooting points, if the cause of the inoperative condition still is not discovered check the cylinder to determine if it has pressure.

(b) Atomizers:

Important: Atomizer or Orifice clogging is a common cause for failure of a system and one reason is dirt that has been allowed to get into the valve when changing fuel cylinders.

To check atomizer, remove from engine and activate the system. If no fuel sprays out of the atomizer, disconnect it from the tubing. Activate system, if fuel flows out of the tubing, atomizer must be replaced.

(c) Tubing: If fuel has not flowed out of the end of the tubing after removing the atomizer, disconnect the tubing from the valve and reactivate system. If fuel flows out of the valve, the tubing is obstructed and should be replaced.

(d) Mechanical Valve: Activate valve by moving lever or knob up and then down, if no fuel is dispensed the valve is clogged or damaged. Replace valve. If valve operates, check control cable for damage and wire stop screw for tightness.

(e) Electrical Valve:

Note: Never hold the Push Button switch in for more than 5 seconds, as this can damage the electric valve solenoid. Activate valve by turning ignition switch on and pressing and releasing the push button switch, if no fuel is dispensed, remove fuel cylinder.

(1) Activate valve. plunger should move up and stay up until the push button switch is released. Valve is operative if plunger responds correctly. Go on to (f).

(2) If plunger does not move up:

(a) Jump the push button switch. If valve is operative, switch is defective and should be replaced. Go on to (f).

(b) If not thermostat is used, go on to (c).Short out the thermostat using a jumper wire. If the valve operates the thermostat is defective and should be replaced.

(c) If after jumping the push button switch (an the thermostat is used) the valve is not operative, check wiring for continuity.

(d) If the valve is still inoperative, replace it.

(f) Reassembly: After correcting the problem, reinstall tubing and' atomizer. Double check to see that all fittings have been replaced properly and are tight.

## 75.3 Preventive Maintenance

Take every precaution to avoid getting dirt inside top of valve, since this can get into valve chamber causing a clogged valve or atomizer. Refer to Troubleshooting" point "A" before replacing empty cylinders.

Check fittings for leaks.

Check all mounting bolts to make sure that they have not loosened. Periodically test unit for proper operation by following the steps recommended in the "Troubleshooting Procedures".

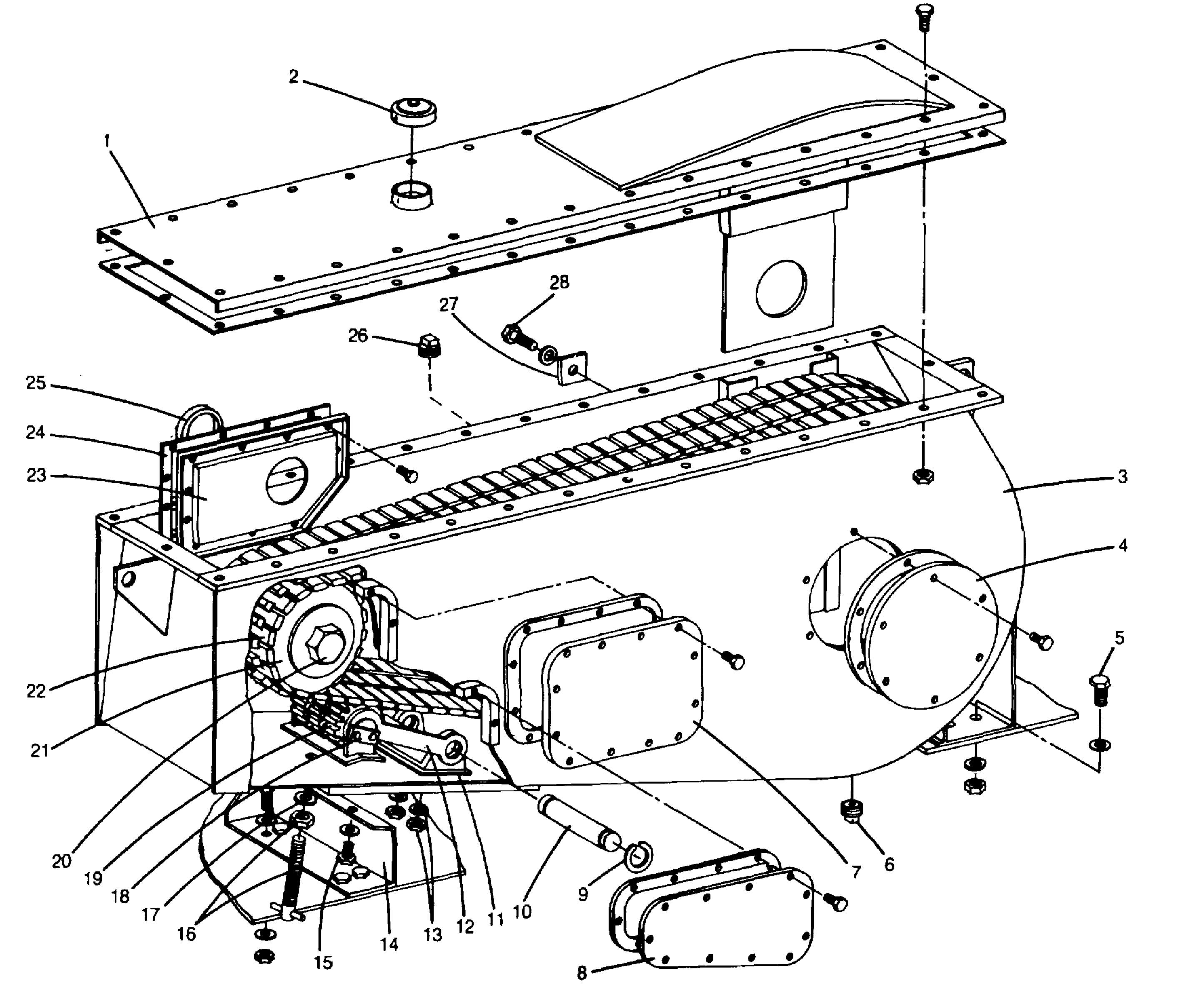



*Fig. 1* KA254-B

*Chain Case W/Chain Tension Adjuster*

(1) Top Cover
(2) Cap
3) Chain Case
(4) Drive Sprocket Cover
(5) Capscrew
(6) Drain Plug
(7) Drive Pinion Cover
(8) Adjuster Cover
(9) Snap Ring
(10) Adjusting Arm Pin
(11) Adjusting Arm Bracket & Gasket
(12) Adjusting Arm
(13 Locknut and Thread Seals
(14) Bracket
(15) Capscrew
(16) Adjusting Screw and Nut
(17) Thread Seal
(18) Lock Bar
19) Sprocket
(20 Capscrew
(21 Drive Pinion
(22) Drive Chain
(23) Retainer
(24) Gasket
(25 Oil Seal
(26 Check Plug
(27 Outboard Bearing Support, Spacer & Capscrews
(28) Capscrew

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The chain case is equipped with a chain tension adjuster. The tension adjuster eliminates the need to move the engine to set drive chain tension. The chain case also dips the chain into oil at the bottom of the case.

### 6.1 Chain Case Removal (Fig. 1 and Fig. 2)

(a) Drain fuel from the fuel tank. Disconnect the fuel lines from the fuel tank. Plug all fuel lines and fuel tank openings to prevent contamination.
(b) Remove fuel tank mounting capscrews. Next, remove fuel tank from the machine.
(c) Remove all covers (items 1, 4, 7, and 8 in Fig. 1) and gaskets. Drain lubricant from the chain case by removing the drain plug (6). Collect the lubricant in a container and clean up any spills.
(d) Loosen the adjusting screw nut and adjusting screw (16). To remove the drive chain, refer to "Engine Drive Removal" next in this SM.
(e) Remove adjusting screw and nut (16) along with the thread seal (17).
(f) Remove the capscrew (20) and the drive pinion (21).
(g) Remove the capscrews (28) connecting the chain case to the outboard bearing support. Also remove the outboard bearing spacers (27).

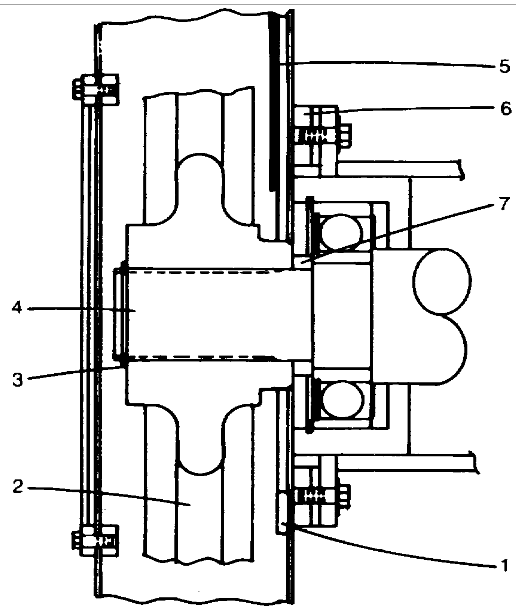


*Fig. 2* *KA254-B*
*Chain Wheel*

(1) Hydroil Washer
(2) Chain Wheel
(3) Snap Ring
(4) Reduction Shaft
(5) Top Chain Case Cover Retainer
(6) Spacer
(7) Upper Reduction Shaft Spacer

(h) Attach 300 lb.(137 kg) capacity hoist to chain wheel. After the chain wheel is securely supported by the hoist. remove the chain wheel snap ring (item 3 in Fig. 2).
(i) Remove the capscrews and nuts (item 13 in Fig. 1) holding the chain case to the house floor. Carefully slide the chain wheel and chain case off of the reduction shaft. At the same time, slide the chain case clear of the torque converter output shaft. Remove the chain case from the machine.

Note: <u>During chain case removal, take precautions to protect the torque converter, torque converter output shaft, and reduction shaft.</u>

**CAUTION**

The Chain Case Must Be Supported At All Times By A Hoist.

(j) Set the chain case, upright, on a flat clean surface. Place 18 inches (45.72 cm) of blocking below the adjuster end of the chain case.
(k) Use the hoist to lift the chain wheel (2) and hydroil washer (item 1 in Fig. 2) from the chain case. Set the chain wheel on its side, hydroil washer on top, on blocking. Disconnect the hoist. Remove hydroil washer.
(l) Remove the locknuts (item 13 in Fig.1) holding the chain tension adjuster assembly to the chain case. Lift the chain tension adjuster out of the chain case. Set the adjuster assembly on a clean, dry, flat surface.
(m) Remove the snap ring (9) and pull the pin (10) out of the adjuster assembly. Remove the two locking capscrews and lock bar (18)from the adjuster assembly. Remove sprocket pin, shims, and sprocket (19) from the adjuster assembly. Remove the bearings from the sprocket with a bearing puller.
(n) Remove the capscrews holding the retainer (23) to the side of the chain case. Remove the retainer (23), gasket (24) and oil seal (25) from the chain case.
(o) Remove spacer (item 7 in Fig. 2) from the upper reduction shaft.

### 6.2 Engine Drive Chain Removal

(a) If the drive chain is not broken, rotate chain wheel until the connecting link is on top of the chain wheel.
(b) Loosen the adjusting nut and turn out the adjusting screw (item 16 in Fig. 1).
(c) Remove the cotter pin from the connecting link. Remove the centering link and afterwards, the drive chain (22).

### 6.3 Chain Repair: If the chain is broken, it can be repaired with new sections. Refer to Fig. 3.

These replacement section can be used:

(1) Three-Pitch Section
(2) Five-Pitch Section
(3) Offset Link or Two-Pitch Section

Note: <u>See Parts Book for Section Part Numbers</u>.

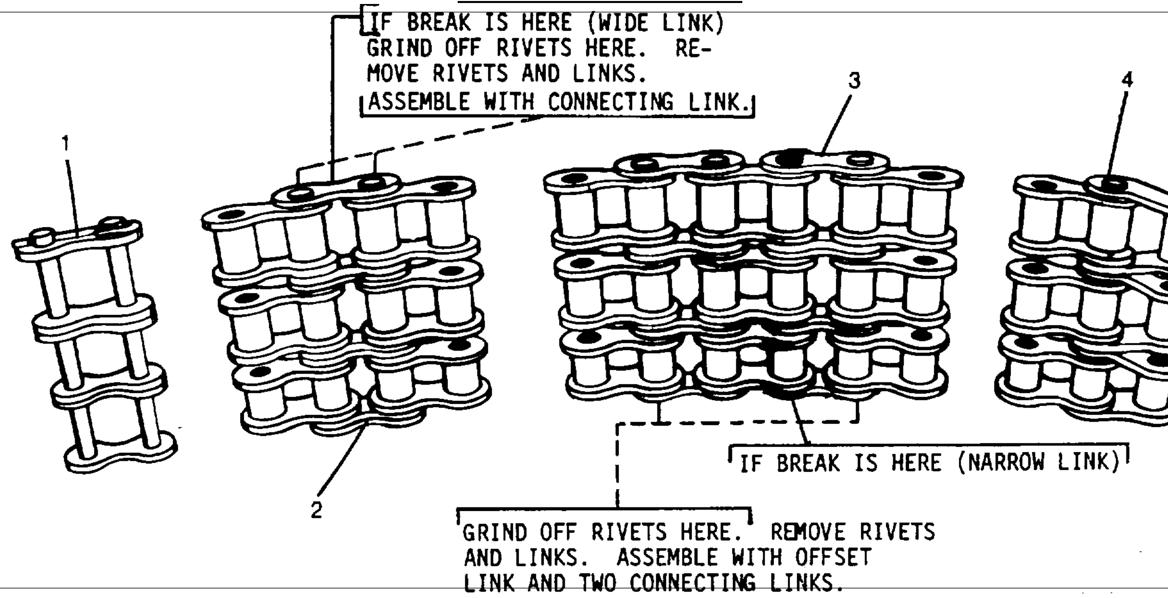


*Fig. 3*
*Chain Links*
(1) Connecting Link
(2) Three-Pitch Section
(3) Offset Link
(4) Five-Pitch Section

(a) To remove broken links, grind rivet heads on each side of the break. Remove the loose links that were hooked to the rivets. Connect chains with connect links. Connect chain with connecting links (see Fig. 3). To remove broken links on a narrow link, grind rivet heads on outside of each adjacent wide link. Remove rivets. Remove the loose links that were hooked to the rivets. Connect an offset link to the chain with a connecting link. Connect the chain with another connecting link.

(b) Connecting links are held with an oil field type cotter. The cotter goes through both pins of the coupling link. The cotter holds better during high speed operation than separate cotters in each pin would. Insert the cotter as shown in Fig. 4. Bend the cotter between the pins with a punch and a hammer. This holds the cotter in place.

(c) If several links are damaged, longer sections must be installed to repair the chain. Count the number of links to be replaced and make up an equal length of new chain by combining two, three, and five-pitch sections. The sections must be connected with connecting links. Grind off rivet heads and remove the damaged section. Connect the new sections to the old section with a connecting link. Connect the chain with a connecting link.

### 6.4 Drive Chain Adjustment (Fig. 5)

Chain tension is adjusted by lowering or raising the adjusting arm and pinion (item 3 in Fig. 5) with the adjusting screw (4). The chain case must be installed on the machine before adjusting drive chain tension. Refer to "Chain Case Installation" procedure, later in this SM, for instructions. To adjust the drive chain, do the following:

(a) Remove cap (1) from top of chain case.

(b) Loosen jam nut (5) on adjusting screw (4). Turn in on adjusting screw until chain is taut.

(c) Measure from the lip where the plug mounts to the top strand of the chain. Back off on the adjusting screw until there is 5/8" (15.8 mm) sag in the top span of the chain. Refer to Dimension 'A'. While making the measurement, push down with a stick or bar on the chain top span to keep the bottom span of the chain taut.

(d) Apply silastic gasket material to the thread

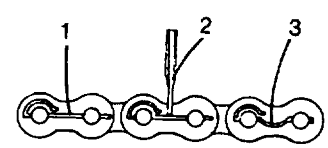


*Fig. 4*
*Oil Field Cotter Installation*
(1) Cotter In Position
(2) Hit Punch
(3) Cotter Bent

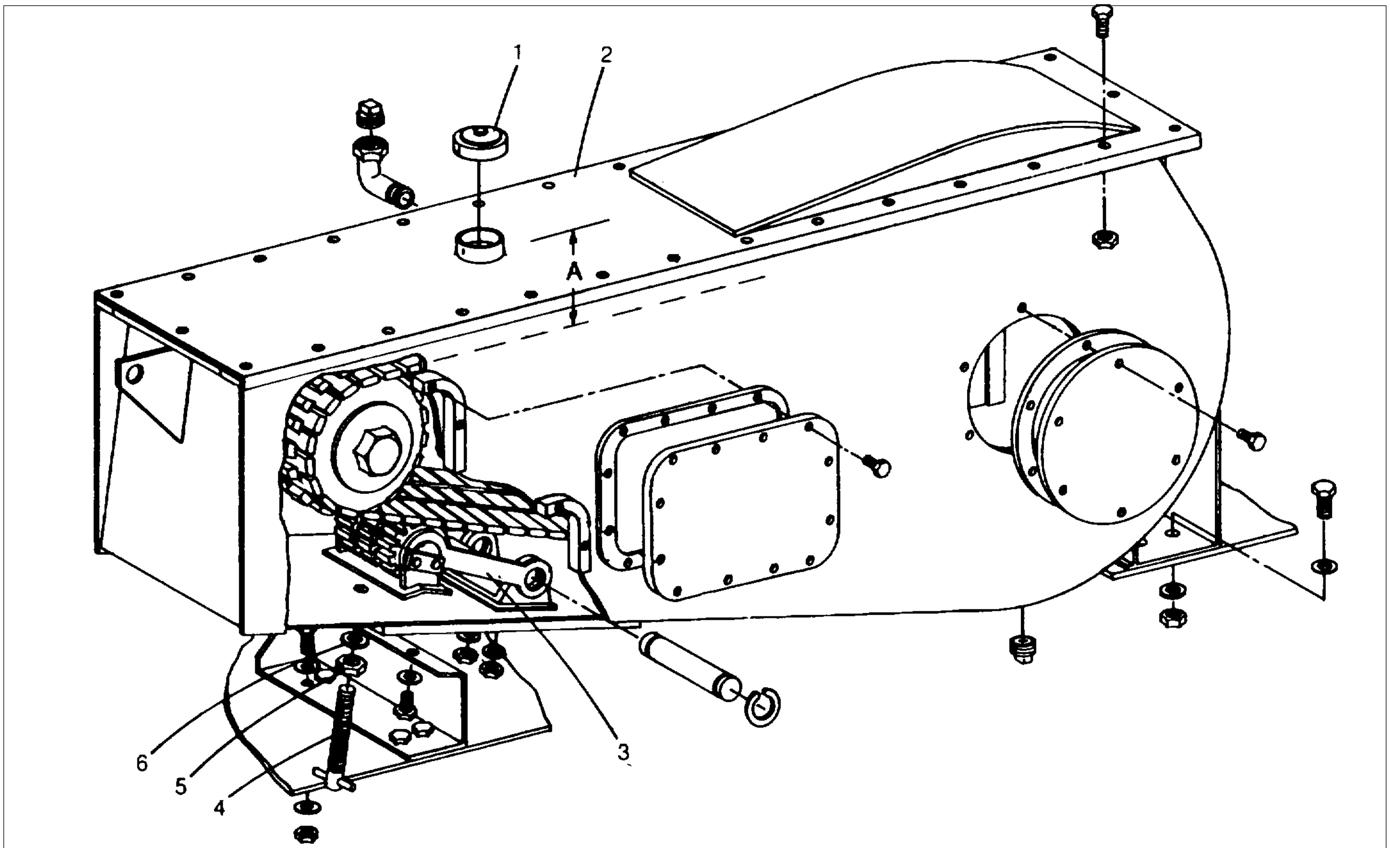


*Fig. 5* KA254-B
*Drive Chain Tension Adjustment*

(A) 5/8" (15.87 mm) Sag In Top Of Chain
(1) Cap
(2) Chain Case Cover
(3) Adjusting Arm and Pinion
(4) Adjusting Screw
(5) Jam Nut
(6) Thread Seal

seal (6), the adjusting screw threads nearest the chain case, and adjust jam nut (5). Tighten jam nut (5) on the adjusting screw (4). Install cap (1).

### 6.5 Chain Case Installation (Fig. 1 and 2)

Before installing the chain case, replace all of the old gaskets. Refer to the Parts Book for part numbers. To install the chain case, do the following:

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(a) Thoroughly clean out the inside of the chain case with an approved solvent. Remove (scrape off) all of the old gasket material.
(b) Before installing the oil seal (item 25 in Fig. 1), gasket (24), and retainer (23), apply Permatex #2 to both sides of the gasket and all the retaining capscrews. Next install the oil seal, gasket, retainer, and retainer capscrews on the chain case.
(c) Pack both the sprocket ball bearings with bearing grease Type 'A' (refer to Operators Manual, Section 2 for Type 'A' lubricant specifications). Press the bearings into the idler sprocket (19). Use a dab of grease to hold two sprocket shims on each side of the idler sprocket. Install the sprocket and shims into the adjuster arm and secure with the sprocket pin, lock bar (16), and locking capscrews.
(d) Apply Permatex #2 to both sides of the adjusting arm bracket gasket (11) and to the studs on the bottom of the bracket. Install the gasket and the adjusting arm bracket on the inside of the chain case. Apply silastic gasket sealer to the thread seals (13) and install the thread seals and locknuts (13), beneath the chain case, to anchor the adjusting arm bracket.
(e) Install spacer (item 6 in Fig. 2) on the upper jack shaft.
(f) Check to see if bracket (item 14 in Fig. 1) is installed on the house floor. If bracket

is not in place, install it.

(g) Install the hydroil washer (item 1 in Fig. 2) on the chain wheel. Use a small dab of Type ’A’ bearing grease to help attach it. Connect a 300 pound (137 kg) capacity hoist to the chain wheel. After the hoist is securely connected, lift the chain wheel and hydroil washer into the chain case. Carefully insert the chain wheel into the chain case and carefully slide the washer into the brackets on the chain case wall. Use the hoist to support the chain wheel at all times.

**CAUTION**

Do Not Disconnect The Hoist From The Chain Wheel. Use The Hoist To Support The Weight Of The Chain Wheel To Prevent Damage To The Hydroil Washer.

(h) Position the chain case on the house floor using the hoist to support the chain wheel. Carefully slide the chain case oil seal (item 25 in Fig. 1) over the torque converter shaft. Also carefully guide the chain wheel onto the upper reduction shaft. Use a snap ring (item 3 in Fig. 2) to secure the wheel on the shaft. Disconnect the hoist from the chain wheel.

(i) After the chain case is set in place, check the alignment of the chain case bracket holes, front and rear. If the holes do not align, move bracket (item 14 in Fig. 1) until holes are aligned.

(j) Place a spacer between the front chain case bracket and the house floor. Attach the bracket to the floor with capscrews (5).

(k) Tighten the capscrews holding the rear chain case bracket (14) to the house floor. Apply Permatex #2 ’on the adjuster arm bracket threads and thread seals (13). Attach the thread seals and locknuts (13) to secure the chain case.

(l) Attach the engine drive pinion (21) to the torque converter output shaft. Secure the drive pinion with capscrew (20).

(m) Install the thread seal (17), jam nut, and adjusting screw (16) in the bottom of the chain case.

Note: Do not lock the adjusting screw in position with the jam nut. The adjusting screw must be free to move.

(n) Install the drive chain (22) around the drive pinion (21) and the chain wheel. Refer to "Drive Chain Installation" in this SM for instructions.

(o) After the drive chain is installed, set the drive chain tension using the "Drive Chain Adjustment" procedure in this SM.

(p) Install chain case drain plug (6).

(q) Fill chain case with required amount of chain lubricant.

(r) Apply Permatex #2 to both sides of all the chain case cover gaskets, along with all the cover capscrews.

(s) Install the cover gaskets, chain case covers (1, 4, 7, and 8), and capscrews on the chain case.

(t) Install empty fuel tank on the machine. Secure fuel tank with capscrews.

(u) Unplug the fuel lines and fuel tank openings. Reconnect the fuel lines to the fuel tanks. Add fuel to the fuel tank.

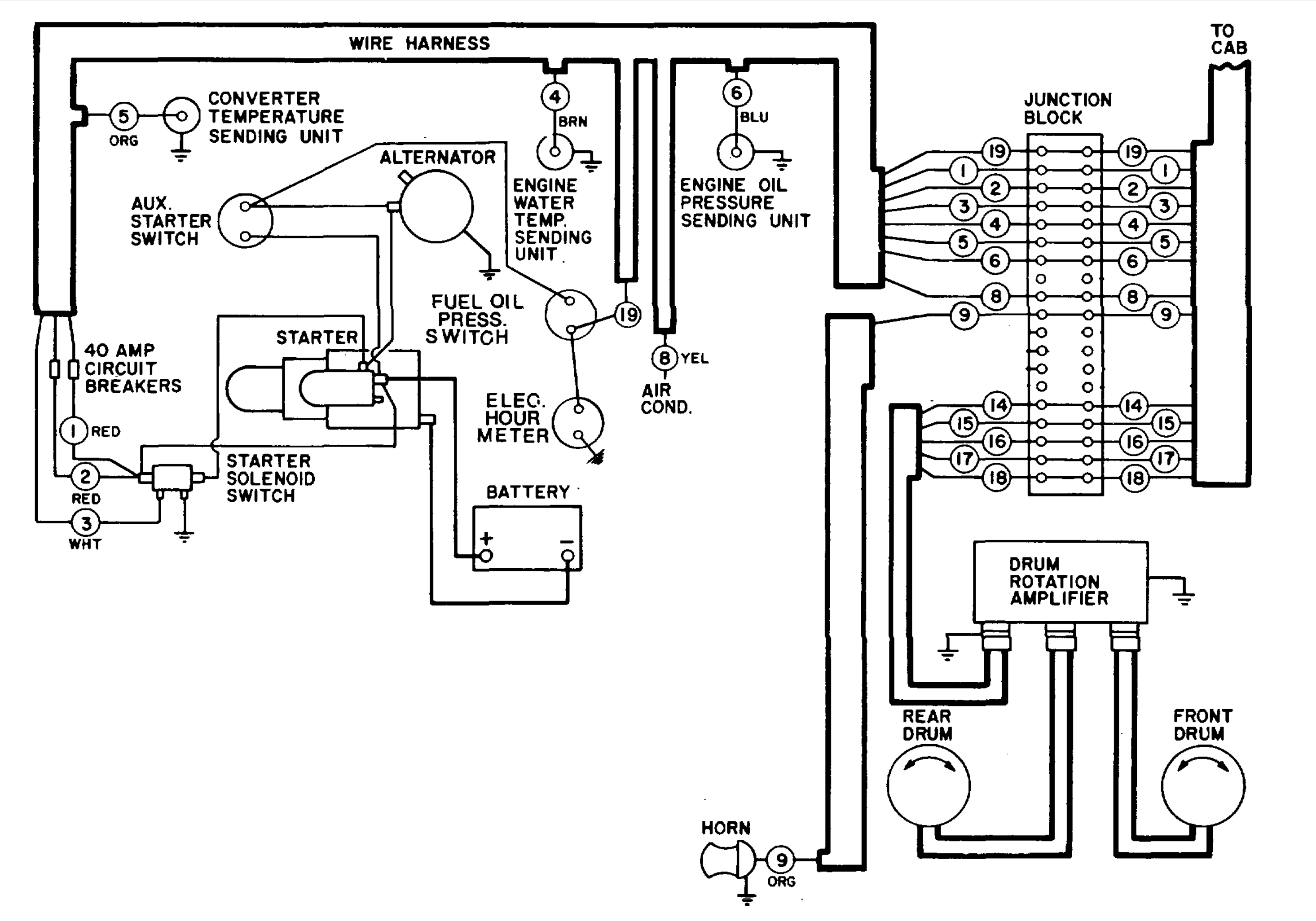


*Fig-. 1* NA293-D '
*Upper Engine and Electrical Wiring*

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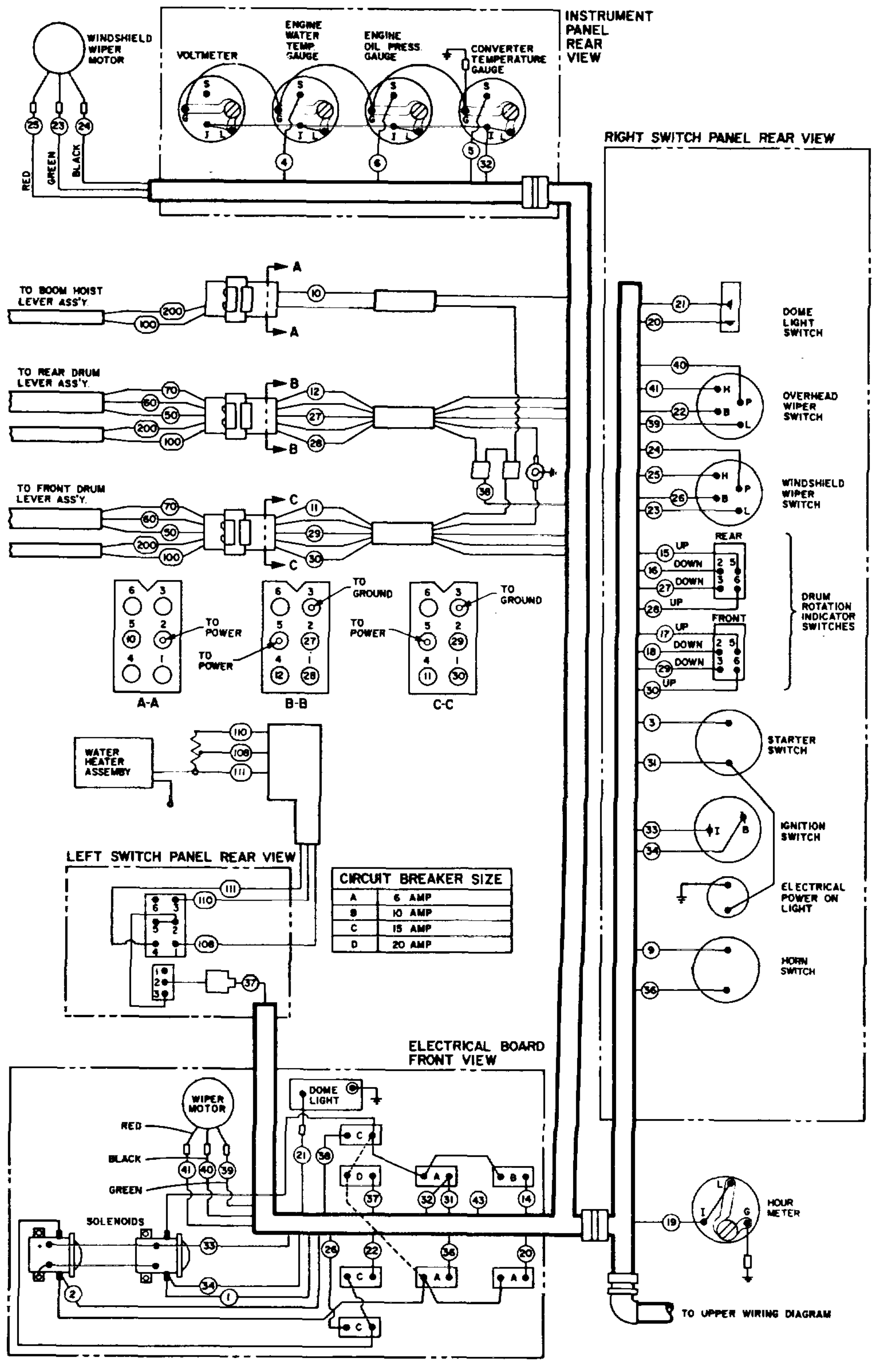



| CIRCUIT BREAKER SIZE | |
|---|---|
| A | 6 AMP |
| B | 10 AMP |
| C | 15 AMP |
| D | 20 AMP |

*Fig. 1-*
*Upper Cab Wiring*

WIRE CHART

| No. | Color | Function | No | Color | Function | No. | Color | Function |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 1 | Red | +12 VDC - Mn. Brk. | 18 | Yel | F.D. Rot. Indic. | 33 | Wht | Ignition Switch - Sol. |
| 2 | Red | +12 VDC - Mn. Brk. | 19 | Grn | Hourmeter | 34 | Red | Ignition Switch |
| 3 | Wht | Starter | 20 | Red | Dome Light | 36 | Red | Horn |
| 4 | Brn | Water Temp. | 21 | Blue | Switch - Light | 37 | Wht | Heater |
| 5 | Org | Convert. Temp. | 22 | Wht | Upper Wiper | 38 | Org | Rt. Lev. |
| 6 | Blue | Oil Pres. | 23 | Grn | Lower Wiper Switch | 39 | Grn | Upper Wiper - Low. |
| 7 | Grn | Fuel Shutdown | 24 | Blk | Wiper - Park | 40 | Blk | Upper Wiper - Park |
| 9 | Org | Horn | 25 | Red | Wiper - High | 41 | Red | Upper Wiper - High |
| 10 | Blue | B.H. Planet. | 26 | Wht | Wiper Mot. | 50 | Blk | Ground Lev. |
| 11 | Grn | F.D. Planet. | 27 | Grn | R.D. Indic. - Lev. | 60 | Brn | Rot. Indic, Blue Button |
| 12 | Brn | R.D. Planet. | 28 | Grn | R.D. Indic. - Lev. | 70 | Wht | Rot. Indic, Gold Button |
| 14 | Wht | Rot. Indic. Amp. | 29 | Yel | F. . Indic. - Lev. | 100 | Blue | Two Speed |
| 15 | Grn | R.D. Rot. Indic. | 30 | Blue | F.D. Indic. - Lev. | 108 | Wht | Heater - Med. |
| 16 | Org | R.D. Rot. Indic. | 31 | Wht | Starter Switch | 110 | Red | Heater - Low |
| 17 | Blue | F.D. Rot. Indic. | 32 | Wht | Gauges | 111 | Vio | Heater - High |
| | | | | | | 200 | Org | Two Speed |

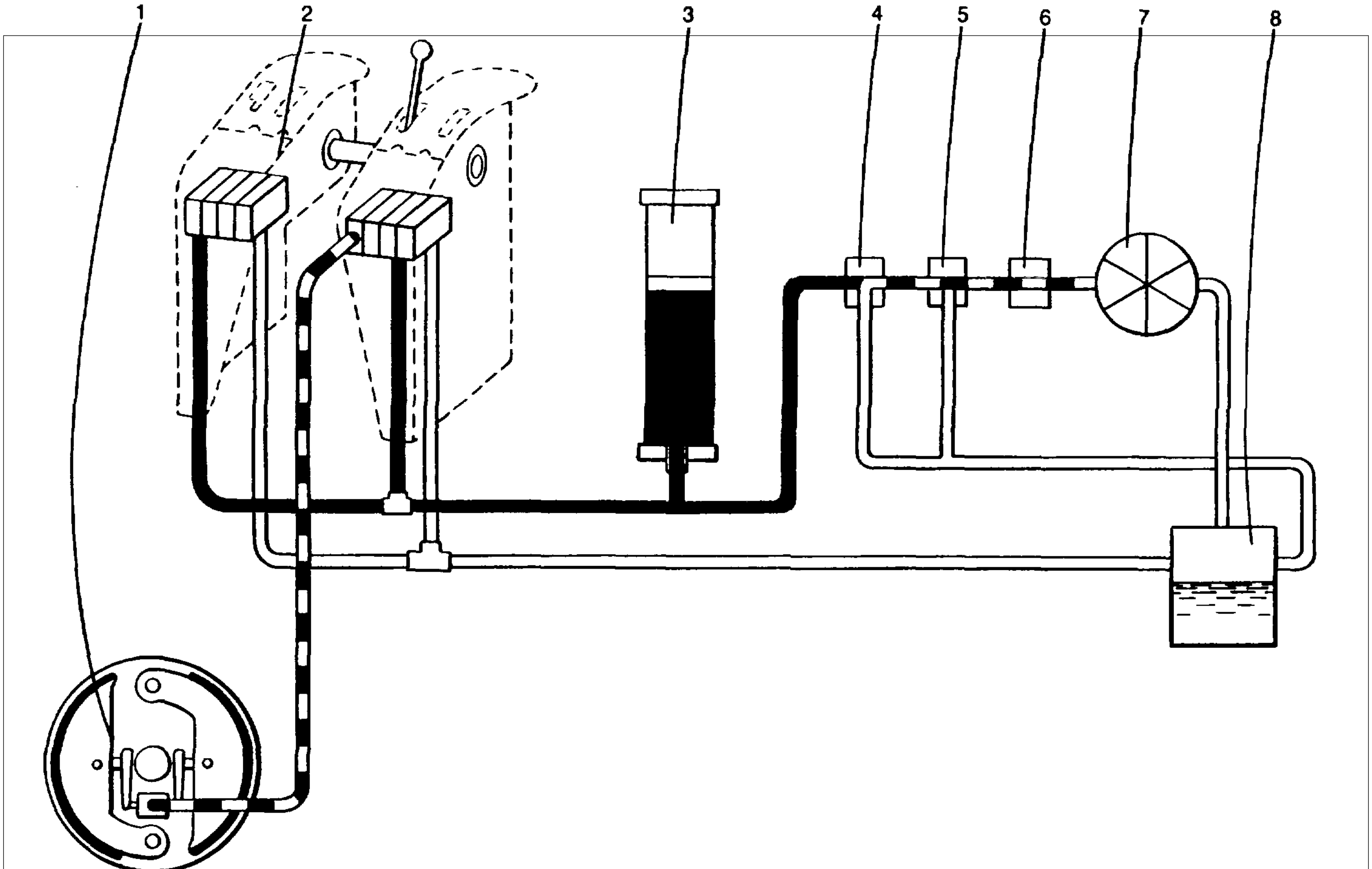
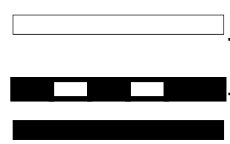



Fig. 1 Z183-B

*Control System Schematic*

(1) Clutch
(2 Control Stand
(3 Accumulator
(4) Unloader Valve
(5) Relief Valve
(6) Filter
(7) Pump
(8) Sump Tank


...........No Pressure

...........Variable Pressure

...........Constant Pressure

Fig. 1 illustrates schematically, the component parts of the S-o-M system. The following series of descriptions, in conjunction with a later series of diagrams, will help in understanding the principle of operation of the Speed-o-Matic system.

## 5.1 Sump Tank

The sump tank contains the oil supply for the S-o-M control system. The tank contains ten gallons of oil.

## 5.2 Oil Check Procedure

The oil level should be checked at the interval listed in Section 2 of the Operators Manual, as follows:

(a) Park the machine on level ground.
(b) Decrease the operating pressure to zero by working the control levers back and forth. Failure to do so will result in a false level reading on the dipstick, due to the amount of oil stored in the accumulator. See "Accumulator" later in this SM.
(c) Fully retract all outrigger beams and jacks.
(d) Remove the dipstick, and read the oil level. Add oil if necessary. Use only FMC hydraulic oil in the system. Several weights of oil are available for use in the system, depending upon the temperatures the machine is being operated under.

(1) 5W oil (5 gallon can - 830661001; 55 gallon drum - 830661002).
(2) 5W20 oil (5 gallon can - 830662001, 55 gallon drum - 830662002).
(3) 10OW20 oil (5 gallon can - 830663001, 55 gallon drum - 830663002).
(4) 20W40 oil (5 gallon can - 830664001, 55 gallon drum - 830664002).

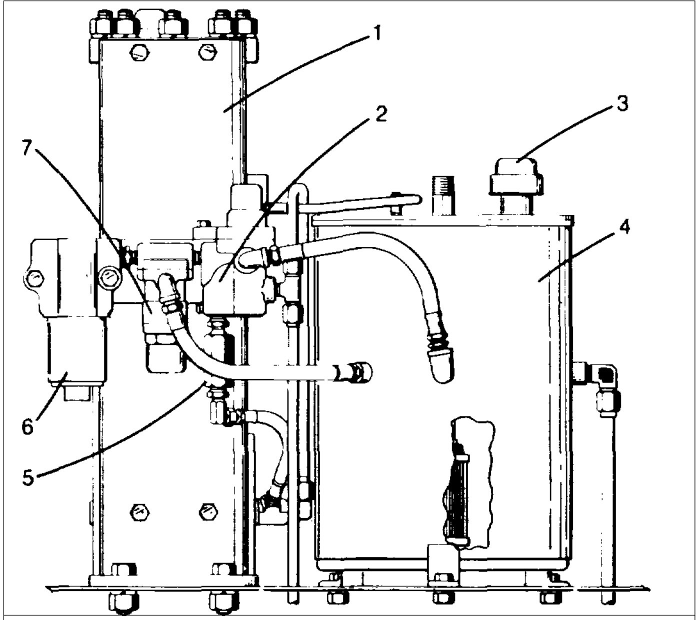



*Fig. 2* L117-C
*Hydraulic Power Assembly*

(1) Accumulator
(2) Unloader Valve
(3) Dipstick & Breather
(4) Sump Tank
(5) External Check Valve
(6) Oil Filter
(7) Relief Valve

Refer to Section 2 of the Operators Manual for more information on these oils, and for a listing of the oil specifications.

The 20W40 oil is to be used in machines consistently operating in temperatures of 300F to 115°F. The 10W20 oil is to be used in machines consistently operating in temperatures of 10°F to 900F. The 5W20 oil is to be used in machines consistently operating in temperatures -35c to 20°F. In machines operating in temperatures -40°F and lower, it is permissible to dilute the oil with uncracked kerosene. Kerosene will evaporate, especially during warm spells; therefore, the sump tank level should be checked periodically. Caution should be exercised in diluting with kerosene in climates where temperatures become this low only upon occasion.

## 5.3 Oil Change Procedure

The oil should be changed at the interval listed in Section 2 of the Operators Manual, as follows:

(a) Park the machine on level ground.
(b) Decrease the operating pressure to zero by working the operating levers back and forth.
(c) Fully retract all outrigger beams and jacks.
(d) Drain the oil by removing the magnetic drain plug in the bottom of the tank.
(e) Remove and thoroughly clean the breather cap on top of the tank. Use kerosene or some similar approved solvent.
(f) Remove the top cover from the sump tank. Remove and thoroughly clean the sump tank strainer in kerosene or some similar approved solvent.
(g) Thoroughly clean the inside and outside of the tank and cover with kerosene or some similar approved solvent.
(h) Reassemble the sump tank strainer and cover. Clean and replace the magnetic drain plug.
(i) Replace the system filter, as explained later in this SM.
(j) Refill the sump tank with oil corresponding to the specifications listed previously in this SM. When adding oil, use a clean funnel equipped with a screen strainer. The importance of cleanliness cannot be stressed too highly when pouring oil into the hydraulic system. Dirt, dust, lint, or water should not be allowed to enter the system.
(k) Submerge the breather cap in heavy lubricant oil before installing it on the sump tank.

## 5.4 General Maintenance Instructions for the S-o-M System

(a) Check frequently to make sure that all connections and fittings are tight. By keeping them tight, the introduction of air, as well as dirt and contamination, will be avoided, and leakage will be kept to a minimum.
(b) Whenever a line or fitting is disconnected, clean an area around the point of disassembly to prevent entry of dirt into the system.
(c) Whenever a component is removed, immediately cap or plug all openings in the lines to prevent entry of foreign material.

## 5.5 System Operation

As illustrated in Fig. 3, the hydraulic pump picks up oil from the sump tank and transfers it through the filter, relief valve, and unloading valve, into the accumulator and pressure manifold which is common to all control valves. As the pump builds up the system pressure, the piston within the accumulator moves in an upward direction, compressing the "dry" nitrogen above the piston to the same pressure as the oil below the piston.

When the hydraulic pressure in the accumulator and the pressure manifold reaches approximately 1050 psi, the unloading valve "cuts out" and changes the direction of the flow of oil from he pump and directs it back to the sump tank t practically zero pressure. This is illustrated in Fig. 4.

Through operation of one or more control valves, he system pressure decreases and the piston within the accumulator moves downward, maintaining the equal pressure above and below it.

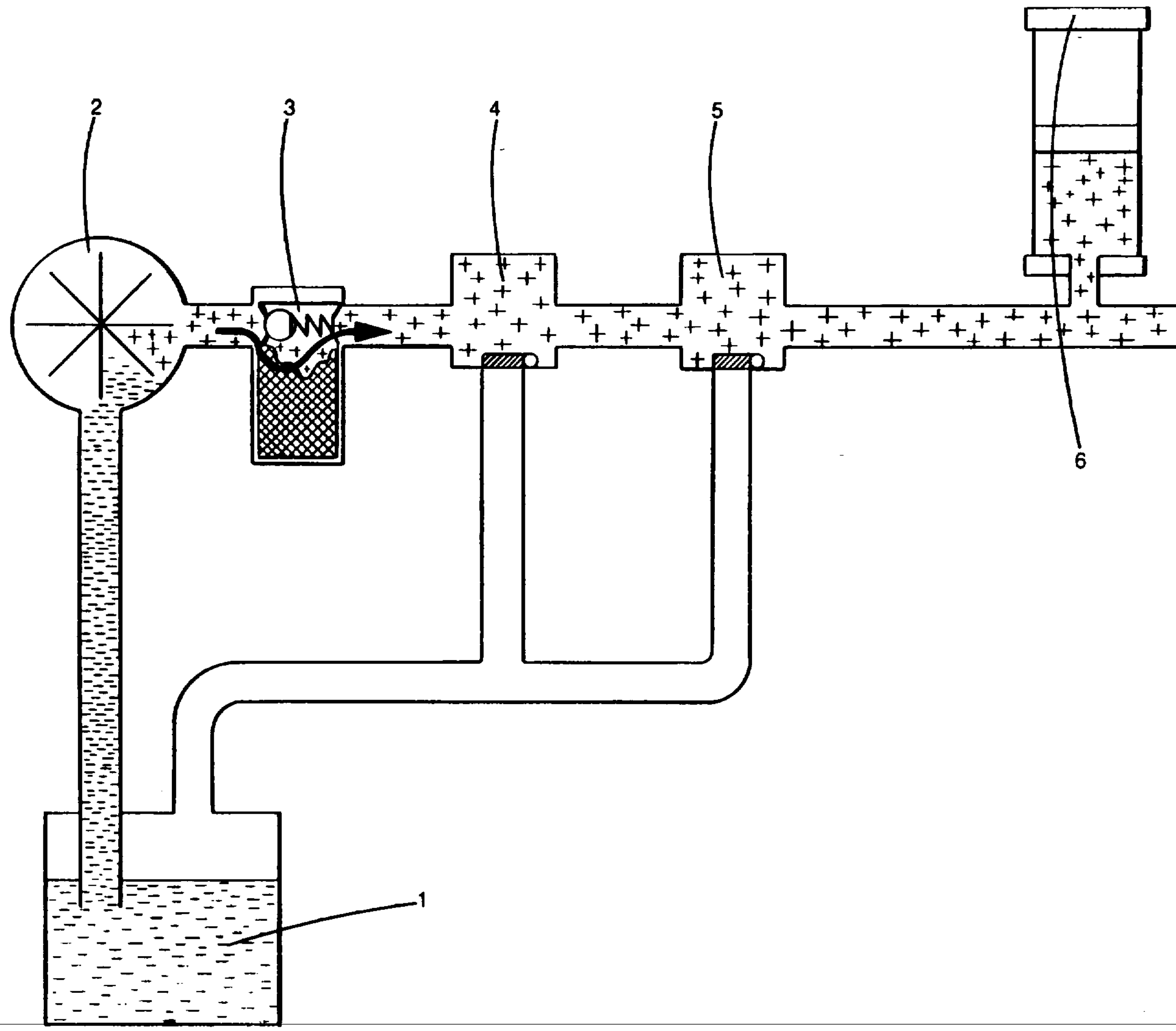



*Fig. 3*
*S-o-M Control System Unloading Valve Directing Pressure To Accumulator And Pressure Manifold*

........................................................... No Pressure ................Pressure

(1) Sump Tank
(2) Pump
(3) Filter
(4) Relief Valve
5) Unloading Valve
6) Accumulator

When the system pressure has decreased to approximately 900 psi, the unloading valve "cuts in" again, directing oil back to the accumulator and pressure manifold until the system pressure is built back up to 1050 psi. This cycle is repeated each time the system pressure decreases to 900 psi. The pump operates against pressure only when charging the system to 1050 psi. Each control valve has what is termed as a pressure and return manifold, which is interconnected with all other control valves.

As illustrated in Fig. 5, through movement of the control lever, pressure is admitted from the common pressure manifold into the valve or valves being operated, and into the operating cylinder. As the control lever is returned to neutral, the valve closes. Pressure beyond the valve decreases to zero, and oil from the operating cylinder flows back to the sump tank.

Fig. 6 illustrates the circuitry if the unloading valve becomes inoperative requiring the relief valve to limit the system pressure to 1250 psi. All oil in excess of 1250 psi is directed back to the sump tank at practically zero pressure. Under this condition, the pump is constantly working against 1250 psi.

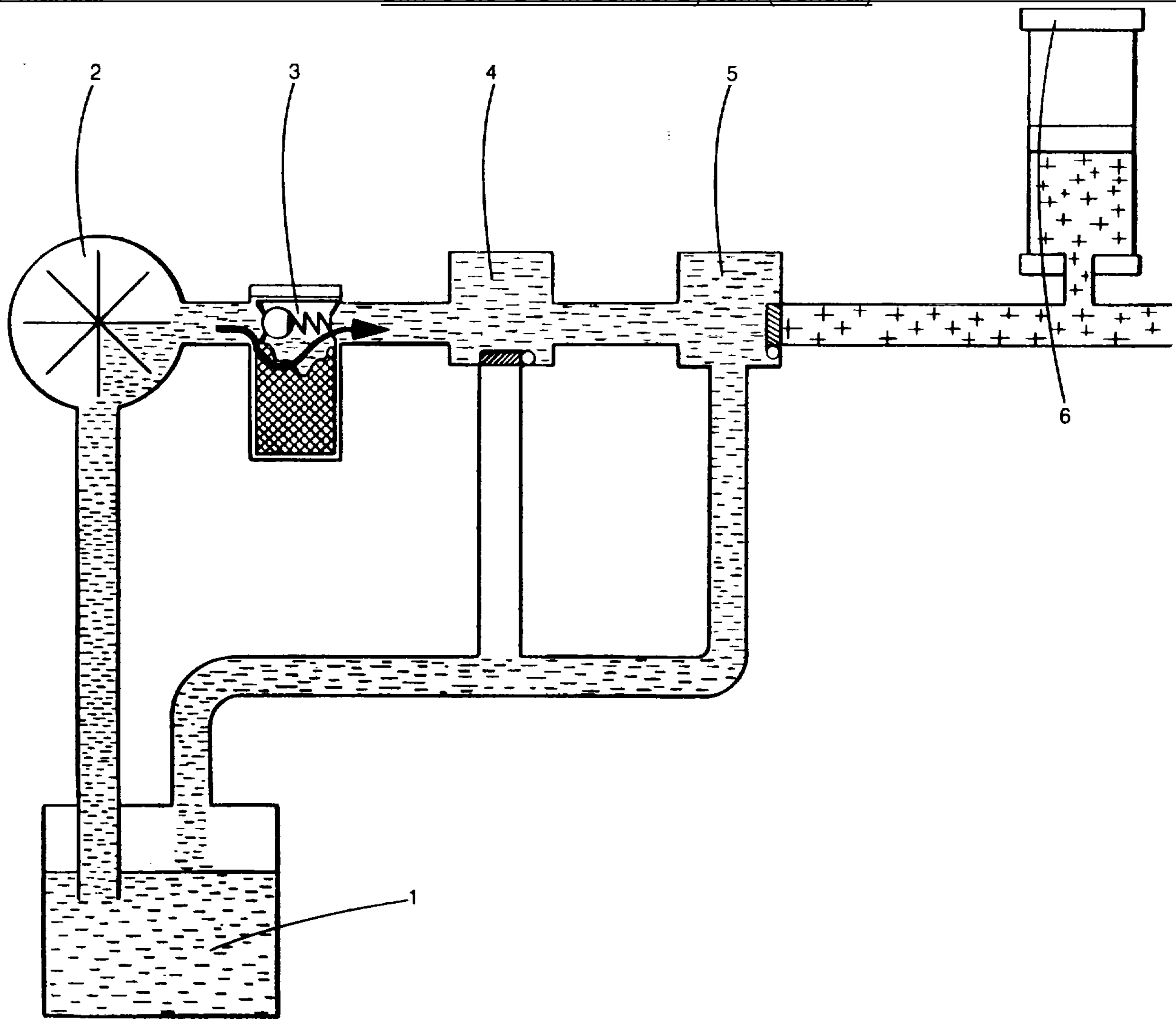



*Fig. 4*
*S-o-M Control System Unloading Valve Directing Oil Back To Tank*

........................................................ No Pressure

................Pressure

(1) Sump Tank
(2) Pump
(3) Filter
(4) Relief Valve
(5) Unloader Valve
(6) Accumulator

Therefore, it can be readily understood that continuous operation at that pressure could result in excessive oil heating and pump damage. Immediate action should be taken to restore the system to normal.

## 5.6 Hydraulic Pressure Gauge

The hydraulic pressure gauge is located to the right of the operator on small gauge panel, or in come cases on the R.H. control stand top. The gauge indicates the working pressure of the S-o-M control system. During normal operations, the gauge needle works in a range between 900 and 1050 psi. If the system malfunctions and is working over relief pressure, the gauge will indicate 1250 psi.

Whenever a clutch is engaged, it is normal for the gauge needle to drop 200 to 300 psi rapidly, and then return to its normal reading. This action does not indicate a defective gauge.

A gauge may best be tested by comparison with a gauge which is known to be accurate.

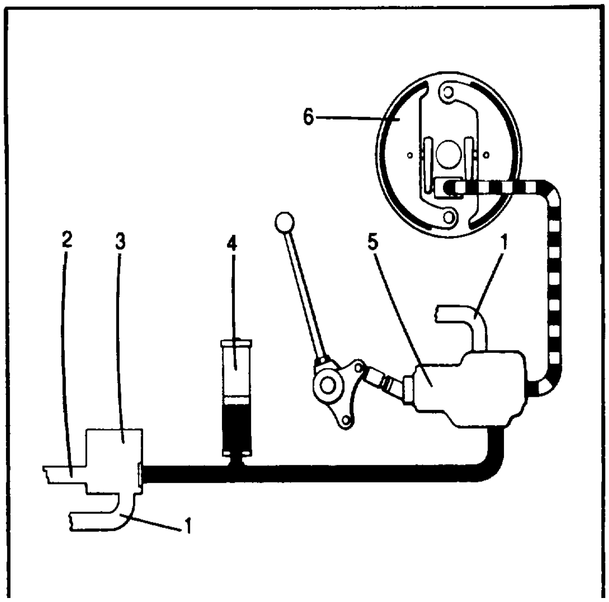



*Fig. 5*
*Speed-o-Matic Control System]*
*Variable Pressure Control Valve*

....... No Pressure
....... Variable Pressure
....... Constant Pressure

| | |
|---|---|
| (1) Return To Tank | (4) Accumulator |
| (2) From Relief Valve | (5) Control Valve |
| (3) Unloader | (6) Clutch |

Pressure readings may be adjusted with the adjusting screw on the face of the gauge. Two restricters are used in the gauge and hose assembly. A restricted adaptor union is used on one end of the hose and another restricter is installed in the gauge itself. Whenever the gauge or hose is replaced, make sure both restricters are left in the assembly. The restricters reduce shocks in the gauge, resulting in a longer-lasting gauge.

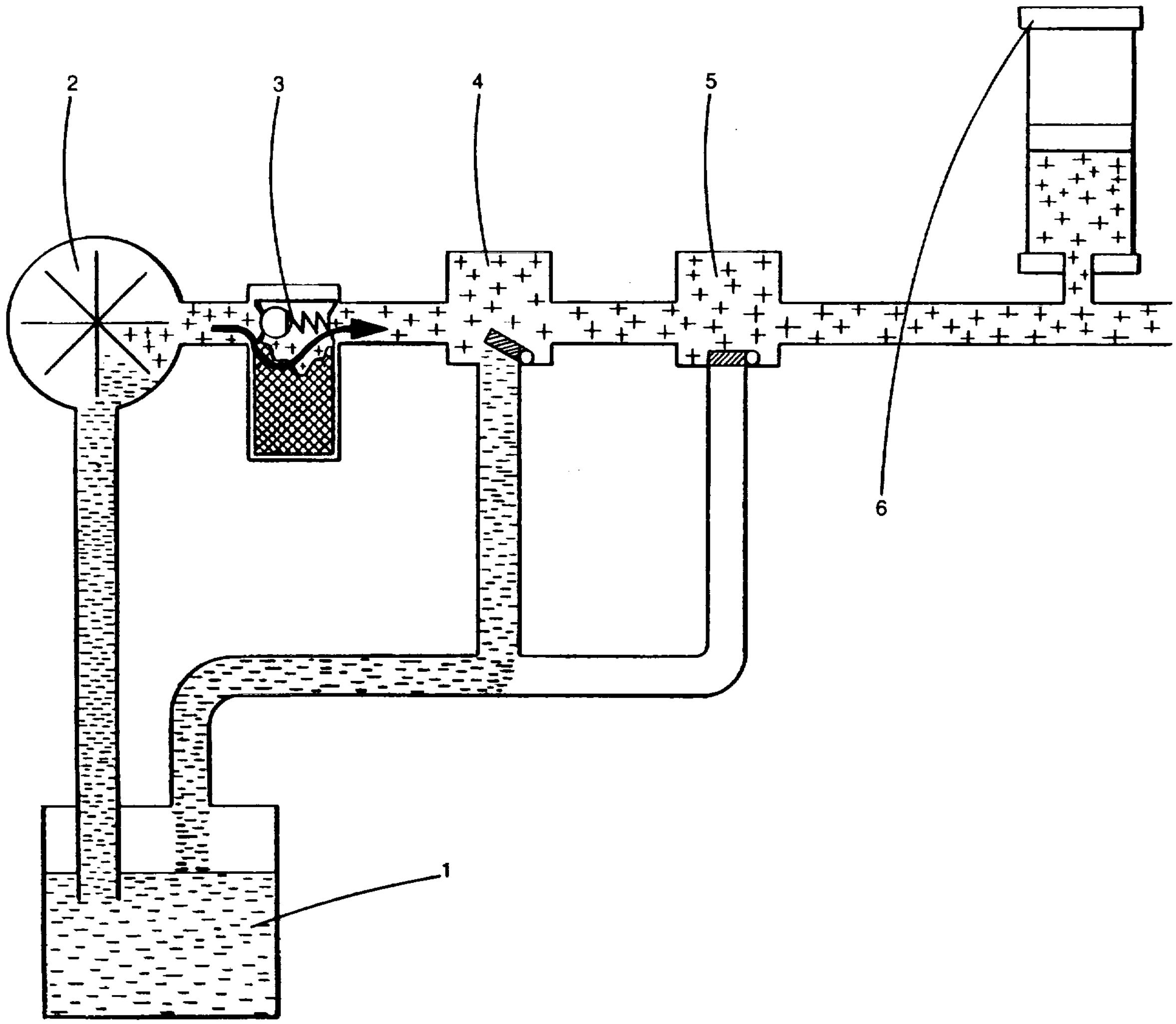



*Fig. 6* *Z187-B*

*Speed-o-Matic Control System*

*Unloading Valve Inoperative; Relief Valve Directing Flow Back to Sump Tank at 1250 PSI*

...... No Pressure ....... Pressure

(1) Sump Tank
(2) Pump
(3) Filter
(4) Relief Valve
(5) Unloader Valve
(6) Accumulator

| | SYMPTOM | POSSIBLE CAUSES REMEDY |
|---|---|---|
| Lack of Pressure | (a) Sump Tank | (1) Low oil level.<br>(2) Incorrect oil weight.<br>(3) Old or dirty oil.<br>(4) Incorrect type oil.<br>(5) Clogged screen. |
| | (b) Suction Hose | (1) Collapsed line.<br>(2) Loose connections above sump oil. level.<br>(3) Leaky hose. |
| | (c) Pump | (1) Loose belt.<br>(2) Sheared key.<br>(3) Broken pump shaft.<br>(4) Seized vanes or rotor.<br>(5) Assembled for wrong rotation.<br>(6) Worn parts.<br>(7) Leaky seals. |
| | (d) Relief Valve | (1) Piston stuck in open position.<br>(2) Broken spring.<br>(3) Worn piston.<br>(4) Set too low. |
| | (e) Unloading Valve | (1) Piston stuck in unloading position.<br>(2) Pistons upside down.<br>(3) Piston broken.<br>(4) Pilot piston spring broken.<br>(5) Worn or loose-fitting piston.<br>(6) Set too low.<br>(7) Pilot piston spring warped. |
| | (f) Pressure Gauge | (1) Defective gauge.<br>(2) Improper calibration. |
| | (g) Control Valve | (1) Broken piston.<br>(2) Worn piston. |
| Pressure Fluctuation | (a) Unloading Valve | (1) Pistons worn.<br>(2) Pistons sticking.<br>(3) Internal check valve stuck.<br>(4) Plugged drain tube. |
| | (b) External Check Valve | (1) Defective |
| | (c) Relief Valve | (1) Set too low.<br>(2) Spring broken.<br>(3) Worn piston. |
| | (d) Control Valve | (1) Pistons worn.<br>(2) Pistons broken. |
| | (e) Accumulator | (1) Discharged.<br>(2) Overcharged.<br>(3) Piston stuck. |
| | (f) Air in the System | (1) See Symptom: Presence of Air in System. |
| | (g) Hot or Noisy Pump | (1) See Symptom: Hot or Noisy Pump. |
| | (h) Other Causes | (1) Clutch cylinder piston travel too long.<br>(2) External leak.<br>(3) Loose pump belt.<br>(4) Defective gauge.<br>(5) Old or dirty oil. |

**Service Manual** SM7-0-6.0 Hydraulic System Trouble Shooting

| | SYMPTOM | POSSIBLE CAUSES REMEDY |
|---|---|---|
| Pressure of Air in System | (a) Sump Tank | (1) Low oil level.<br>(2) Old or dirty oil<br>(3) Incorrect oil weight.<br>(4) Incorrect type of oil.<br>(5) Clogged screen. |
| | (b) Suction Line | (1) Collapsed line.<br>(2) Loose connections above sump oil<br>(3) Leaky hose. |
| | (c) Pump | (1) Worn parts.<br>(2) Leaky seals. |
| | (d) Accumulator | (1) Worn ’0’ rings.<br>(2) Worn cylinder. |
| | (e) Hot or Noisy Pump | (1) See Symptom: Hot or Noisy Pump.<br>(2) Old or dirty oil. |
| Hot or Noisy Pump | (a) Sump Tank | (1) Low oil level.<br>(2) Old or dirty oil<br>(3) Incorrect oil weight.<br>(4) Incorrect type of oil.<br>(5) Clogged screen. |
| | (b) Pump | (1) Leaky seals.<br>(2) Pump belt too tight.<br>(3) Worn vanes and rotor. |
| | (c) Relief Valve | (1) Set too low.<br>(2) Spring broken.<br>(3) Worn piston. |
| | (d) Unloading Valve | (1) Set too high.<br>(2) Pistons sticking.<br>(3) Worn or loose-fitting pistons.<br>(4) Internal check valve stuck.<br>(5) Pilot piston spring warped.<br>(6) Drain tube plugged. |
| | (e) External Check Valve | (1) Defective. |
| | (f) Pressure Fluctuation | (1) See Symptom: Pressure Fluctuation. |
| | (g) Presence of Air in System | (1) See Symptom: Presence of Air in System. |
| Slipping Friction Clutch | (a) Control Valve | (1) Out of adjustment. |
| | (b) Lining | (1) Greasy, oily, or glazed.<br>(2) Poor drum contact.<br>(3) Worn or aged.<br>(4) Inferior lining. |
| | (c) Clutch | (1) Improper adjustment.<br>(2) Assembled for wrong rotation. |
| | (d) Lack of Pressure | (1) See Symptom: Lack of Pressure.<br>(2) Overcharged. |
| Grabbing Friction Clutch | (a) Accumulator | (1) Discharged.<br>(2) Overcharged<br>(3) Piston stuck. |
| | (b) Control Valve | (1) Pistons sticking.<br>(2) Tie bolts too tight.<br>(3) Broken springs. |

| SYMPTOM | POSSIBLE CAUSES | REMEDY |
|---|---|---|
| | (c) Lining | (1) Greasy, oily, or glazed.<br>(2) Poor drum contact.<br>(3) Inferior lining. |
| | (d) Clutch | (1) Improper adjustment. |
| Failure of Clutch to Release | (a) Sump Tank | (1) Improper weight oil for prevailing temperature. |
| | (b) Control Valve | (1) Piston sticking.<br>(2) Tie bolts too tight.<br>(3) Valve cap retaining clip bent. |
| | (c) Clutch | (1) Binding of clutch arms.<br>(2) Binding of clutch shoes.<br>(3) Binding of clutch cylinder pistons. |
| | (d) Restricted or Pinched Tubes | (1) Check tubing. |

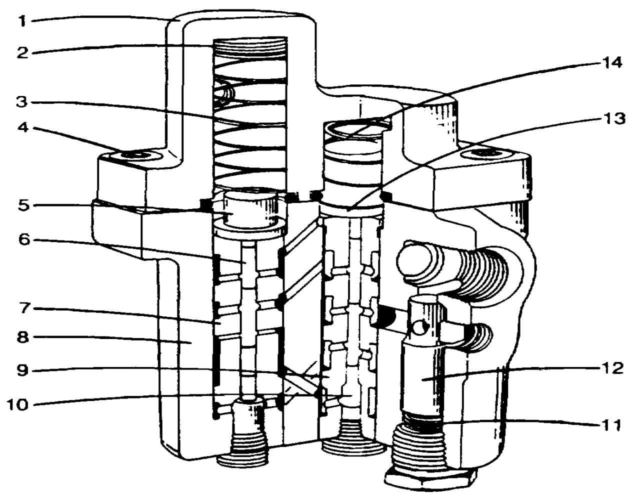



Fig. I
Unloading Valve Assembly

(1) Valve Cap
(2) Shims
(3) Control Piston Spring
(4) Capscrews
(5) Piston Follower
(6) Control Piston
(7) Liner
(8) Valve Body
(9) Piston Liner
(10) Directional Piston
(11) Spring
(12) Internal Check Valve
(13) Piston Follower
(14) Directional Piston Spring

The unloading valve acts as a pressure regulator which will automatically unload the pump by directing oil from the pump to the sump tank, when the system and accumulator pressure reaches 1050 psi. When the system pressure drops to 900 psi, due to control operation, the unloading valve will automatically direct oil from the pump to the system until the pressure builds back up to 1050 psi. At this point, the unloading valve will once again direct oil to the sump tank at practically zero pressure.

The essential parts of the unloading valve are the control piston spring (3) which balances against accumulator hydraulic pressure, the control piston (6) which controls movement of the directional piston (10),the directional piston which directs oil flow from pump to tank or accumulator and system, and an internal check valve (12) which prevents the reverse flow of oil should engine be stopped while unloader is directing oil flow from pump to accumulator and system.

1.1 Unloading Valve Range Adjustment

The unloading valve is preset at the factory to "cut in" the pump at 900 psi and "cut off" the pump at 1050 psi. If the pressure range should vary from this, make no attempt to change the range until other possible problems such as defective gauge, or dirt in the valve, are checked. If the unloading valve continues to have an incorrect "cut in, cut out" cycle, proceed as follows:

(a) Decrease the system pressure to zero by working the control levers back and forth.
(b) Unbolt and remove the valve cap (1) from the valve.
(c) Adjust the pressure by adding or subtracting shims (2) between the valve cap (1) and the control piston spring (3). Add shims to increase pressure and subtract shims to decrease pressure. When adding shims, add enough to increase the pressure to 1050 psi. Adding an excessive amount of shims may raise the pressure above 1 operate against pressure constantly. This would cause the pump to overheat, resulting in possible damage to the system. If the pressure cannot be raised to 1050 psi by the addition of shims, the relief valve is probably malfunctioning, by-passing oil to the sump tank before the unloading valve "cut out" pressure is reached. This condition is usually indicated by excessive heating of the system, and relatively steady pressure on the operators gauge when the machine is operating.
(d) Install the valve cap and tighten down.

1.2 Unloading Valve Disassembly and Repair

Frequent or rapid cycling of the unloading valve is generally caused by too low a gas charge in the accumulator, excessive lining clearance in the clutches, excessive oil seepage through the control valves, or too light a grade of S-o-M oil. These possibilities should be checked out before disassembling the valve itself.

Excessive pressure fluctuation, or failure of pressure to develop when the pump starts, may be caused by one or both of the pistons in the unloading valve binding due to dirt or some other obstruction. The valve may be disassembled for inspection and cleaning as follows:

(a) Decrease the system pressure to zero by working the control levers back and forth.
(b) Thoroughly clean the exterior of the valve, and a section of lines leading to it, to prevent entry of foreign material.
(c) Remove the valve from the machine. Immediately cap or plug all openings to prevent entry of foreign material.
(d) Remove the valve cap (1).
(e) Remove the shims (2), spring (3) and piston follower (5) from the top of the control piston (6).
(f) Remove the spring (14) and piston follower (13) from the directional piston (10).

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(g) Remove the pistons (6 and 10). Make a note of which hole the piston was removed from, and which end was up, as they can be reinstalled upside down. Wash all parts in clean kerosene or some similar approved solvent. Oil the pistons lightly, and re-assemble by following the previous steps in reverse. If the valve pistons are scored or damaged in any way, do not attempt to remove the marks by polishing or grinding. The valve pistons are hand-lapped fits and are not replaceable. Grinding or polishing will destroy the fit, making the valve inoperable.

(h) Replace the valve in the system and test. If it still malfunctions, the valve must be replaced.

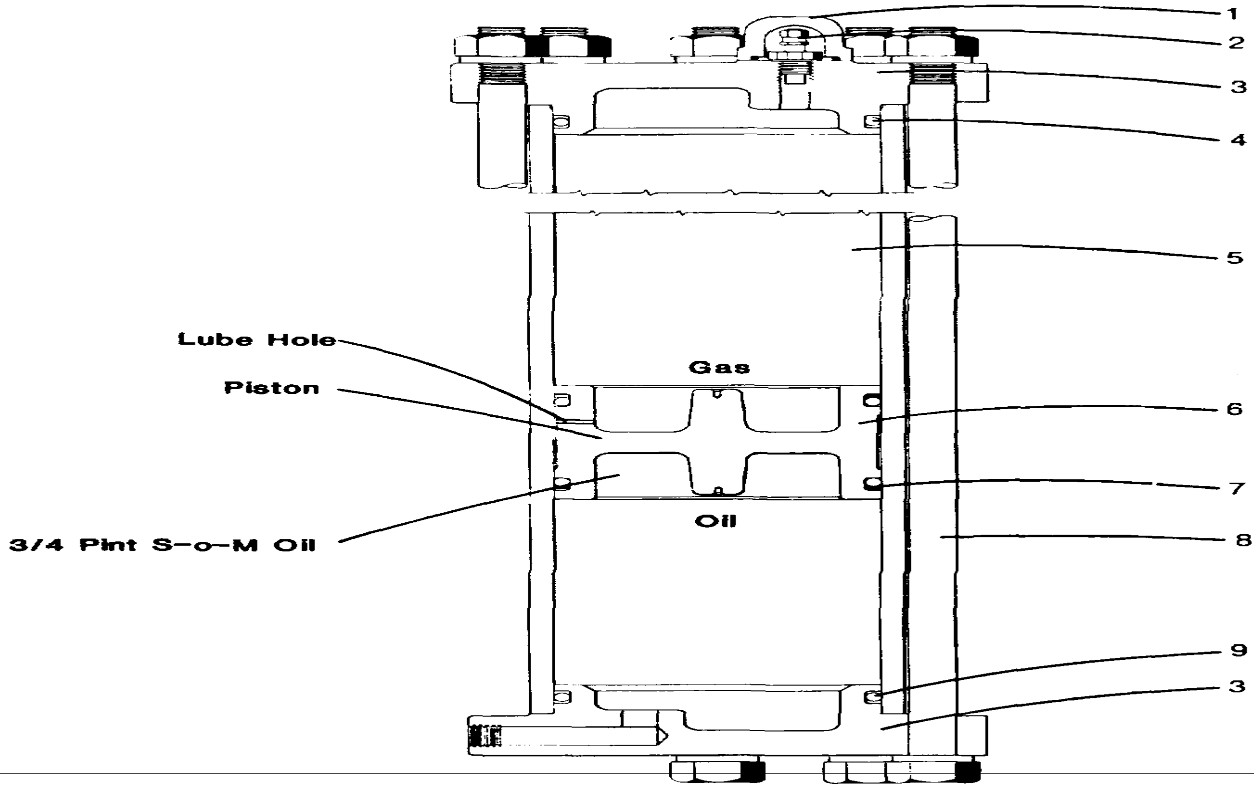



Fig. 1
Accumulator

(1) Cover
(2) Valve
(3) Heads
(4) '0' Ring
(5) Body
(6) Piston
(7) Back-Up Rings & "O" Ring
(8) Tie Bolt
(9) '0' Ring

The accumulator serves as an oil storage reservoir, and pressure head, maintaining operating pressure in the system while the unloader valve is in the "cut out" position.

The accumulator is in the form of a steel cylinder, sealed at both ends with end caps and 'O' ring seals, and held together by tie bolts. Inside the cylinder is a piston which is free to travel up and down as the pressures above and below it dictate. The piston is sealed against internal leakage by 'O' rings and back-up washers. During normal operation, the piston is balanced by "dry nitrogen gas" above it and oil pressure beneath it.

The compressed dry nitrogen gas, which is referred to as "accumulator precharge", maintains a pressure head within the accumulator.

As oil is forced into the accumulator by the pump, the piston raises, compressing the dry nitrogen gas above it. After the system is charged to 1050 psi, and the oil from the pump is diverted to the sump tank, pressure for control operation is provided from the pressure head in the accumulator. When the system reaches approximately 900 psi, the pump is cut in and the piston is again forced up to replenish the pressure head.

A dry nitrogen precharge is installed at the factory. This precharge amounts to 650 psi with the accumulator piston on the bottom of the accumulator. The nitrogen is put in through a valve (2) at the top of the accumulator, and may be recharged in the field.

2.1 Accumulator Trouble Shooting

Failure of the accumulator to maintain a charge generally indicates a defective charging valve, or defective 'O' rings on the piston.

To check the valve, remove the cover and spray a little soapy water on the valve core. If the core leaks, it may be replaced in the same manner as a valve core in an automobile tire.

**WARNING|**

Drain All Pressure From The Accumulator Before Removing The Valve Core.

Although it requires no attention on the part of the operator, and should function for a long time before recharging, an occasional test of the accumulator on the machine should be made. This may be done with the gauge on the accumulator charging equipment, or if the gauge on the operator's control stand is in good condition, the test *may* be made as follows:

(a) With all valves in the neutral position, start the engine and raise the hydraulic pressure to 1050 psi.

(b) Stop the engine.

(c) Reduce the pressure in the control system by moving a control lever back and forth. If the accumulator is in good condition, the pressure will decrease gradually to about 600 psi, hesitate momentarily, then drop rapidly to zero. If the pressure drops to zero, or drops rapidly from full pressure to zero, the accumulator is inoperative and should be repaired or recharged.

**WARNING**

Always Decrease Operating Pressure To Zero Before Removing The Accumulator From The System.

2.2 Accumulator Disassembly

The accumulator may be disassembled for inspection or repair as follows:

(a) Exhaust all hydraulic pressure in the S-o-M system.

(b) Remove the accumulator from the machine. Thoroughly clean the exterior of the accumulator to prevent entry of foreign material during disassembly.

(c) Exhaust all "precharge" from the accumulator. This must be done before disassembly.

(d) Remove the tie bolts (8) and heads (3). Slide out the piston (6).

(e) Remove the '0' rings and back-up rings (7). Thoroughly clean and inspect all parts. Replace any worn parts.

2.3 Accumulator Reassembly

(a) Install an 'O' ring and back-up ring (7) in each groove in the piston (6). The back-up rings are installed in the outside of the groove.

(b) Lubricate the outer edge of the piston with S-o-M oil and install it in the cylinder.

Note: There is a lube hole drilled from one side of the piston into the area between the two ring grooves. The hole is to provide lubrication between the sealing rings. This oil hole must be on the gas side of the piston when the accumulator is assembled.

(c) Install an 'O' ring (9) on the bottom head, and install it on the cylinder.

(d) Fill the cup in the precharge end of the piston with S-o-M oil. Install an '0' ring(4) on the top head and install it on the cylinder.

(e) Install and tighten down the tie bolts, as required to flatten the lockwashers.

(f) Reinstall the accumulator on the machine.

2.4 Charging the Accumulator

(a) Loosen the capscrews which hold down the charging valve cover (1). Break the seal between the cover and the accumulator head in case pressure has leaked into the cover, before removing it completely.

(b) Install a PX101 accumulator charging kit on a bottle of commercial Dry Nitrogen. Charge only with dry nitrogen.

**WARNING**

Do Not, Under Any Circumstances, Charge With Oxygen, Acetylene, Or Any Other Combustible Gas.

(c) Attach the chuck on the end of the charging hose to the charging valve on top of the accumulator.

(d) With the handle on the regulator valve turned in a counterclockwise direction until all tension on the regulator diaphragm is released, open the valve on the nitrogen tank. This will allow the nitrogen to flow as far as the regulator.

(e) Check the reading on the cylinder pressure gauge, and if the pressure is sufficient for charging, slowly open the regulator valve. Admit the nitrogen slowly, while working the control levers back and forth until 150 to 200 psi is built up in the accumulator. This allows the piston to settle to the bottom of the accumulator.

(f) Open the regulator valve until the pressure in the accumulator equals 650 psi. Again, work the control levers to make sure the piston is on the bottom of the accumulator.

(g) Close the valve on the nitrogen bottle. Remove the charging hose chuck from the accumulator charging valve. A slight release of pressure will be noticed when the chuck is removed. This is caused by nitrogen trapped in the charging hose, and does not affect the accumulator precharge.

(h) Check the accumulator for leakage by pouring S-o-M fluid, or soapy water, in and around all joints and connections. Tighten the air valve cap to insure a positive seal in case the check valve core may be leaking.

2.5 Checking Accumulator Precharge

The accumulator precharge may be checked with the PX101 charging kit as follows:

(a) Remove the charging valve cap.

(b) Reduce the pressure in the system to zero by working control levers back and forth.

(c) Attach the chuck on the charging hose to the accumulator charging valve.

(d) Turn the handle on the chuck in, to depress the valve core.

(e) Read the accumulator precharge pressure directly from the regulator pressure gauge.

A machine may be operated for a short period of time with a dead accumulator. Operation should be slowed down as the control system will be depending entirely upon pump pressure for operation. Continued operation with a dead accumulator will cause severe shock to the system, resulting in severe vibration and line breakage. Pump damage may also result.

**Service Manual** SM7-1-4.0 External Check Valve

The external check valve is located in a secondary line, leading from the unloading valve to the accumulator. Its purpose is to prevent the system going over relief pressure when the directional piston shifts to the charging piston.

As the spools shift in the unloading valve, there is an instant when the directional piston will be in a neutral position (not open to either outlet port), while the pump is pumping.

Since both outlet ports are blocked, the pump pressure will start to build up to relieve pressure. As the pressure builds up, the external check opens, allowing oil to flow into the accumulator, before the relief valve will open.

When the directional spool completes its shift, the external check valve will close, causing the oil to flow through the unloading valve, and into the accumulator.

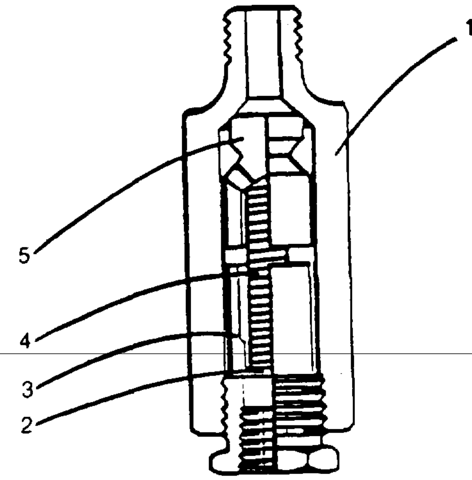


Fig. 1
External Check Valve

(1) Body
(2) Washer
(3) Spring Guide
(4) Spring
(5) Poppet

4.1 External Check Valve Trouble Shooting

Usually the check valve will function normally; however, if the poppet (5) becomes worn or does not seat properly because of dirt or other foreign material, excessive fluctuation of pressure may result. This may be checked by watching the pressure gauge. The pressure will build up to 1050 psi, then drop to 900 psi, without operating any control valves. The operation of the check may be checked as follows:

(a) Build up hydraulic pressure to 1050 psi and then stop the engine.

(b) Observe the pressure gauge. If the pressure drops to around 900 psi, and remains, the external check valve is leaking.

(c) If the pressure drops below 900 psi, or almost to zero, check for internal leakage elsewhere in the system.

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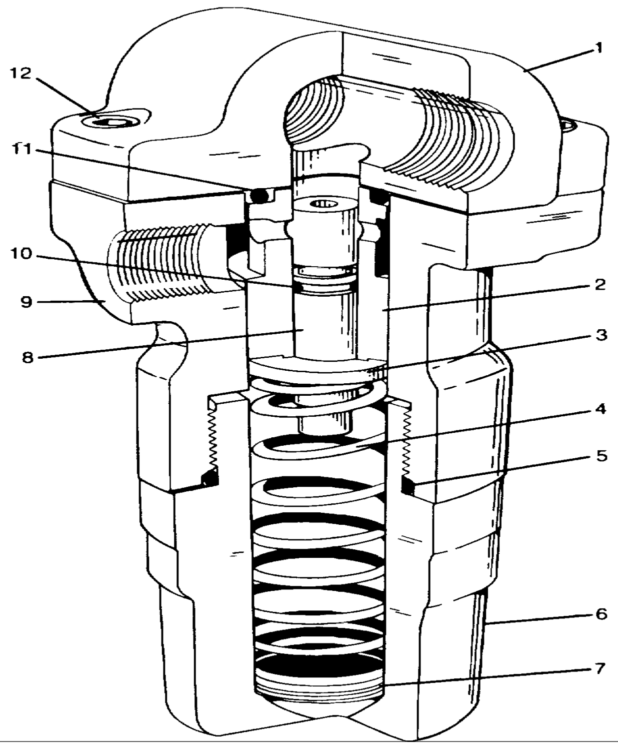


Fig. 1 Z147-
Relief Valve Assembly

| | |
|---|---|
| (1) Base | (7) Shims |
| (2) Liner | (8 Piston |
| (3) Spring Cap | (9) Body |
| (4) Spring | (10) "0" Ring |
| (5) "0" Ring | (11) "O" Ring |
| (6) Cap | (12) Capscrew |

The relief valve is used as a safety valve to protect the system against excessive pressure if the unloading valve fails to cut the pump out of the system after the accumulator is charged. Since the unloading valve normally cuts out the pump when pressure in the accumulator reaches 1, 050 p.s.i. and the relief valve is set at 1, 250 p.s.i., it is apparent that the relief valve will not function unless the unloading valve fails to relieve the pump. If the unloading valve pressure should be set above, 1, 250 p.s.i., the relief valve would limit pressure in the system to 1, 250 p.s.i., keeping the unloading valve from relieving the pump, and causing the pump to pump against pressure constantly. If the relief valve pressure is set too low, say 1, 000 p.s.i., it would limit pressure in the system to 1, 000 p.s.i., and prevent pressure from building up high enough to cause the unloading valve to cut out the pump. This will also cause the pump to operate continuously resulting in excessive heating of the oil and pump and resulting in possible damage to the system.

5.1 Relief Valve Adjustment: The relief valve must be adjusted to 1, 250 p.s.i, as follows:

(a) With the engine shut down, reduce operating pressure to zero by working control levers back and forth.

(b) Remove the return line leading from the unloader valve to the sump tank, at the unloader end. Place a pipe plug in the hole, to force the system to build up to relief valve pressure.

(c) Start the engine, and providing the gauge on the operators control stand is in good condition, the relief valve setting may be read directly off the gauge.

**CAUTION**

If The Gauge Reading Is 1, 300 P.S.I. Or More, Immediately Shut Off The Engine. This Would Indicate Too High A Setting, Or A Stuck Spool Within The Valve.

(d) In the event the relief valve setting is not 1, 250 p.s.i., the setting may be changed by removing the valve cap (6), and adding or subtracting shims (7) beneath spring (4).

**WARNING**

Reduce Control System Pressure To Zero Before Attempting To Disassemble The Relief Valve.

5.2 Relief Valve Disassembly And Repair:

The piston (8) in this valve is individually lapped fit with the housing, and is not replaceable separately. Dirt, old oil, or improper handling may cause the piston (8) to stick in the liner (2) making the valve inoperative. If the piston sticks, or the valve fails to function, remove piston (8) and inspect.

**WARNING**

Use Solvent In A Well Ventilated Area, Away From Flames.

In many cases, the trouble may be eliminated by thoroughly cleaning the valve, piston, and liner in clean approved solvent. If the piston or liner is scored or damaged, the valve must be replaced. Never attempt to remove metal from the piston or liner by polishing or grinding as this will destroy the lapped fit which is necessary for proper operation. The valve may be disassembled as follows:

(a) Decrease operating pressure to zero.
(b) Thoroughly clean the exterior of the valve to prevent entry of foreign material.
(c) Remove the four capscrews (12) from the base (1).
(d) Unscrew and remove the cap (6).
(e) Remove piston (8) from liner (2).

Reassemble the valve by following the above procedure in reverse. Replace any worn or damaged "0" rings. See Fig. 1 for correct parts placement. Light oil the piston and "0" rings before reassembly. Reset the relief valve pressure as explained previously in this SM.

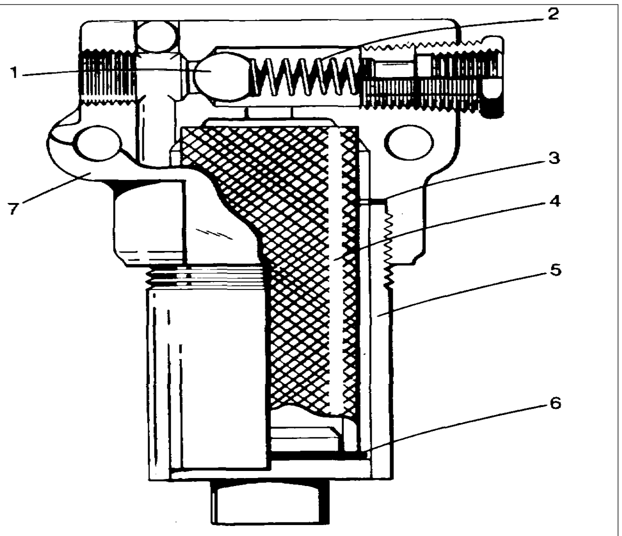


Fig. 1 Z146-B
S-o-M Oil Filter

(1) Ball
(2) Spring
(3) 0' Ring
(4) Element and Gasket
(5) Housing
(6) Rubber Washer
(7) Head

Dirt is one of the worst enemies of any hydraulic system. The S-o-M filter helps to remove dirt from the hydraulic oil, resulting in a longer-lasting system. The filter is a high pressure full flow type mounted on the pressure side of the pump. A bypass valve is included in the filter to permit oil flow if the filter element clogs up due to contamination or cold thick oil.

8.1 Filter Change Procedure

The filter must be changed after the first 50 hours of operation on a new machine, and every 250 hours after that. The element is changed as follows:

(a) Decrease S-o-M pressure to zero by working the control levers back and forth.
(b) Remove the filter housing (5).
(c Remove the filter element (4) from the housing.
(d) Remove the gasket from the filter head (7) and the rubber washer (6) from the filter housing.
(e) Thoroughly clean all parts.
(f) Install a rubber washer and filter element in the housing.
(g) Install a gasket in the head.
(h) Install and tighten down the housing to 150 ft/lb. torque.

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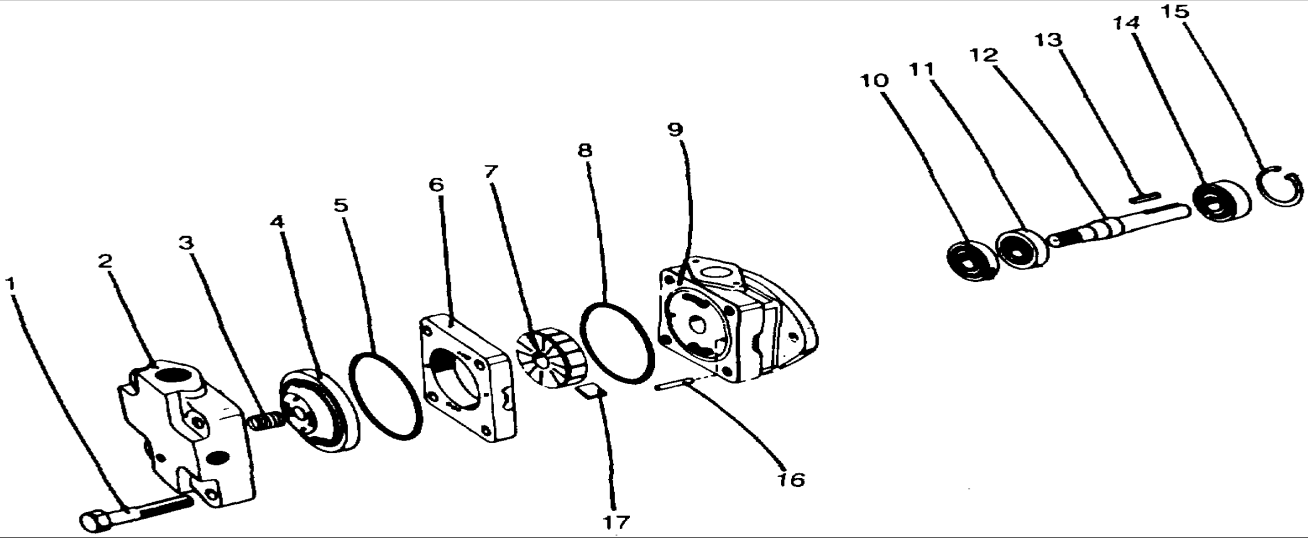


Fig. 1
S-o-M Pump

(1) Screw
(2) Cover
(3) Spring
(4) Pressure Plate
(5) 'O' Ring
(6) Ring
(7) Rotor
(8) 'O' Ring
(9) Body
(10) Bearing
(11) Seal
l12) Shaft
(13) Key
(14) Bearing
(15) Snap Ring
(16) Pin
(17) Vane

The pump is a high pressure, rotary vane pump that is capable of delivering 5 g.p.m. at 1200 RPM. It is driven off the front pulley on the engine crankcase.

The pump is assembled for left hand (counterclockwise) rotation. Direction of rotation is determined by viewing pump from the shaft end, and by the arrow stamped on the pump ring. Never drive the pump in the wrong direction. This could cause the pump to seize, necessitating expensive repairs. If the pump is found to be rotating in the wrong direction, it may be corrected as follows:

(a) Remove the outer cover (2) and pressure plate (4).
(b) Remove the rotor (7) and pump ring (6) as a unit.
(c) Turn the rotor and ring assembly around until the arrow on the ring points to the left when viewed from the shaft end.
(d) Reassemble the pump.

6.1 S-o-M Pump Disassembly

A pump which runs excessively hot, or noisily, is a potential trouble spot. Pump failure may indicate problems elsewhere in the system. If a pump becomes noisy, or runs hot, the machine should be shut down immediately, and the cause of trouble corrected. The pump may be disassembled for inspection or repair, as follows:

(a) Remove the pump from the machine. Cap or plug all openings to the S-o-M system to prevent entry of foreign material.
(b) Remove the four screws (1) from the pump cover.
(c) Remove the cover (2), pressure plate (4), and ring (6). In addition to screws, the ring is held in position by two locating pins (16) which are a slip fit in the ring and the body (9). Make a note of the relative position of the rotor (7), vanes (17), and ring (6), so they may be reassembled correctly later on.
(d) Remove the snap ring (15) which holds the outer bearing (14) in place.
(e) Tap on the splined end of the shaft to remove the shaft assembly from the body. This may also be accomplished by standing the unit on the splined end of the shaft, and pressing downward on a soft block.
(f) The outer bearing (14) will be removed with the shaft, and may be removed with an arbor press.
(g) The seal (11) is a press fit within the body, and will be destroyed during removal.
(h) The small inner bearing (10) is a press fit, and may be tapped from the body with a hammer and drift punch.

## 6.2 Pump Reassembly

Prior to reassembly, thoroughly clean and inspect all parts. Reassemble the pump as follows:

(a) Press the small bearing (10) in place in the body (9).
(b) Press the seal (11) in place in the body with the lip in.
(c) Press the large bearing (14) into place on the shaft.
(d) Install the shaft and bearing assembly in the body. Install the retaining snap ring (15) in place in the body.
(e) Install pin (16) and '0' ring (8) on the face of the body.
(f) Assemble the vanes (17), rotor (7), and ring assembly (6) for L.H. rotation. Install the vanes with the radius edge facing the cam ring.
(g) Install the ring assembly on the body. Install a new '0' ring (5) on the ring assembly.
(h) Install the pressure plate (4) and spring (3) on the cam ring assembly.
(i) Install the pump cover (2) and retaining screws (1). Tighten the screws.

## 6.3 Pump Trouble Shooting

Of utmost importance in proper pump operation is cleanliness. Do not permit dirt, dust, water, or lint to enter same, and take all precautions in cleanliness when dismantling and reassembling unit.

All piping used in connection with the pump must be clean and properly tightened. Air leaks in the pump intake connections will cause the pump to operate with an irregular snapping noise. Often, such leaks may be located by spreading oil over each joint successively with an oil can while pump is operating, and listening meanwhile for a momentary cessation of the abnormal pump noise.The noise will cease if the leaking joint is completely covered with oil. When this oil is drawn in or runs off, air is once more allowed to enter and noise will recur. It has been found that the general tendancy is to tighten connections too much, rather than not enough. This may distort the pump body or the pipe fittings, and results in a leak which cannot be stopped either by tightening or loosening, Pipe threads must be cut sharp and smooth. When using pipe fitting dopes, apply same sparingly to the male threads only, leaving the first three threads dry. In this way, it will not be pushed into the pump body where it would eventually find its way into the unit.

Failure of the pump to deliver oil as indicated by pressure gauge may result from aeration, sheared key, broken shaft, seizing vanes, scored ring, operation oil too light, or loose pump driving belts. Aeration may be the result of poor connections between sump tank and pump, cracked flexible hose between sump tank' and pump, too heavy an oil in sump tank, defective pump head packing, or loose pump head bolts.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

In rare instances, a sheared key (13) or broken shaft (12) may be caused by wedging of foreign matter between vanes and rotor or between rotor and ring. When foreign material, wedged between rotor and one of the vanes, prevents the vane from expanding due to centrifugal force, an unbalanced condition in the pump exists and same will be rough in operation, as well as noisy. The pump should not be allowed to run any length of time under these conditions. Dismantle pump and wash thoroughly with clean solvent in manner described previously.

Seizing vanes or rotor may result in pressure loss for the same reasons as described in preceding paragraph. A scored ring will result in pressure fluctuation, and eventual pressure loss. A pump repair kit, including ring, rotor and vanes, is available which will restore the pump to normal operating condition (see Parts Book).

The use of too light an oil in the sump tank may result in "pump slippage"; that is, bypassing oil past fluctuation and possibly complete pressure loss at the time the engine is idling. Refer to Operators Manual for recommended oils.

Inferior or old oil may result in these same pressure trouble tendencies. The use of too heavy an oil in the tank may result in failure of the pump to raise pressure upon starting. We cannot stress too highly the importance of proper oils. The greater majority of pressure troubles can be traced directly to this source.

## 6.5 Pump Priming

When starting up a new machine or a machine that has been in storage, it is good practice to prime the hydraulic pump before starting the engine. The pump can be primed by disconnecting the suction line at the sump tank and filling with oil. Turn the pump over several times to get oil into the pump and the refill suction line. Reconnect the line and start the engine.

Drum rotation indicators are used on the front and ear drum shafts. Two indicator "buttons" are mounted in each control handle assembly. The front button operates when lifting a load (winding on wire rope). The rear button operates when lowering a load (winding off wire rope). The buttons are solenoid activated, and move in or out as the drum shaft rotates. The faster the drum shaft rotates, the faster the indicator buttons move in and out.

A sending unit connected to the drum shaft sends electronic pulses to the electronics box (Fig. 2). This box is mounted on the right hand side of the revolving frame, near the boom foot lugs. The electronics to operate the indicators for both drums are enclosed in the one box. The sending unit sends out a different signal for each direction of shaft rotation, and the speed of this signal varies with shaft rotation speed. This signal is fed to the electronics box, which controls the pulsing of the indicator solenoids within the control handle.

By placing a thumb on the buttons when operating the front or rear drum shaft, the operator can tell which direction the shaft is turning, and with experience will be able to tell how fast the shaft is rotating.

The rotation indicators work only when the rotation indicator switches are in the engage position. These switches are located on the upper control panel above the operator's right shoulder.

There are two thumbwheel switches on the cover of the electronics box, one for each of the two drums. These switches adjust the frequency of movement of the indicators to compensate for changes in the number of parts of line being used. Determine the number of parts of line being used and adjust the thumbwheels accordingly.

Also on the cover of the electronics box are four indicator lights, two for each drum. As a drum turns, both of its corresponding lights will flash in a set sequence.The sequence will reverse itself when the drum changes direction of rotation. The lights flash at a rate proportional to drum speed. The primary purpose of these lights is to assist in trouble shooting.

Fig. 3 is a block diagram of the drum rotation indicator system. Terminal numbers are shown where wiring connects to the electronics box. These terminal numbers are for use in the trouble shooting section.

2.1 Adjustments

The only adjustment required is that to the parts of line thumbwheel switches. The indicators respond to the rotational speed of the sending units attached to the drum shafts.

They do not correspond directly to the speed of the hook, but only indirectly via the parts of line being used on the crane boom. A change in parts of line will necessitate resetting the thumbwheel switches. For example, if the parts of line from the front drum is changed from 3 to 5, then reset the front drum thumbwheel from 3 to 5. Note that even numbered settings would produce slightly higher or lower pulses from the normal settings, which are odd.

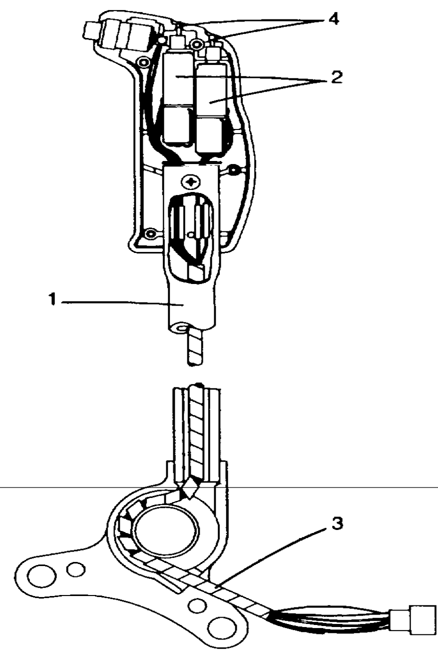


Fig. 1
Control Handle (Typical)

(1) Lever Assembly (3) Wire Assembly
(2) Solenoid (4) Indicators

Note, too, that a zero setting can be used to eliminate signals altogether.

2.2 Maintenance and Trouble Shooting

Required test equipment:

(a) 1 multimeter (E.G. Simpson Model #260). Requires DC voltage range that includes +12 volts, and resistance ranges that include 0-5 ohms and 500, 000 ohms.

(b) 1 jumper wire 3" to 12" (76.2 to 53.3mm) long, preferably insulated. Can be any gauge, with flat tipped probes or small alligator clips at ends, preferably clips.

2.3 Maintenance

The only maintenance consists of making sure all electrical connections are clean and tight, and that none of the components are visibly damaged.

2.4 Trouble Shooting

The electronics box is a dual channel unit, containing electronics for both the front and rear drums. Both channels are identical in operation and are powered by the machine's 12-volt battery.

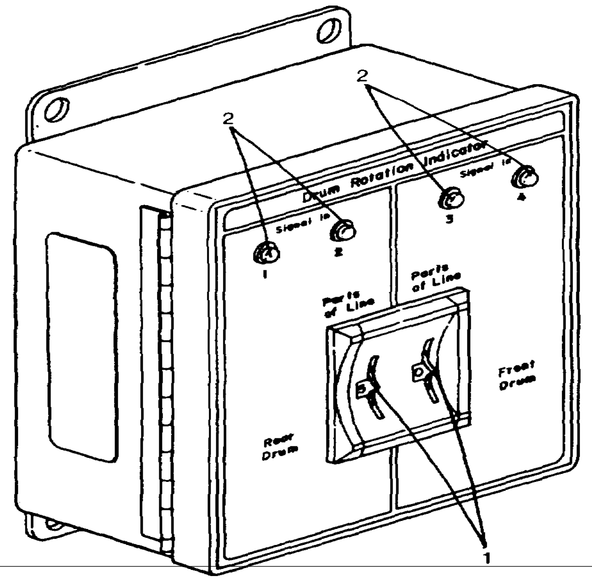


Fig. 2 WZ74-A
Electronics Box

(1) Thumbwheel Switches (2) Indicator Lights

2.5 Function Of Indicator Lights

On the cover of the electronics box are four indicator lights, two for each drum. Each pair of lights flash in a fixed sequence as a drum turns.The sequence reverses itself with drum directions up or down. The lights flash simultaneously with signals received from the sending unit. Lights 1 and 2 indicate signals from the front drum and lights 3 and 4 indicate signals from the rear drum. The indicators in the cab pulse at a rate equal to the rate that either of a corresponding pair of indicator lights flash, divided by the number which is set on the corresponding parts of line thumbwheel switch. Above a fixed threshold of about 50 pulses per second, the indicators are automatically disabled.

The set sequence in which a pair of lights flash, as the corresponding drum turns, is demonstrated in the following chart. If the front drum turns in the lowering direction, light #2 will come on after light #1 and will stay on until after light #1 has gone off.

If the front drum turns in the raising direction, the roll of the two lights is reversed, and light #1 will come on after light #2, and will stay on after light #2 has gone off. These lights flash

| | Light #1 | Light #2 |
|---|---|---|
| Time 1 | • | 0 |
| Time 2 | • | • |
| Time 3 | 0 | 0 |
| Time 4 | • | 0 |
| Sequence repeats | | |

at low and moderate hook speeds, but the above sequence in their flash can only be visually resolved at low drum speeds.

2.6 Preliminary Inspection

Prior to entering the trouble shooting tables, check the following:

(1) Check that all cable interconnections are secure.

(a) Cable to sending unit, one place each unit.

(b) Cable to electronics box, three places oh the box.

(c) Cable to control handle, one place each handle.

(2) Check integrity of mechanical couplings between the sending unit shafts and their respective drum drives. Shaft couplings must be secure.

(3) Check that both thumbwheel switches are set to provide correct pulse rates at control handles. A zero setting keeps signals from reaching the indicators.

(4) Check for visible damage to any of the parts in the system: sending units, connectors, cables, electronics box, and drum control handles. 2.7 Faults Involving One Drum Only (Or Involving Up Indicator Of One Drum, And Down Indicator Of The Other Drum)

Since the drum rotation indicator is a dual channel system, trouble shooting is greatly simplified when a problem exists in only one of two channels. Interchanging channel usage by switching cable connections at the sending units, box and drum control handles enables the isolation of the problem to one of the basic components of the system.

2.8 Trouble Shooting Sequence

If the signal lights are not operating properly on one drum only, proceed with the following Steps 1 and 2. If all four signal lights work properly, but a fault appears at the indicators on the drum control handles, then go to Step 3.

Step 1: Switch the cable connected to the front drum sending unit over to the rear drum sending unit and vice versa. Do not change the cable connections at the electronics box. Determine which of the following four results occurs.

Result la: The faults with the signal lights on the channel now appear on the signal lights of the other channel. If the drum is truly turning the sending unit connected to the faulty channel, then it is the sending unit which must be replaced.

Result lb: The fault does not switch channels. It still appears on the same indicator lamps as before. This result means that the fault is with either the

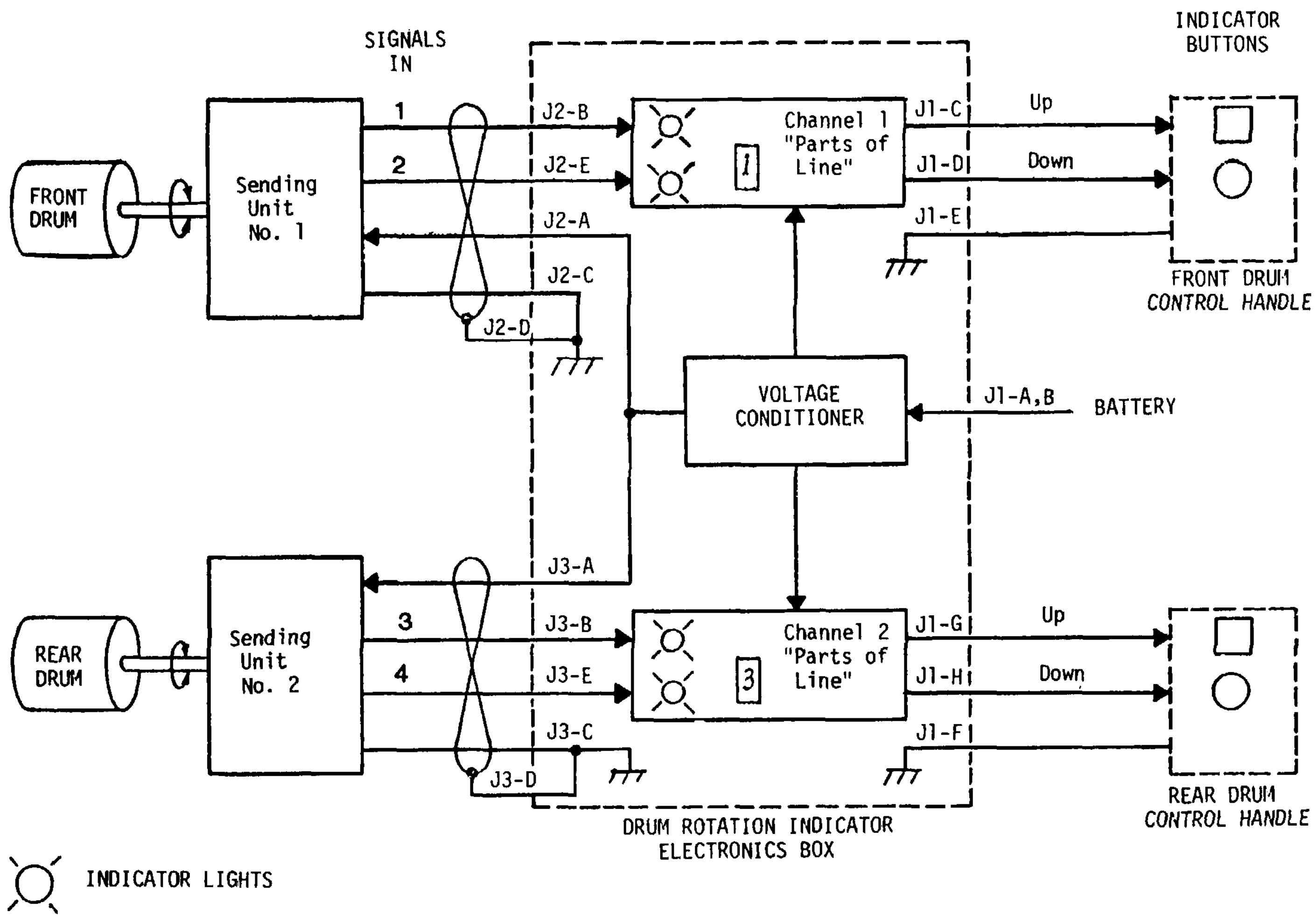


Fig. 3
Block Diagram Of Drum Rotation Indicator System

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electronics box or the cable from the sending unit. In this case, go to Step 2 to continue trouble shooting.

Result ic: No problem remains apparent. This means that there is a faulty connection at the sending unit. First check for shorts or breaks in the connecting cable. If no faults are found in the cable, then replace a faulty sending unit.

Result 1d: Faults now exist with lights from both sending units. In this case, replace a faulty sending unit and a faulty cable.

Step 2: Having switched cable connections at the sending units in Step 1, now also switch these cables at the electronics box. Determine which of the following four results occurs.

Result 2a: The fault(s) with the signal light(s) now switches channels. In this case, replace the faulty cable from the sending unit.

Result 2b: The fault(s) with the signal light(s) does not switch channels in this step either. In this case, replace the faulty electronics box.

Result 2c: No fault with the indicator lamps is now apparent. In this case, there is a faulty connection at the electronics box. First check for shorts or breaks in the connecting cable. If no faults are found in the cable, then replace the faulty electronics box.

Result 2d: Faults now exist with lights from both sending units. In this case, replace a faulty cable and the faulty electronics box.

If all four signal-input indicator lights work correctly, but the faults exist with the indicator(s) on a drum control handle(s), then perform Step 3.

Step 3: Switch the cable connected to the front drum control handle over to the rear drum control handle, and the cable connected to the rear drum control handle over to the front drum. Determine which of the following four results occurs.

Result 3a: The fault in the indicators now appears on the opposite control handle. This means that either the cable to the control handle is faulty or the electronics box is faulty. Go to Steps 5b, 5c, and 6a on Trouble Shooting Chart for more information.

Result 3b: The fault remains on the same control handle. In this case, repair the faulty drum control handle.

Result 3c: No faults are now apparent on the indicators of either control handle. In this case, there is a faulty connection at the drum control handle. First check for shorts or breaks in the connecting cable (see Trouble Shooting Chart). If no faults are found in the cable, then repair or replace the faulty drum control handle.

Result 3d: Faults now exist with indicators on both drum control handles. In this case, replace the faulty cable and repair or replace the one faulty

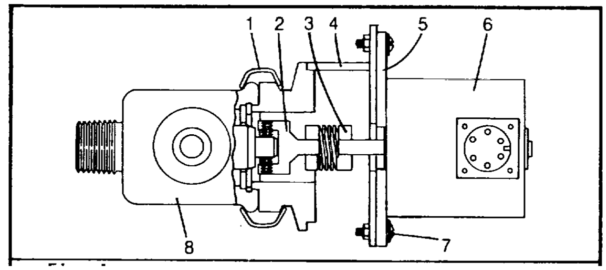


Fig. 4
Sending unit Assembly

| | |
|---|---|
| (1) Coupling | (5) Adaptor Plate |
| (2) Adaptor | (6) Sending Unit |
| (3) Shaft Coupler | (7) Lock Screw |
| (4) Sending Unit Mount | (8) Rotating Joint |

handle.

### 2.9 Faults Involving Both Drums In The Same Direction(s) Of Rotation

The following procedures should be used primarily for those situations in which the indicators for the same or both directions on the two drum control handles are not working properly.

Conditions 1 through 4 of the following are for trouble shooting faults which show up on the indicator lamps.

Steps 5 and 6 are for trouble shooting faults in the indicators when all indicator lamps are operating correctly.

Note: <u>The electronic box is not repairable with the exception of replacing indicator lights of thumbwheel switches. If something goes wrong internally, the box must be replaced</u>.

All wiring harnesses, and component parts inside the drum control levers are replaceable. Refer to the Parts Book for more information.

| CONDITION | PROBABLE CAUSES | TESTS (Test Probable Causes In Sequence) | REMARKS |
|---|---|---|---|
| (1) None of the indicator lights will light. | a) Discharged battery | Does any other equipment work that is connected to the same battery? | If not, recharge or replace the battery. |
| | b) Disconnected (open) or shorted cable between battery and electronics box. | Disconnect the cable at J1 (large connector located on the electronics box) and measure the DC voltage on terminals A and B of the plug. At least one *of* these terminals must measure approximately +12 volts.<br><br>CAUTION: Do Not Touch Terminals A Or B (+12 Volts) Of The Plug To Terminals E Or F (O Volts), To The Connector Shell, Or To Any Other Metal Surface. | If not +12 volts on A or B, replace cable. |
| | c) Faulty electronics box. box). | Reconnect J1. Disconnect both Ja and J3 (these are the two smaller connectors on the electronics Within each receptacle (J2 and J3), connect each terminal B and E to terminal C. Use a small jumper wire to do this. Each indicator light should light in turn.<br><br>CAUTION: Do Not Connect Terminals A *(+12* Volts) To C Or D (O Volts), To The Receptacle Shell, Or To Any Other Metal Surface. | If one or more lights will not light, replace the electronics box. |
| | d) If Fault not found in a, b, or c above, then proceed to condition (2). | | |
| (2) Some of the indicator lights will not light. | a) Drums not turning or the mechanical couplings of the sending units are faulty. | Perform a visual check of shaft sending units while their respective drums turn. | Replace mechanical couplings, if necessary. |
| | b) Disconnected or open cables between shaft sending units and electronics box. | Disconnect the cables between the shaft sending units and the electronics box. With a jumper wire, sequentially interconnect pairs of terminals at one end of each cable, and at the other end measure the resistance between the corresponding terminals for each pair. | If the resistance of any pair is greater than 2 ohms, replace that cable. |
| | c) Faulty electronics box. | Perform test lc Also measure the DC voltage on terminals A of the two small receptacles J2 and J3 on the electronics box. Measure with respect to the chassis or vehicle ground.<br><br>CAUTION: Do Not Short Terminals A(+12 Volts)To Terminals C Or D (O Volts), To The Receptacle Shells, Or To Any Ohter Metal Surface. | f the voltage does not approximately equal +12 volts on both terminals A, then replace the electronics box. |
| | d) Faulty shaft sending units. | No test is required at this point. | Replace the faulty sending unit. |
| (3) Some of the lights stay on. | a) See 2a.<br>b) Shorting to ground of conductors in cables between shaft sending units & electronics box. | See 2b and 3b and wiggle cables during tests to search for intermittent connections in the cable wiring or their junctions at the plug ends. | If the resistance between a pair of terminals at one end of a cable is less than 1 million ohms, replace the cable. |

| CONDITION | PROBABLE CAUSES | TESTS (Test Probable Causes In Sequence) | REMARKS |
|---|---|---|---|
| - | c) See 2c<br>d) See 2d. | | |
| (4) Some of the indicator lights are erratic or otherwise not in sequence. | a) Intermittently disconnected (open) shorted cables between shaft sending units and the electronics box.<br>b) See 2c.<br>c) See 2d. | See 2b and 3b and wiggle cables during tests or to search for intermittent connections in the cable wiring or their junctions at the plug ends. | |
| (5) One or more signals on both drum control handles don't pulse, pulse weakly, pulse erratically, or pulse for the wrong direction of drum rotation. | a) Faulty handles or faulty cable between electronics box and handles. Indicators may be jammed or electrically shorted or open. | Disconnect J1, the large connector on the electronics box. Use a jumper wire to con nect terminals A or B of the plug to neighboring terminals C, D, G and H individually. Upon making each connection, g5b one of the indicators should push up. Terminals C, D, G and H correspond respectively to the Up and Down indicators of the front drum and the Up and Down indicators of the rear drum.<br>CAUTION: Do Not Connect A Or B (+12 Volts) To E Or F (O Volts), To The Shell Of The Plug, Or To Any Other Metal Surface. | If all indicators push up on command, go to 5c. Otherwise, go to |
| | b) Disconnected, shorted or open cables between handles and electronics box. | i) Disconnect the cables from the drum control handles. To check for shorts in these cables, measure resistance between each pair of terminals at the ends of the cables nearest the handles. ground, replace<br>ii) Check for breaks within the wires of the cable assembly or for poor junctions of the wires to the plug terminals. To do this, first use a jumper wire to connect terminals A and B (in the large plug near the box) to C, D, E, F, G and H also in the plug. These can be done individually or all at once. Measure for +12 volts on each terminal within the two plugs at the ends opposite the large plug.<br>CAUTION: Do Not Connect Terminals A Or B (+12 Volts) In The Large Plug To The Shell Of The Plug Or To Any Other Metal Surface. | If any of the readings are not approximately +12 volts with respect to chassis<br>the cable assembly. |
| | | iii) No further test required. | Replace or repair drum control handles. Replace electronics box. |
| | c) Faulty electronics box. | No further test is required. | Replace the electronics box. |

| CONDITION | PROBABLE CAUSES | TESTS (Test Probable Causes In Sequence) | REMARKS |
|---|---|---|---|
| (6) Signals seem normal in both directions and at low speeds; pulse rates increasing drum speeds but pulse rates are not in the correct range. | a) Incorrect setting of the parts of line thumbwheel switches. | Verify correct setting of thumbwheel switches. They should be set to a numerical value that is equal to the parts of line being used on the boom for each drum. | Reset thumbwheel switches if necessary. |
| | b) Faulty electronics box. | No further test required. box. | Replace electronics |
| (7) Signals occur on wrong drum control handle. | a) Cables are improperly connected. | No test required. | Switch connections around at one end of the two cables running between the shaft sending units and the electronics box. Or, switch cables connected to the drum control handles. |

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11.1 Operators Control Stand

There are left and right operator control stands. On these control panels are grouped the operating levers; except for the master clutch control, swing brake control, swing lock control, and swing-travel controls (see Operators Manual). The S-o-M valves are bolted together in a bank, and form the pressure and return manifold. All valves are of the "variable pressure" type.
Descriptions and operation of these valves will be explained later in this SM.

11.2 Control Valve Replacement

Valves may be replaced in the valve bank as follows:

(a) Reduce operating pressure in the system to zero by moving the control levers back and forth with the engine shut down.
(b) Loosen tie capscrews on the end of the valve bank. Pull the tie capscrews from the valve bank far enough to clear the valve that is to be replaced.
(c) Loosen the capscrews which hold the valve bank end cap in place.
(d) Remove the valve. Insert the new control valve in the space that was occupied by the valve being removed. Install an 'O' ring on the pressure and return manifold holes to provide a seal between valves.

Note: Lubricate 'O' ring with hydraulic oil.

(e) Insert the tie capscrews back into the valve bank. Tighten to 35 in/lb. (3.9 N.m) torque.

Note; <u>This torque value is to be added to what is required to torque through the nylon locking patch.</u>

(f) Tighten the capscrews which hold the valve bank end cap in place to 23 ft/lb. (31 N-m) torque.

Note: <u>Make sure bolts don't bottom on valve cap. Over-tightening can cause sticking valve spools.</u>

All control levers and their functions may be determined by the name plate located next to the lever on the control panel top.

11.3 Operating Valve And Levers

All operating valves are of the variable pressure type. The valve is under a constant head of full operating pressure from the pump, but as the valve is opened by the hand lever, it permits controlled amounts of pressure to enter the operating cylinders. Increasing the pressure on the hand lever will correspondingly increase the amount of pressure being delivered by the control valve. Returning the control handle to neutral vents oil pressure in the clutch operating cylinders back through the valve, to the sump tank.

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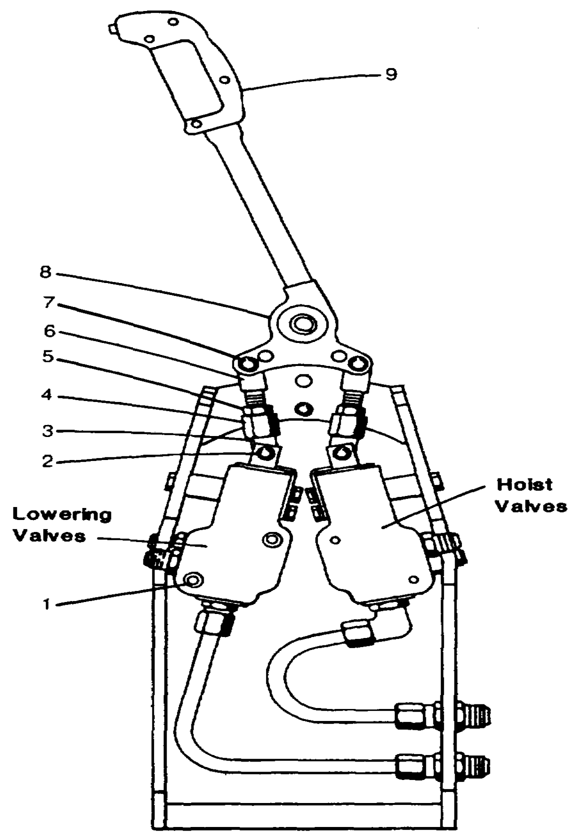



Fig. 1 ZZ189-C
Control Levers (Split Control. Stand)

| | |
|---|---|
| (1) Tie Capscrews | (6) Toggle Link |
| (2) Rollpin | (7) Rollpin |
| (3) Toggle Link | (8) Toggle Lever |
| (4) Adjusting Nut | (9) Lever |
| (5) Jam Nut | |

The valves are precision built at the factory and require no internal adjustment. The pistons are individual lapped fits, and are not interchangeable with one another. As dirt, or improper handling may cause the valves to become inoperative, the pistons must not be removed 1 of 2 except when necessary to inspect or replace the inner valve spring. Disassembly and inspection procedures are listed later in this SM.

11.4 Control Lever Adjustment

Adjustment of the control lever linkage should be checked occasionally to assure full operating pressure at the operating cylinders. To adjust the linkage, proceed as follows:

(a) With the master clutch disengaged, toggle the control lever.

(b) Loosen the jam nut (see Fig. 1).

(c) Adjust the toggle links until the control valve piston is just short of bottoming in liner when linkage is on center.

(d) Tighten the jam nut. Don't overtighten.

Adjustment of the linkage must always permit maximum pressure in the operating cylinders, otherwise clutch slippage may result, or travel jaws may not fully engage.

11.5 Rollpin Instructions

When assembling rollpins in the toggle lever links, assemble so the gaps in the rollpins art facing toward the levers and away from the valves as shown in Fig. 1.

11.6 Lubrication

Periodic and systematic lubrication of toggle levers, rollpin, and linkage is important for an efficiently operating system.The squirt oil method of lubrication should be used so all points are thoroughly lubricated. The toggle levers and shaft may be lubricated by removing the control levers and squirting oil down the mounting hole. Use Molykote (830332).

Lubricate valve caps periodically. Use clean S-o-M oil.

11.7 Control Valve Disassembly

If a valve does not function properly, it may be disassembled as follows:

(a) Reduce pressure in the system to zero by working the control levers back and forth.

(b) Remove the valve bank cover.

(c) Drive out the rollpin which connects the lever linkage to be swung out of the way to gain access to the valve. The control lever may be removed to allow the toggle lever to be rotated on its shaft for additional working clearance.

(d) Remove the valve cap stop.

(e) Remove the valve cap.

(f) Remove and inspect the outer valve spring. If the spring is broken, replace it.

(g) Replace the valve cap but omit the outer spring. Check the free action of the valve cap by pushing in on it. If the valve cap has a tendency to bind, remove it and polish with fine emery cloth. Wash the cap thoroughly in clean approved solvent, and oil lightly before replacing the valve cap on the valve. (h) If the valve cap is free, remove it and test the action of the valve piston by pushing on it. A sticky or binding piston usually indicates the presence of a scratch or foreign material on the piston. If this should be the case, the valve assembly must be replaced. Do not attempt to polish scratches or high spots. The piston is a lapped fit within the liner, and satisfactory repairs may be made at the factory only. In some cases, depending upon the condition and location of the scratches and high spots the piston may be repaired by polishing and cleaning. A mechanic not acquainted with the working principles of this valve should not attempt this, as an inoperative valve may result. Do not attempt to interchange pistons from one valve to another, as they are individual lapped fits.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well connected. Ventilated Area, Away From Flame.

(i) Thoroughly wash all parts in clean approved solvent, oil lightly with clean S-o-M oil, and reassemble by following the previous instructions in reverse.

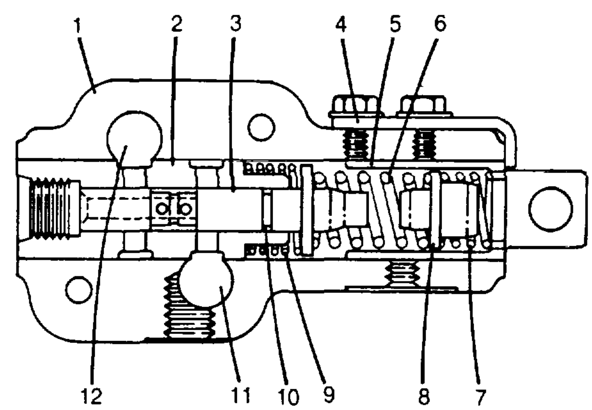



Fig. 2 NA306-A
Variable Pressure Control Valve

| | |
|---|---|
| (1) Valve Body | (7) Spring |
| (2) Piston Liner | (8) Spacer |
| (3) Piston | (9) Return Spring |
| (4) Cap stop | (10) 'O' Ring |
| (5) Valve Cap | (11) Return Manifold |
| (6) Spring | (12) Pressure Manifold |

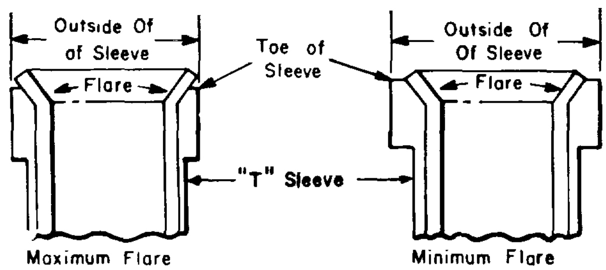



Fig. 1
Proper Tube Flare

The best hydraulic machine system is only as good as the operator's maintenance of the tube fittings.

The basic causes of fluid system leakage are human error and lack of education resulting in improper assembly or mismatched part. Use of properly matched parts, correct tube preparation, correct installation procedure and time table inspection will go far toward maintaining leak-free hydraulic system machinery operation.

1.1 Tube Preparation

As a general rule, tubes should be cut off square and concentric and internal and external burrs removed from both flareless and flared tube fitting applications.

Although incorrectly formed flares may seem to make up satisfactorily and pass initial pressure tests, they cannot be depended upon for continuous service.

If the tube is properly prepared and a flaring tool properly used, the flare will normally be correct.

Angle, length, and diameter of flare must conform to the-fitting where used. Identify fitting and flare tube accordingly.

Flares for 37°, 3-piece fittings should extend beyond the maximum inside diameter of the toe of the sleeve, but not beyond the outside diameter of the sleeve for correct length and diameter.

Diameter of maximum flare is equal to the outside diameter of the sleeve; diameter of the minimum flare is equal to the maximum inside diameter of the sleeve.

Note: SAE 450 nuts -- when connected to an SAE 37° male flare fitting, will leak. The SAE 450 nut is too long and will bottom on adaptor hex in sizes 8 and 10 before the seats are tight; therefore, use all 37° flare parts (see Fig. 2).

Inspect leaking flared tube fittings for the following:

(a) Flare too short. Full clamping area of fitting not utilized, resulting in thinning causing leakage or breakage due to pullout strains.

(b) Flare too long. Flare will stick and jam on nut threads when assembled.

(c) Incorrect flare angle for fitting where used.

(d) Flare not square and concentric – tube not properly prepared before flaring.

(e) Damaged or distorted flares.

Important: <u>Do not attempt to repair damaged flares. Cut off and reflare if tube of sufficient length; otherwise, replace tube.</u>

Flaring tools are available from the parts department. Tool #PX110 should be used to flare 3/16" through 5/8" tube, and tool #PX355 used to flare 3/4" tube.

1.2 Tube Fittings

Inspect leaking fitting for following:

(a) Proper assembly and nut tightness.

(b) Foreign material in tube or fitting.

(c) Tube damage or improper preparation of tube for flaring.

(d) Correct flaring for that particular fitting.

(e) Damaged or mismatched parts (see Fig. 2).

Important: Replace fittings or fitting parts by manufacturer, size and type. A variety of fittings may be found in the same hydraulic system. Due to similarity, careful identification is required. 7

Representative types of reuseable tube fittings to be found in Link-Belt machinery, as follows: 37 Degree Flare: Three-piece fitting consisting of a body, nut and sleeve, requiring 370 tube flaring (see Fig. 2).

Locking and sealing is accomplished by tightening the nut and compressing the tube against the body. Note that the nut turns on the sleeve, rather than the tube providing a "triple-lok" action.

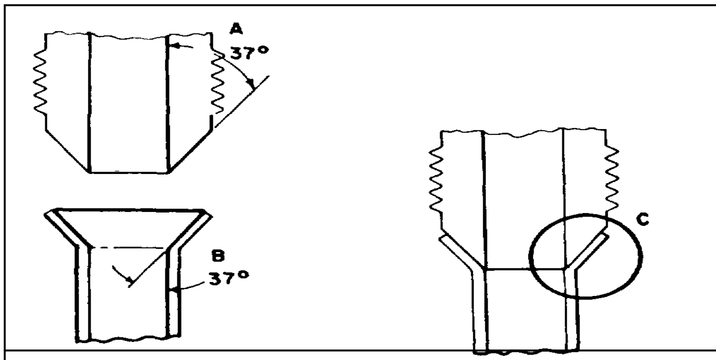



Fig. 2
Typical 37° Flare

(A) 37°
(B) 37°
(C) Proper Fit

This fitting can be identified as to type visually, by sleeve extending out on tube from back of nut.

1.3 Reassemble as follows:
- (a) Assemble nut and sleeve on tube.
- (b) Reflare tube.
- (c) Check flare angle, diameter, and length in relation to tube before tightening nut.
- (d) Tighten nut.

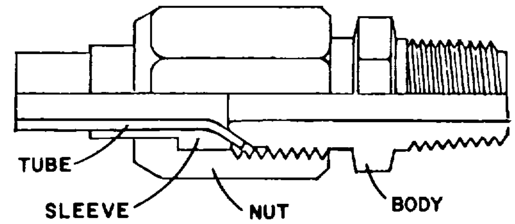



Fig. 3
"Flared" Fitting

1.4 "Lenz" 0 Ring

Three-piece fitting consisting of a body 'O' ring and teflon, back-up washer assembly, tapered split ring and nut. The 'O' ring and teflon washer are replaceable in the body.

Tube locking is accomplished by tightening the nut over the tapered split ring, compressing the tapered split ring against the tube, and is independent of the seal. Sealing is accomplished by the '0' ring.

This fitting can be identified as to type visually, without disassembly by the split flange, flush with and visible from the back of the nut.

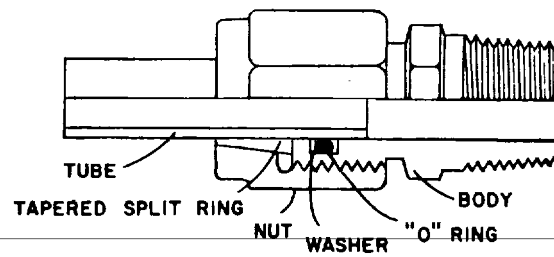



Fig. 4
"Lenz" 'O' Ring Fitting

1.5 Reassemble as follows:

- (a) Check tube for burrs and deburr if required.
- (b) Slide nut and tapered split ring on tube with large end of split ring facing the fitting.
- (c) Replace and lubricate '0' ring.
- (d) Insert the tube into the body past the '0' ring.
- (e) Position the split ring against the fitting.
- (f) Tighten nut hand tight.
- (g) With a wrench, tighten nut per Chart B.

1.6 Straight Thread 'O' Ring Seal

Two-piece fitting consisting of a body, washer, and jam nut assembly and an '0' ring. The 'O' ring is replaceable.

Sealing is accomplished by threading the fitting into the port, compressing the '0' ring into the "gland" formed in assembly, between the port and the flat surface of the fitting. Locking is accomplished by tightening the jam nut against the washer to the spot face.

Lubrication of the '0' ring and correct assembly procedure are extremely important on this type fitting.

1.7 Reassemble as follows:

- (a) Replace and lubricate '0' ring.
- (b) Make sure that port and fitting threads are clean and free from damage.
- (c) Position washer and '0' ring as far back on the flat surface of the fitting as possible.
- (d) Position jam nut against washer.
- (e) Thread the fitting into the port until the washer bottoms on the spot face.
- (f) Position the elbow by turning the fitting counter-clockwise up to 359°.
- (g) Tighten jam nut, maintaining the elbow position. Tighten per Chart B.

Note: <u>The importance of lubricating the '0' ring and backing up the washer and '0' ring cannot be overstressed.</u>

When the '0' ring is dry, rotary motion of the assembly can cause friction, pinching the '0' ring between the washer and the spot face.

If the washer and '0' ring are not backed up before assembly, there is not sufficient room

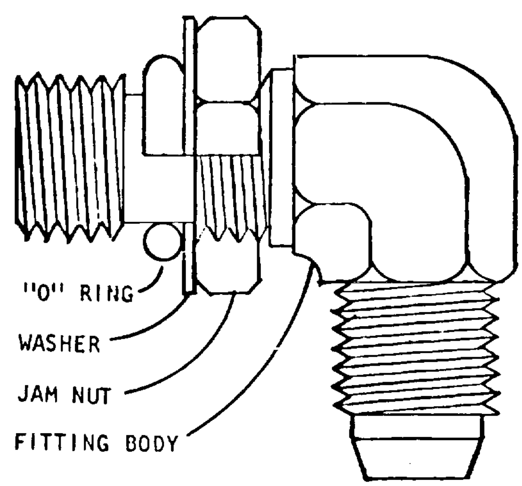



Fig. 5
Straight Thread 'O' Ring Seal Fitting

for the '0' ring compression into the reduced gland area, causing the '0' ring to pinch off between the washer and the spot face, or catch between the fitting and port threads.

This fitting depends on compression of jam nut, washer, face of the boss and the body threads for locking. The washer cannot bottom properly if the '0' ring is pinched, resulting in a loose and usually leaking connection. If the jam nut is not locked because of 'O' ring obstruction, the jam nut will loosen and the whole fitting will become loose and leak.

1.8 4 Bolt Split Flange Connection

This connection is face sealing and is extremely sensitive to bolt torquing. The shoulder which contains the '0' ring must fit firm all four bolts.

The flange halves are designed to overhang the shoulder containing the 'O ring seal to insure that the shoulder will make contact with the mating surface before the flange halves.

Because of flange overhang, the flanges tend to tip up when the bolt at one end is excessively tightened before the bolt at the other end.

Tightening the bolt at the other end can then cause the flange to bow, tip up in a see-saw fashion, or bend around and away from the sleeve shoulder, resulting in bent bolts or bent flanges, resulting in loss of flange to shoulder contact and leakage.

If leakage is suspected, check bolt torque level and flanges for distortion.

Note: Torque wrench reading could be at required level, but shoulder tension could be dissipated due to bent bolts and distorted flanges.

1.9 Reassemble as follows:

(a) Check flange halves for bending or bowing and make sure that bolts are not bent or threads damaged.
(b) Replace and lubricate 'O' ring to insure compression in flange seal groove.
(c) Make sure that all mating surfaces are clean and undamaged.
(d) Make sure that the sleeve is lined up with the port and that the shoulder containing the '0' ring fits flush against the mating surface before installing the flange halves.
(e) Lubricate bolts and install lockwashers. Lockwashers should be installed with the cupped side toward the flange.
(f) Position flanges over sleeve shoulders and install bolts. DO NOT TIGHTEN.
(g) Finger tighten all four bolts evenly and alternately. Make sure that flanges do not hang up on bolt threads during tightening. Do not tighten any one bolt before going on to another, until all bolts are finger tight.

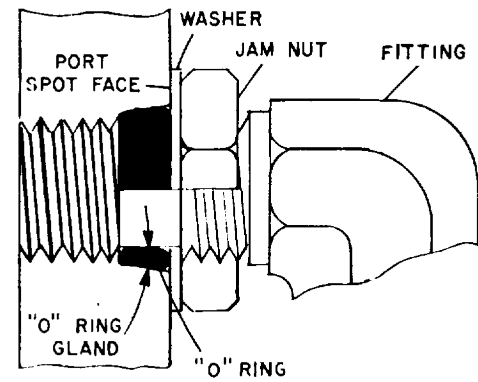



Fig. 6
Proper Assembly With Washer Bottomed Against Spot Face Of Port, '0' Ring Compressed Into Sealing Gland

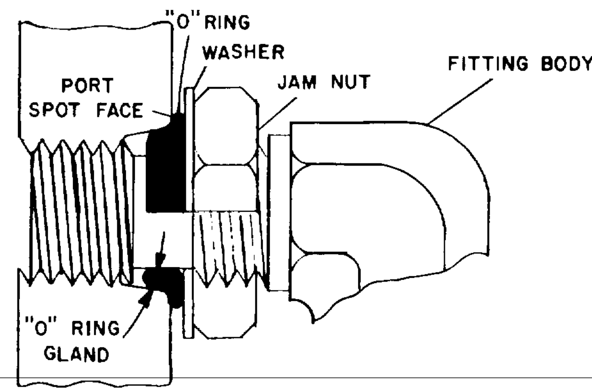



Fig. 7
'0' Ring Punched Between Washer And Port Spot Face Due To O' Ring Not Lubricated Prior To Assembly

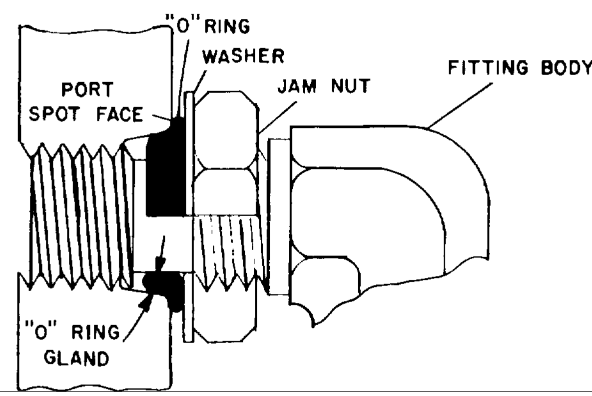



Fig. 8
'0' Ring Pinched Between Washer And Spot Face, Due To Washer and '0' Ring Not Being Backed Up Prior To Assembly, Causing Reduced Gland Area

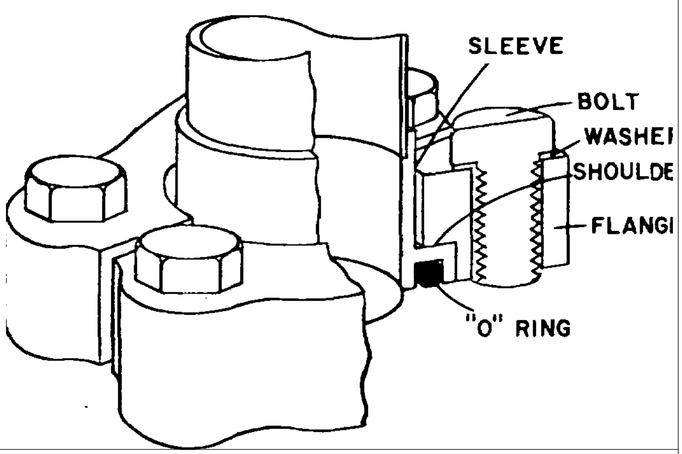



Fig. 9
4-Bolt Split Flange Connection

(h) Refer to chart and tighten bolts to recommended torque level using a hand torque wrench. Do not fully tighten any one bolt before going on to another until recommended torque is attained on all bolts. Note: Air wrenches tend to tip flanges. (i) Check installed flanges for distortion.

Note: Capscrews must be tightened to the values given in Chart A to insure proper flange connections. Lubricate all threads with oil before tightening.

Proper alignment of sleeve to port prior to assembly is of extreme importance to assure correct assembly and a leak free connection.

Align bent or replacement sleeve to port as follows:

(a) Clamp one end of tube in place, aligning other end for best fit possible.

(b) Using a torch, with a large heating tip,

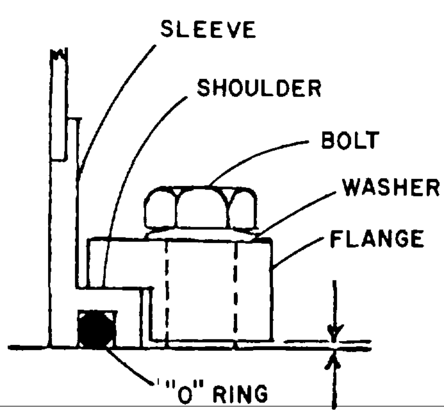



Fig. 10
4-Bolt Split Flange Connection

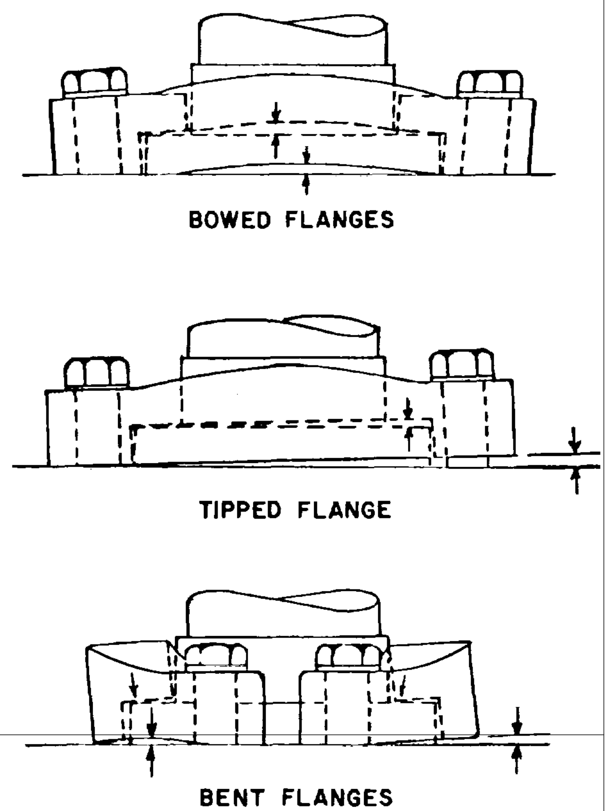



Fig. 11
Incorrect Flange Installation

heat the tube cherry red in the area previously bent when originally formed.

Note: Adhere to all Safety Precautions.

(c) Heat a large area before attempting to bend tube for the largest possible radius bend. Always heat the tube in such a way that bending the tube will stretch the heated metal, rather than compressing. This will keep the tube from upsetting or wrinkling. Do not overheat.

(d) Clamp or hold sleeve in position and allow the tube to cool slowly in the air.

(e) Recheck the alignment. If necessary, reheat and rebend tube.

(f) Install flanges and check for unobstructed fit over the shoulders.

1.10 Marman Joints

"Flexmaster" Self Restrained: Consists of two couplings, two gaskets with notched retention rings, two gasket retainers and one sleeve.

This joint cannot be identified visually, without disassembly, from the Marman 6500 series joint. The difference between the two joints being that a notched retention ring is used in the special buna rubber gasket for the "Flexmaster Self Restrained" joint.

Lock and sealing action is by compression of the gaskets during tightening of the couplings, exerting pressure on the gasket and notched, split retention rings which in turn grip the pipe or tube.

Note: This is a sealing joint and is not intended to support pipe or tube end load.

1.11 Reassemble as follows:

(a) Clean and align both pipe ends.

(b) Install retainer, gasket and sleeve on opposing pipe end.

Note: Assembly can be made easier by dipping the gaskets in water prior to use. Do not use petroleum or non-drying lubricant.

(c) To simplify installation of the self restrained gasket, install the lower half of the gasket first, leaving the split area of the steel retention ring free at the top of the tube as shown by dotted line in previous sequence illustration. Then stretch the gasket and split area of the pipe or tube into position.

(d) Center sleeve over the pipe ends and position gaskets and retainers flush against the sleeve.

(e) Make sure that sleeve overlaps pipe ends (dim. A, Fig. 12) *by* 1/4" (6.35 mm) minimum on 2 inch and smaller diameter pipe, and by 1/2" (50.8 mm) minimum on larger diameter pipe.

(f) Assemble both couplings and tighten nuts (dim. B, Fig. 12) until 0-1/4" (0-6.35 mm) gap is obtained between coupling ends.

(g) Make sure that coupling encompasses all components before tightening. Do not tighten either coupling until the entire joint is assembled.

1.12 "Marman Flexmaster - Model 6500":

Consists of two couplings, two gaskets, two gasket retainers and one sleeve. This joint cannot be identified visually, without disassembly, from the Marman Flexmaster Self Restrained joint. The "Flexmaster" and Model 6500 joints are identical except that the notched retaining ring in the gasket is not used in the Model 6500 joint.

Lock and sealing action is by compression of the gaskets during tightening of the couplings, exerting pressure on the gasket which in turn grip the pipe or tube.

Installation procedure is identical to procedure as outlined for the "Flexmaster Self Restraining" joint.

Note: This is also a sealing joint and is not intended to support pipe or tube end load.

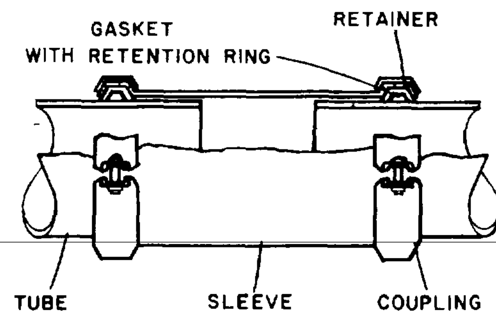



Fig. 12
"Marman Flexmaster Self Restrained"

1.13 Preventive Maintenance

There is no shortcut to hydraulic machinery tube fitting preventive maintenance. It is impossible to detect a potential leaking joint or fitting until the trouble actually begins. There is no way of telling if a fitting is loose without tightening it. Leaks can develop in a new machine or any time during continuous service from fittings which appear secure and leak free.

Seemingly time consuming preventive maintenance inspections can result in avoiding costly hydraulic system component damage and loss of costly operational efficiency.

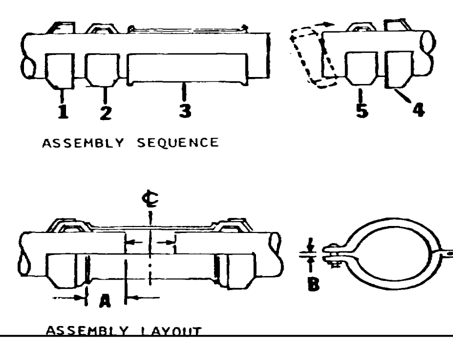



Fig.13
Assembly Sequence & Layout

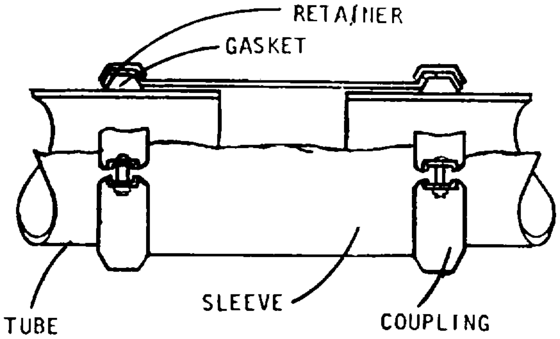



Fig. 14
"Marman Flexmaster Model 6500"

Check all hydraulic system tube fittings upon receiving a new machine. Pay particular attention to hard-to-reach fittings which might be missed or ignored during subsequent "on the job" routine inspections.

Adhere structly to recommended time table inspection schedules. Do not assume that a fitting will remain tight if no evidence of loosening or leakage. Check all fittings and tighten if necessary during each scheduled inspection.

Maintain an "open eye" policy for evidence of leakage at all times. Consider any evidence of leakage as a red flag. Check and tighten or replace leaking fittings or fitting parts immediately to avoid resultant hydraulic system component damage.

Consider every fitting as a working component of the hydraulic system. Become acquainted with the characteristics of every fitting used in the particular hydraulic system.

1.14 When Replacing Fittings or Fitting Parts:

(a) Make sure that tube is properly prepared.
(b) Make sure that flare is properly formed for that particular fitting.
(c) Replace fitting or fitting parts by manufacturer, size and type.
(d) Follow correct assembly procedures for each particular fitting.
(e) Use Loctite on threaded fittings.
(f) Use a torque wrench where torque specifications apply.

1.15 "Loctite" #242

As a product improvement, "Loctite" now has on the market a new pipe thread sealant #242, that does not require the use of a primer. Fittings can now be used in the "as received" condition (see instructions below for using the sealant).

We feel that using this newer "Loctite" product #242 will aid in preventing hydraulic pipe fittings from leaking and too that it should prove to be easier and quicker to apply. Therefore, we recommend that as soon as "Loctite" 242 becomes available to you that it be used in place of the existing "Loctite" pipe sealant (FMC spec 806004) where the thread is the sealing mechanism. The following quantities of "Loctite" #242 can be obtained from the factory. Order accordingly.

| Item Number | Quantity (Bottle) |
|---|---|
| 806033-001 ............................... | 250 cc |
| 806033-002 ............................... | 50 cc |
| 806033-003 ............................... | 10 cc |

The following instructions are for using "Loctite" #242 Pipe Thread Sealant; to be used on all connections where threads are the sealing mechanism.

(1) New fittings may be used in the "as received" condition.
(2 Be certain used fittings are free of dirt, oil, grease, paint and other contaminants by cleaning male and female threads with solvent (806006) and allowing to dry.
(3) Shake Loctite (806033) thoroughly and apply to male threads of the joint. Use application nozzle on the bottle to apply enough sealant to fill the first three threads. Avoid excessive application.
(4) After tightening threads, allow to cure for one hour.

Notes:
(a) Locquic primers must be used on nonmetallic parts.
(b) Locquic primers may be used on metallic surfaces where a rapid cure is desirable.

1.16 Recommended Torque Values for Hydraulic Fittings

In conjunction with using the new Loctite #242 to prevent hydraulic fittings from leaking, our engineering department has issued recommended torque values for various sizes of split flange connections, '0' ring boss fittings, JIC tube connections, and pipe swivel adaptors. These torque specifications are being adhered to during the assembly of the machine. (See torque specifications later in this bulletin)

1.17 Yellow Crackling Paint

As a quality control measure, a small strip of "crackling paint", yellow or orange in color, is applied across critical connections after the connections have been tightened to the proper torque value. This crackling paint will later serve as an indicator to show if the connection has loosened after the machine has been operated for a period of time.

If, upon examination of the connection, you should find the strip of paint has cracked or broken, this would be a good indication that the connection has seen some stress and has loosened. Therefore, retighten the connection to the proper torque value to alleviate or prevent a potential leak.

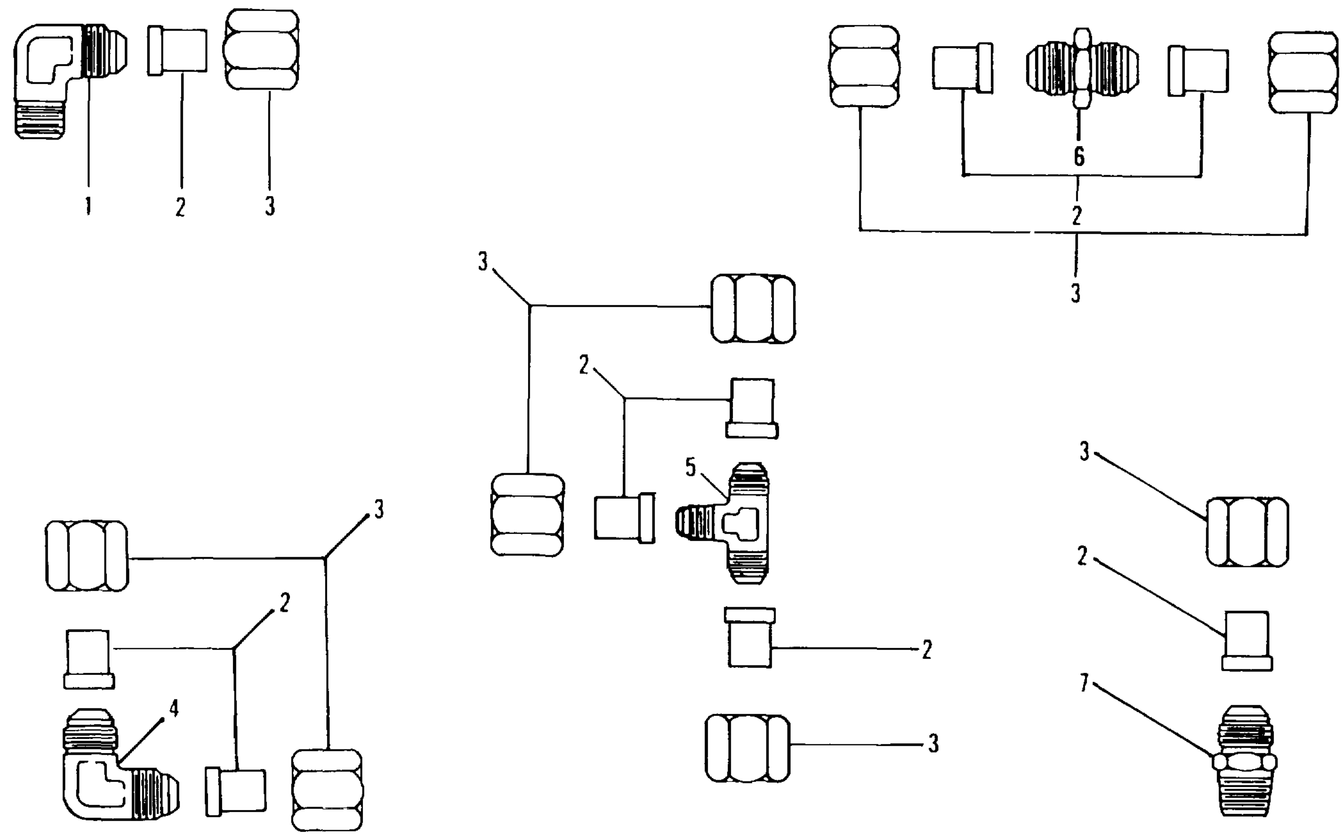



Fig. 15 (5) Union Tee
Hydraulic Tube Fittings

(1) Male Elbow
(2) Sleeve
(3) Nut
(4) Union Elbow
(6) Union Body
(7) Male Connector

Chart A

SAE Capscrew Head

Grade 5 Grade 8

Metric Capscrew Head


Grade 5 Grade 8

Torque Values For Bolts Used For SAE Split Flange Clamps

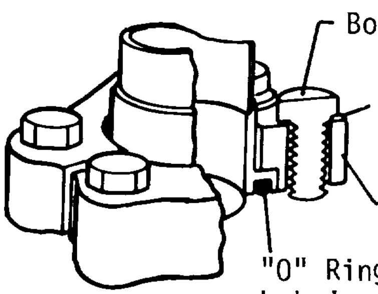
Torque Values Shown Are For Dry & Lubricated Threads

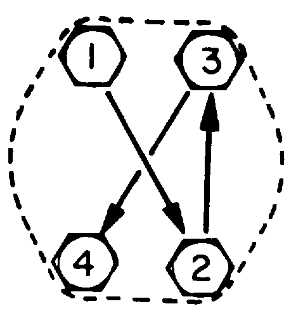
Clamps That Use:

| Bolt Dia. | | Bolt Torques | | |
|---|---|---|---|---|
| SAE Std. Thread | Metric Thread | In/lbs. | Ft/Lbs. | N·m* |
| 5/16 | M8 | 156 | 13 | 17 |
| 3/8 | M10 | 276 | 23 | 31 |
| 7/16 | — | 420 | 35 | 47 |
| 1/2 | M13 | 660 | 55 | 73 |
| 5/8 | M16 | 320 | 110 | 147 |
| 3/4 | M20 | 2400 | 200 | 267 |

Note: Bolts must be Grade 5 or better.

* N·m = Newton Meter(s)




SAE 4 Bolt Flange Tightening Sequence 1-2-3-4

Chart B

| Tube O.D. | Thread Size On Fitting Major Thd Dia. | 'O' Ring Boss Torque In/Lbs | Ft/Lbs. | N·m * |
|---|---|---|---|---|
| 1/8 | 5/16-24 | 36 | 3 | 4 |
| 3/16 | 3/8-24 | 96 | 8 | 11 |
| 1/4 | 7/16-20 | 96 | 8 | 11 |
| 5/16 | 1/2-20 | 132 | 11 | 15 |
| 3/8 | 9/16-18 | 225 | 19 | 25 |
| 1/2 | 3/4-16 | 360 | 30 | 40 |
| 5/8 | 7/8-14 | 456 | 38 | 51 |
| 3/4 | 1-1/16-12 | 648 | 54 | 72 |
| 7/8 | 1-5/16-12 | 900 | 75 | 100 |
| 1-1/4 | 1-5/8-12 | 1350 | 113 | 150 |
| 1-1/2 | 1-7/8-12 | 1896 | 158 | 211 |
| 2 | 2-1/2-12 | 2700 | 225 | 301 |

Examples of "O" Ring Boss

Do not over-tighten reducing fittings. See installation instructions.

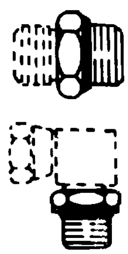


Chart D

Pipe Swivel Adapter For Fittings and Hose Assemblies

| Pipe Thread Nom Size | Major Thd Dia. | Torque In/Lbs | Ft/Lbs. | N·m * |
|---|---|---|---|---|
| 1/8 | 13/32 | 225 | 19 | 25 |
| 1/4 | 17/32 | 270 | 23 | 31 |
| 3/8 | 11/16 | 360 | 30 | 40 |
| 1/2 | 27/32 | 516 | 43 | 57 |
| 3/4 | 1-1/16 | 735 | 61 | 81 |
| 1 | 1-5/16 | 900 | 75 | 100 |
| 1-1/4 | 1-21/32 | 1163 | 97 | 130 |
| 1-1/2 | 1-29/32 | 1350 | 113 | 151 |
| 2 | 2-3/8 | 2700 | 225 | 301 |

Examples Of Pipe Adapters

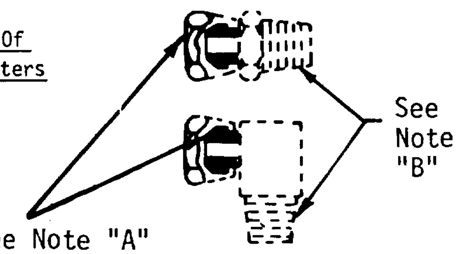
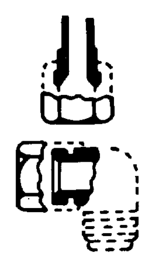



Chart C

JIC 37° Flare Swivel Nut

| Torque In/Lbs. | Ft/Lbs. | N·m* |
|---|---|---|
| 36 | 3 | 4 |
| 96 | 8 | 11 |
| 132 | 11 | 15 |
| 180 | 15 | 20 |
| 276 | 23 | 31 |
| 456 | 38 | 51 |
| 648 | 54 | 72 |
| 900 | 75 | 100 |
| 1056 | 88 | 118 |
| 1200 | 100 | 134 |
| 1896 | 158 | 211 |
| 2700 | 225 | 300 |
| 3996 | 333 | 445 |



Note A: Use above torques on this type of swivel nut only. Do not use Loctite.

Note B: No torque values for this type of pipe thread. See "Loctite #242" application instructions on page 6.

* N·m = Newton-Meter(s)

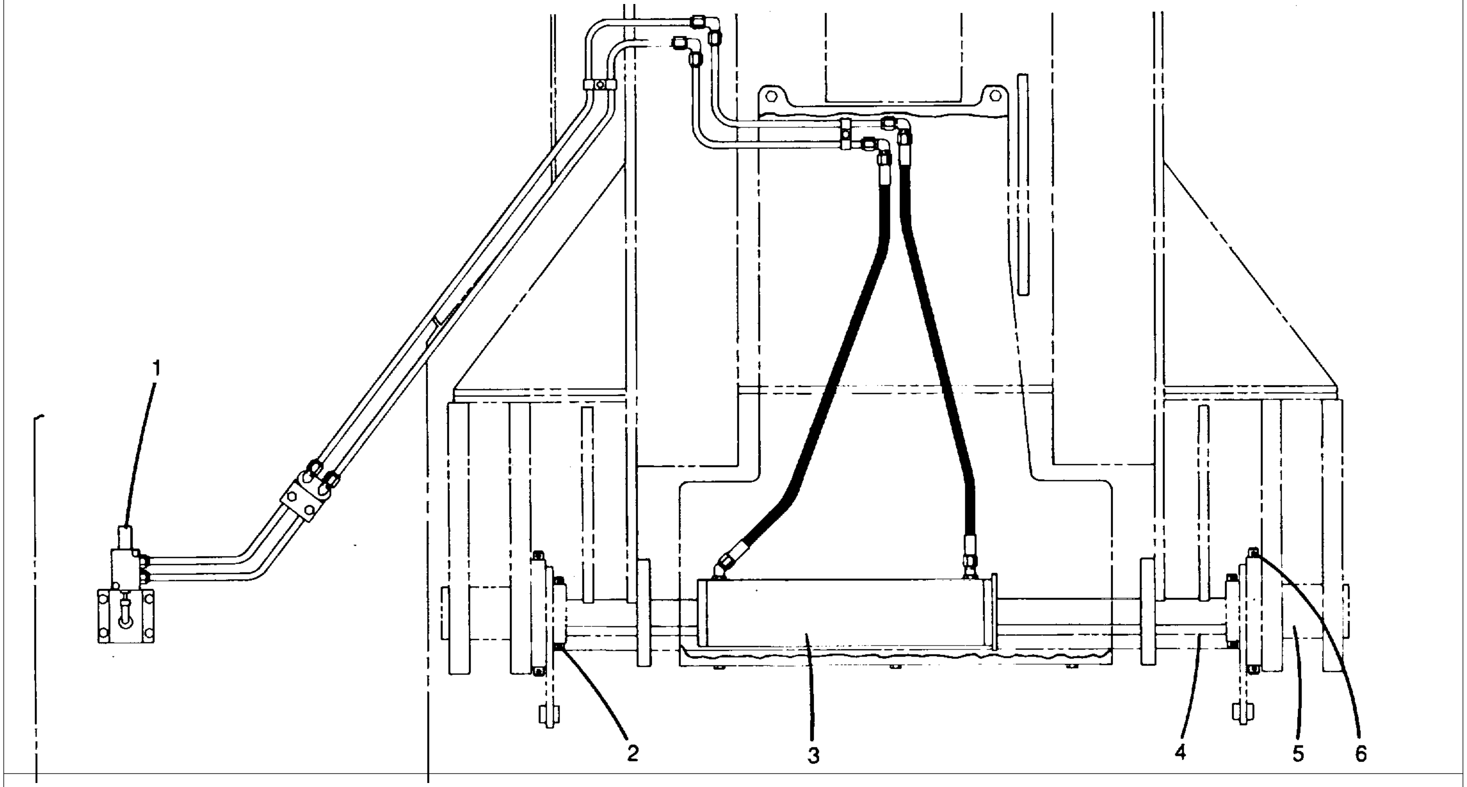



*Fig. 1*
*Boom Foot Pin Removal*

(1) Control Valve
(2) Connecting Pin & Cotter Pins
(3) Boom Foot Pin Removal Cylinder
(4) Pin (Retracted Position)
(5) Pin (Normal Position)
(6) Keeper Pin & Cotter Pins

The boom foot pin removal system uses b-o-m pressure to activate a cylinder connected to the boom foot pins. The cylinder pulls the pins from the boom foot lugs for easy removal of the boom lower section. A control valve mounted under the R.H. platform of the machine operates the cylinder. Refer to Section 1 of the Operators Manual for operating instructions.

1.1 Boom Foot Pin Cylinder Removal (Fig. 1)

(a) Before working on the boom foot pin cylinder remove the boom lower section from the machine. Refer to the boom sections of the Operators Manual for boom removal instructions. After the boom lower section is removed, remove the keeper pins and cotter pins.
(b) Remove connecting pins and cotter pins securing the cylinder to the boom foot pins.
(c) Fully retract the cylinder to withdraw cylinder rods from the pins. Refer to Section 1 of the Operators Manual for operating instructions.
(d) Shut off the engine and bleed S-o-M pressure to zero. For instructions, refer to the Operators Manual. Disconnect hydraulic hoses from the cylinder. Immediately cap or plug all lines to prevent entry of foreign material.

1.2 Cylinder Disassembly

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well ventilated Area. Away From Flame.

(a) Thoroughly clean the outside of the cylinder with approved solvent.
(b) Remove capscrews connecting locking plate (18) and gland (13) to cylinder case. Remove locking plate and gland from case.
(c) Remove rod (1) and piston (5) from cylinder
(d) Remove capscrews (7). Remove piston from
(e) Remove capscrews (1). Remove end cap (2) from the case.
(f) Remove and discard all old seals, '0' rings,
(g) Thoroughly clean and inspect all parts for nicks, scratches, etc. Replace any worn or damaged parts.

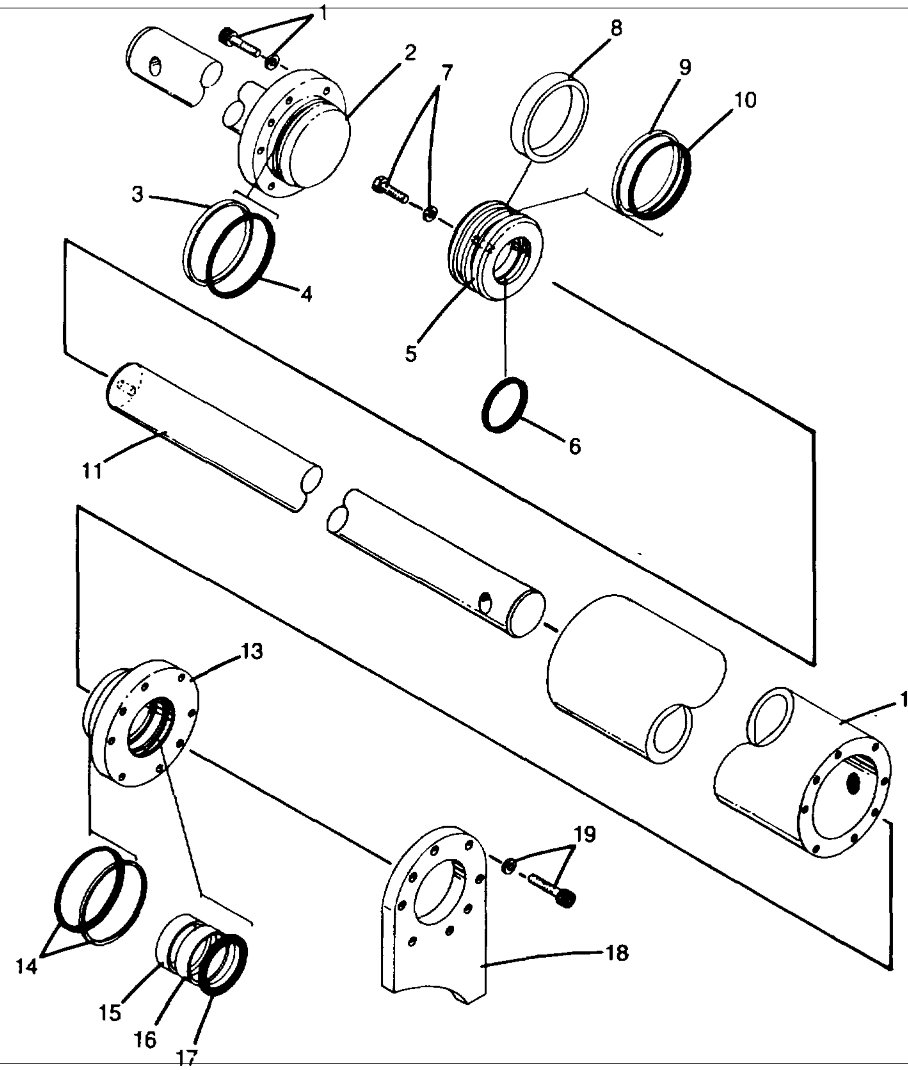



*Fig. 2*
Pin Removal Cylinder

(1) Capscrew and Lockwasher
(2) End Cap
(3) Back-Up Ring
(4) '0O' Ring
(5) Piston
(6) 'O' Ring

(7) Capscrew and Washer
(8) Wear Ring
(9) Piston Seal
(10) "O" Ring
(11) Piston Rod
(12) Cylinder Case

(13) Gland
(14) '0' Ring, Back-Up Ring
(15) Rod Ring
16) Seal
(17) Rod Wiper
(18) Locking Plate
(19) Capscrew and Lockwasher

1.3 Cylinder Reassembly (Refer to Fig. 2)

Always replace the old cylinder seals, '0' rings, etc. before reassembling the cylinder. Coat all seals, '0' rings, etc. with Cosmolube #2 or equal before installation. To reassemble the cylinder, do the following:

(a) Install 'O' ring (item 4 in Fig. 2) and back-up ring (3) in groove in outside diameter of end cap. Install end cap on cylinder, but be careful not to damage '0' ring or back-up ring.
(b) Install washer on capscrews (1). Install capscrews and tighten evenly to 30 ft/lb.
(c) Install 'O' ring (6) inside piston. Install piston on rod (11). Install capscrews (7) and tighten evenly to 30 ft/lb. (40 N-m) torque.
(d) Install '0' ring (10) in groove on piston. Install piston seal (9 ) in groove on top of '0' ring. Install wear ring (8 ) in the other groove.
(e) Coat the O.D. of piston with Cosmolube #2 or equal. Slowly slide the piston into the cylinder, and be very careful to prevent damage to the seals.
(f) Install the '0' ring and back-up ring (14) in the groove on the outside of the gland (13). Back-up ring is located behind the

'O' ring and is closest to the large end of the gland.

(g) Install rod ring (15), poly pack seal (16), and rod wiper (17) in the three grooves inside the gland.

(h) Coat I.D. (inside diameter) and O.D. of gland with Cosmolube #2 or equal. Slowly slide gland over rod and into the case, and be very careful to prevent damage to any '0' rings or seals.

(i) Use an approved solvent to clean the locking plate thread holes. Apply "No-Weld" antiseize compound (830005) to the capscrew threads (19). Install washers on capscrews and tighten both evenly to 35 ft/lb. (40 N.m) torque.

(j) Install cylinder on machine by inserting rod on end cap into boom foot pin. Install keeper pins and cotter pins (item 6 in Fig. 1) to secure boom foot pins.

(k) Connect hydraulic hoses to the cylinder. Start engine and build up S-o-M pressure. Move control valve to extend cylinder. Align the boom foot pin holes with the cylinder rod holes (refer to Fig. 1). Install the connecting pins and cotters to secure the boom foot pin to the cylinder rod.

2.1 Introduction:

(a) The purpose of this SM is to provide information for the identification, inspection and repair of tubular tower, boom and jib sections manufactured by FIC Corporation, Crane and Excavator Division, which have suffered certain specific types of damage. FMC Corporation cannot assume responsibility for any repairs of any kind made to tower, boom and jib sections because we will neither control nor inspect the repairs. This SM is informational only.

(b) The alloy steel used in the manufacture of tubular tower, boom and jib sections necessitates the use of special procedures for the removal and replacement of damaged lattice and diagonals. Strict adherence to the following procedures is absolutely necessary.

(c) It is very important to maintain the supporting lattice work on a tower, boom or jib section in good condition. Damaged lattic allow deflection of the main chord tubes under load so that they are no longer in line; this destroys the true column effect of the boom. The result is reduced boom strength and capacity.

(d) All maintenance and inspection work should be done by qualified workmen. The welding of lattice and diagonals requires a unique skill and conscientious workmanship. It is therefore of the utmost importance that the workman studies these instructions, learns them, follows them, and takes time to develop the skill through practice.

(e) An explanation of the terms used through out this SM are given in Figure 1.

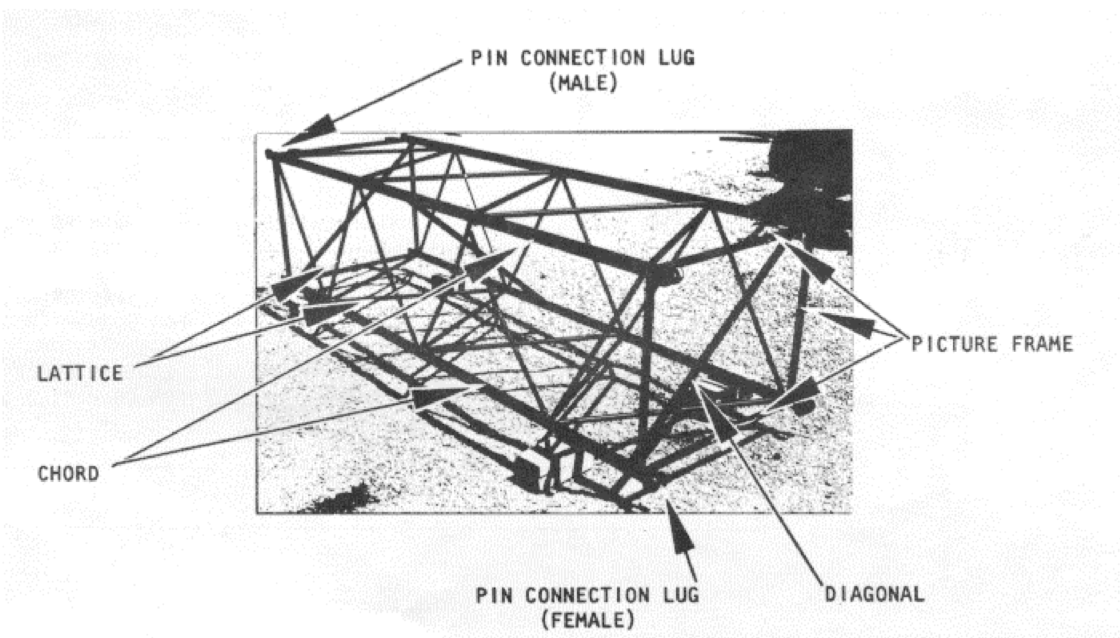



*Fig. 1*
*Description Of Terms*

Fig. 1
Description Of Terms

2.2 Preparation For Repair:

2.3 Identification: Different types of material, coded "A", "B", or "C" by the factory, are used in the chord members of different models. It is important to determine the correct material type in the section to be repaired since different welding procedures are required.

Locate the identification tag (Figure 2) and record the serial number and chord material type (See Figure 3). If the material type is not marked, the material is type "A" or "B", which have the same welding procedure. If the identi fication plate cannot be located or is unreadable, the section is to be considered as NON-REPAIRABLE

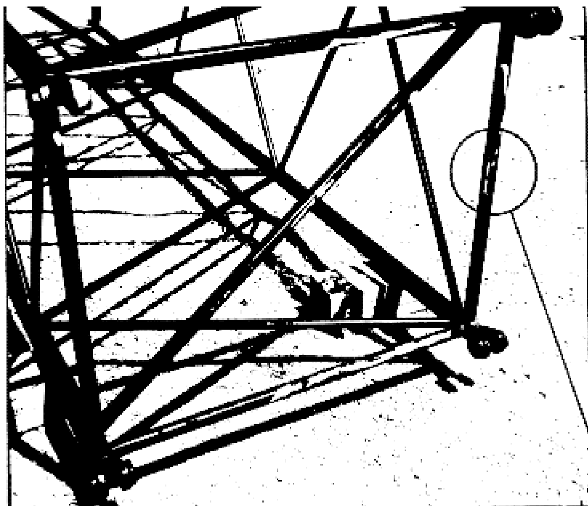


Fig. 2
I.D. Plate Location

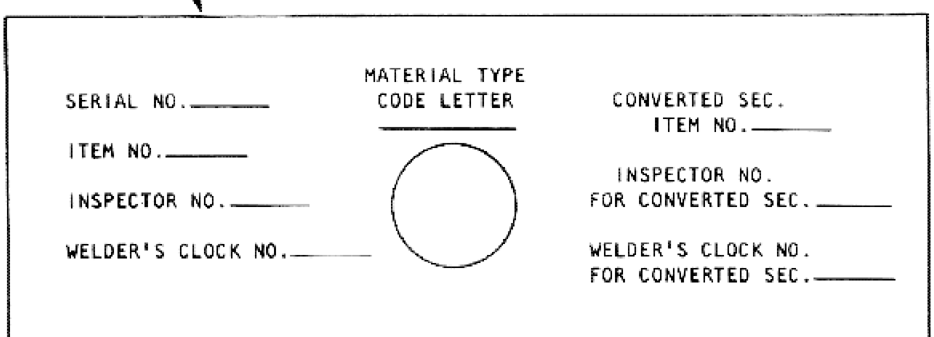



Fig. 3
I.D. Plate

.2.4 INSPECTION: All inspection and repair work suggested in these procedures must be done on a non-working tower, boom or jib which has been separated into individual sections. These sections are then to be positioned in such a manner that the work can be performed in a safe and ready fashion.

Prior to repair, the entire section should be thoroughly inspected so all areas in need of repair can be located. The inspection should proceed as outlined below:

(a) The inspection equipment should be such standard equipment as portable light, wire brush, probe, IOX magnifying glass, marker (chalk, crayon, etc.) magnetic particle, dye penetrant and other non-destructive testing equipment.

(b) Inspection procedure.

(1) Thoroughly clean the entire tower, boom or jib section of all mud, dirt, grease, oil, etc. so adequate inspection may be performed.

(2), Establish a pattern by which you work from one connection to the next and the manner each connection Is examined.

(3) Observe closely those areas where the paint has been chipped, wrinkled or missing or contains faint rust lines or marks. (See Figure 4).

(4) Inspect the section and note the points listed in Table 1.

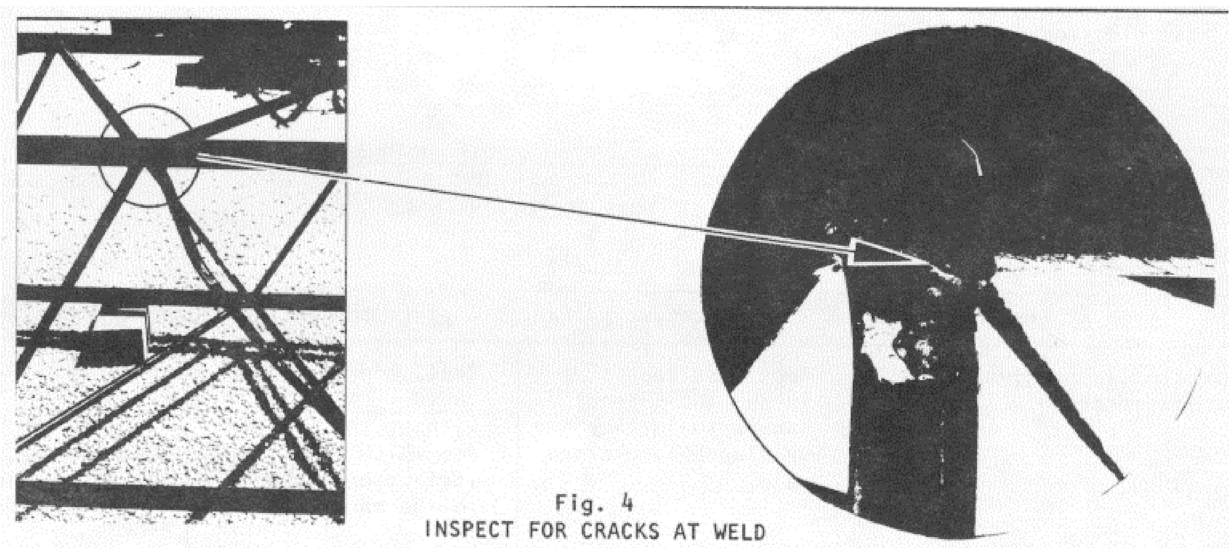
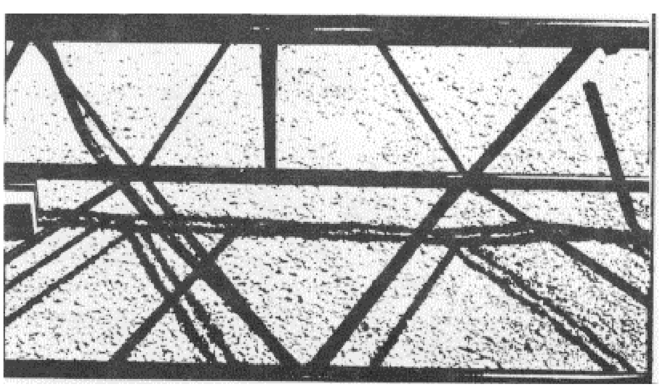


Fig. 4
INSPECT FOR CRACKS AT WELD

TABLE 1

| REPAIRABLE CONDITIONS WHICH MUST BE CORRECTED<br>1. Broken, bent, kinked or missing lattice (see Figure 5).<br>2. Cracks in welds or braces other than chord members | NON-REPAIRABLE CONDITIONS WHICH REQUIRE THE SECTION TO BE DESTROYED TO AVOID ALL POSSIBILITY OF FUTURE USE. |
|---|---|
|  | 1. Any cracks in main chord members.<br>2. Dents in the chord members.<br>3. Overall straightness of each of the chords is not within 3/16" per free span (distance between lattice).<br>4. Any prior repairs on the chord members (other than authorized lattice replacement).<br>5. Cracks which continue into the chord in welds Joining parts to chord members.<br>6. Chord members which have had brackets, rigging parts, walkways, etc. welded on which are not original equipment.<br>7. Obvious deformation of the section.<br>8. Broken, bent cracked or missing picture frame elements. |

5 GENERAL INSTRUCTION AND PROCEDURE SELECTION:

(a) The section serial number, the nature of the work performed, the date of the repair and the names and clock numbers of those people involved should be recorded and made part of the machine records.

(b) Environmental conditions should be such that they do not hinder the performance of the maintenance or create an unweldable surface condition such as wetness, extreme cold, etc.

(c) Proper tooling and safety equipment, in good working order, should be used. ANSI Z49 "Safety in Welding and Cutting" (current edition) is a good reference.

(d) The use of low-hydrogen electrode is re-quired in many portions of these procedures. See Appendix A for the care of low-hydrogen electrodes.

(e) Unless otherwise noted, all welding should be performed with DC reverse polarity or AC current.

(f) All repairs other than on chord members may be repaired by good conventional methods. Vee out and weld with low-hydrogen type welding electrode such as E7018.

(g) For any additional Information concerning repair of chords, picture frame sections, or welding of various additions to the chords, please consult the factory giving identification tag information, amount and location of damage, location and object to be welded on, etc.

(h) Select the proper repair procedure using Table 2. Refer to Appendix B to order repair kits and replacement lattice.

GENERAL PROCEDURE SELECTION INDEX

TABLE 2

| TYPE OF SECTION | TYPE OF DAMAGE - REFER TO SECTION GIVEN | | |
|---|---|---|---|
| Refer to figure given below for Illustration. | Bent less than 1" in 36" and without damage to lattice or diagonal to chord weld. | Bent, kinked, broken or otherwise damaged: Without the weld damage which joins the lattice or diagonal to the chord. | Bent, kinked, broken or otherwise damaged: With the weld damage which joins the lattice or diagonal to the chord. |
| Towers, Figure 6 | C | E | Non-repairable |
| Booms | | | |
| Coped, Figure 7 | C | D,G | G |
| Pinched, Figure 8 | C | D,G | G |
| Flattened, Figure 9 | C | D,F,G | G |
| Jibs | | | |
| Pinched, Figure 8 | C | D,G | G |
| Flattened, Figure 9 | C | D,F,G | G |

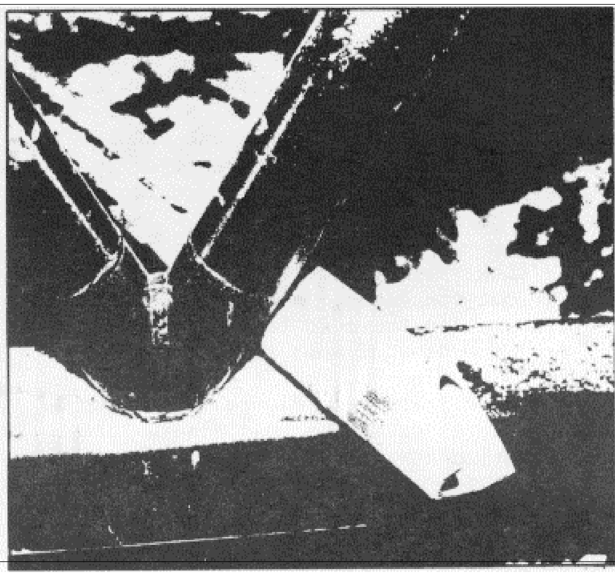


*Fig. 6*
*TOWER BOOM LATTICE*

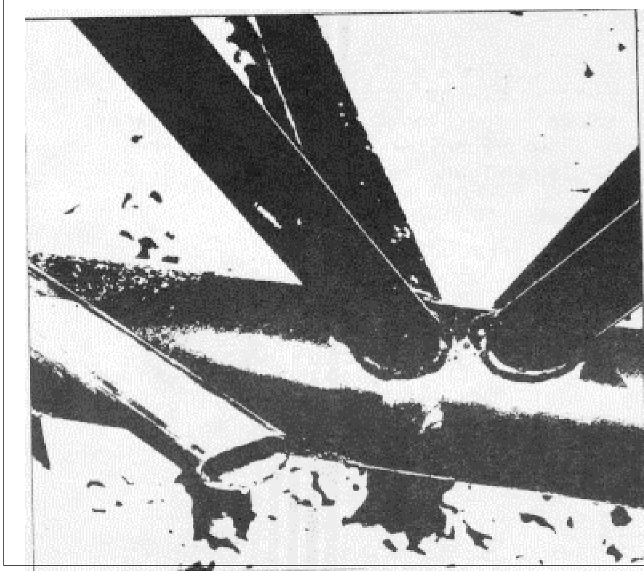


*Fig. 7*
*COPED LATTICE*

*Fig. 8*
*PINCHED LATTICE*

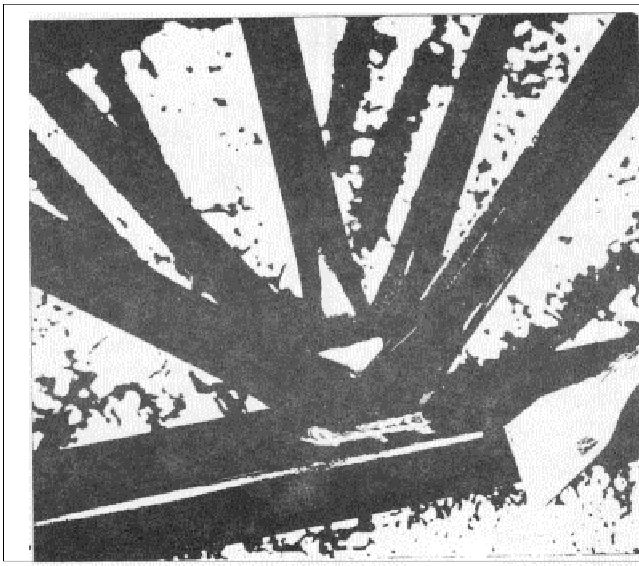


*Fig. 9*
*FLATTENED LATTICE*

2.G STRAIGHTENING OF LATTICE, DIAGONALS, & ROUND PICTURE FRAME TUBES:

Lattice or diagonal with a uniform curvature not in excess of the ratio of 1 inch In 3 feet may be straightened. Curvature in excess of this amount required replacement of the lattice (See Figure 10).

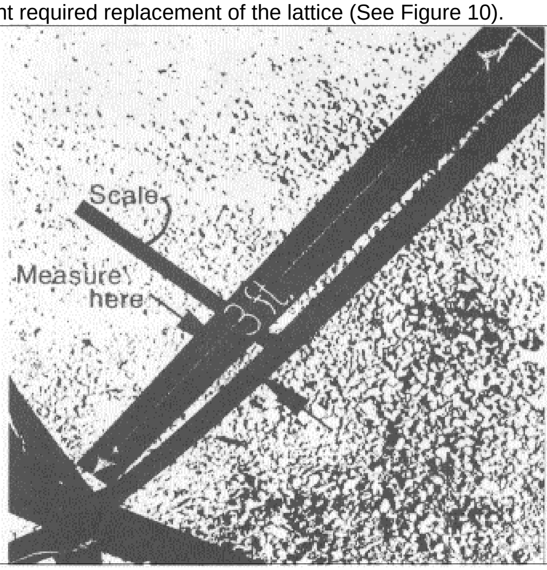



*Fig. 10*
*MEASURING FOR STRAIGHTNESS*

1. PROCEDURE FOR STRAIGHTENING:
   - (a) Bends should be drawn out by clamping a 4" X 4" timber against the bent lattice or diagonal tube with large "C" clamps. Care should be taken to prevent localized crushing or denting of the tube with the clamps. It may be necessary to block away from the tube to allow for overbend and spring back.
   - (b) Section should be at 320F. or warmer when straightening smoothly bent lattice or diagonal tubes.
   - (c) Do not use a hammer or otherwise strike the tube. This may result In localized structural damage to the tube.
   - (d) Do not use heat. Heat may destroy the physical strength of the steel in the area where heat is applied.
   - (e) After straightening, reinspect the lattice or diagonal to chord welds per section on "INSPECTION" earlier in this procedure.

2.7 REPLACEMENT OF LATTICE OR DIAGONALS BY SLEEVE/TUBE SPLICE PROCEDURE - BOOMS AND JIBS ONLY:
   - (a) Lattice or diagonals with curvature in excess of that given In "STRAIGHTENING OF LATTICE DIAGONALS & ROUND PICTURE FRAME TUBES," or with kinks may be repaired by a sleeve/tube splice procedure provided the lattice or diagonal to chord weld is sound.
   - (b) Sleeve/tube splice procedure.
     (1) Cut out the damaged area of the lattice making the cuts far enough away from the damaged area to Insure a round section (so that the sleeve will fit over it). (See Figure 11). Make the cut as square as possible (a tube cutter works nicely). Be careful not to cut too close to the chord, in which case there would not be enough room for the sleeve to fit properly or be welded properly. Make the cut with a hacksaw or tubing cutter.

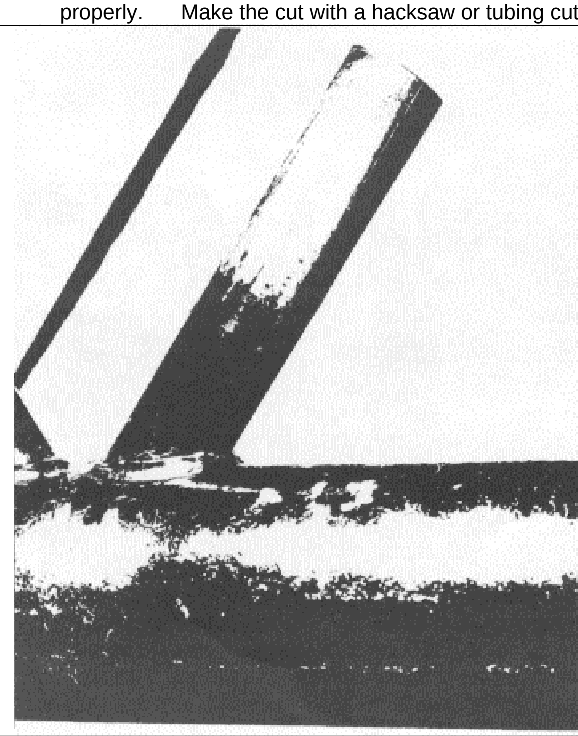


*Fig. 11*
*REMAINING LATTICE-STUB*

(2) At this point check to see if that portion of the lattice remaining ("stub") Is Inline with the other lattice along that chord. To do this, lay a straight edge or pull a string along several lattice to check its alignment. It will be necessary to bring the "stub" into proper alignment. One way to straighten "stub" would be placing a 4 X 4 across the chords over the span where the lattice was cut away then clamp against the 4 X 4 and the "stub" until it is Inline. Be careful not to crush or dent the "stub" with clamps. Reinspect the lattice or diagonal to chord welds.

(3) Measure the distance between the "stubs" for cutting the replacement tube to length. Allow 1/8" gap at each end of the tube.

(4) Cut the replacement tube to the length determined in step 3. Clean the tube and stubs to bright clean metal (See Figure 12) and de-burr each end.

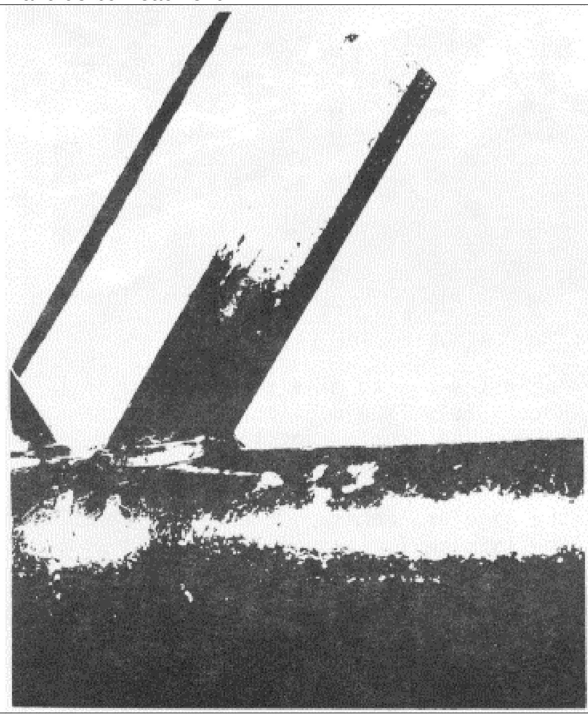


*Fig. 12*
*REMAINING LATTICE STUB*

(5) Slip both sleeves onto the replacement tube and set it into place between the "stubs."

(6) Position one sleeve so that it is midway over the gap. The other end should have approximately 1/8" gap. See Figure 13.

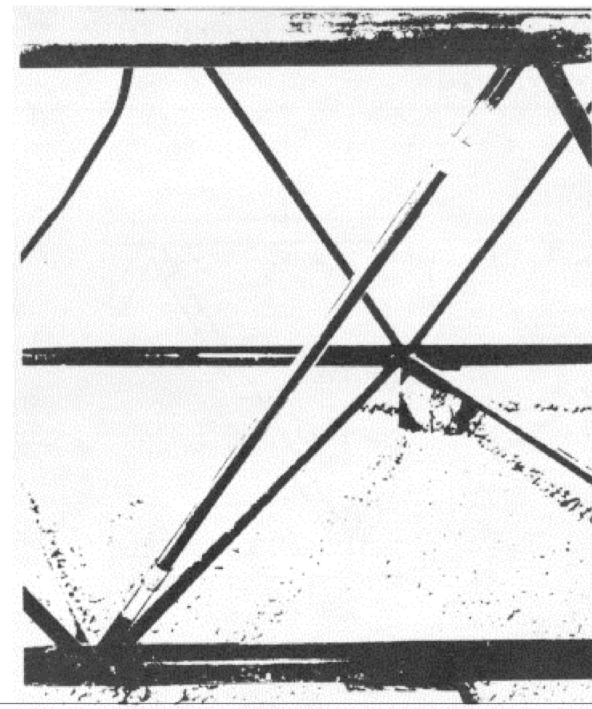


*Fig. 13*
*POSITION OF SLEEVES - NOT YET WELDED*

(7) Weld all around each end of the sleeve positioned per step 6. Use an A.W.S. E6013 or E7018, either 3/32" or 1/8" diameter. (The amperes and voltage should be set within the ranges recommended by the electrode manufacture. See Appendix C).

(8) Repeat steps 6 and 7 for the sleeve at the opposite end.

(9) Inspect welds - correct if required.

(10) Repaint.

2.8 REPLACEMENT OF LATTICE BY SLEEVE/TUBE SPLICE PROCEDURE - TOWERS ONLY:

(a) Lattice which are bent or kinked must be repaired by a sleeve/tube splice procedure provided the lattice to chord weld is sound.

(b) Sleeve/tube splice procedure - tower only.

(1) Cut out the damaged lattice 1-3/16" from the weld of the adaptor. See Figure 14.

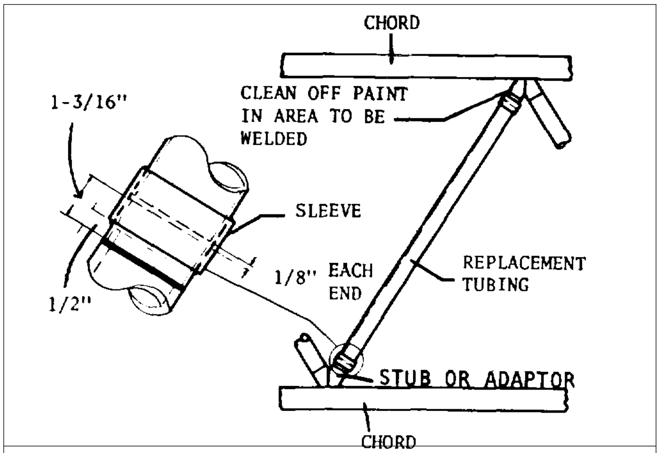



*Fig. 14*
*TOWER SLEEVE/TUBE SPLICE*

(2) Measure the distance between the "stubs" for cutting the replacement tube to length. Allow 1/8" gap at each end of the tube as shown in Figure 14.
(3) Cut the replacement tube to the length determined in step 2. Clean the tube and "stubs" to bright clean metal and de-burr each end.
(4) Slip both sleeves onto the replacement tube and set it into place between the "stubs".
(5) Position one sleeve so that it is midway over the gap. The other end should have approximately 1/8" gap. See Figure 14. Weld all around each end of the sleeve positioned per step 5. Use an A.W.S. E6013, or E7018, either 3/32" or 1/8" diameter. (The amperes and voltage should be set within the ranges recommended by the electrode manufacture, see Appendix C).
(6) Repeat steps 4 and 5 for the sleeve at the opposite end.
(7) Inspect welds correct if required.
(8) Repaint.

2.9 REPLACEMENT OF LATTICE BY LAP REPLACEMENT - FLATTENED LATTICE BOOMS AND JIBS ONLY:

(a) Lattice which are damaged too extensively to permit the use of a sleeve/tube splice procedure are replaced by the lap replacement described below. If cracking occurs in any welds of the lattice/chord tube joint, the procedure for complete replacement given in "REPLACEMENT OF LATTICE OR DIAGONALS BY COMPLETE REPLACEMENT - BOOMS AND JIBS ONLY" must be used.
(b) THIS SECTION DOES NOT APPLY TO DIAGONAL REPLACEMENT.
(c) Procedure.

(1) Remove the damaged lattice by cutting at each end as indicated in Figure 15.

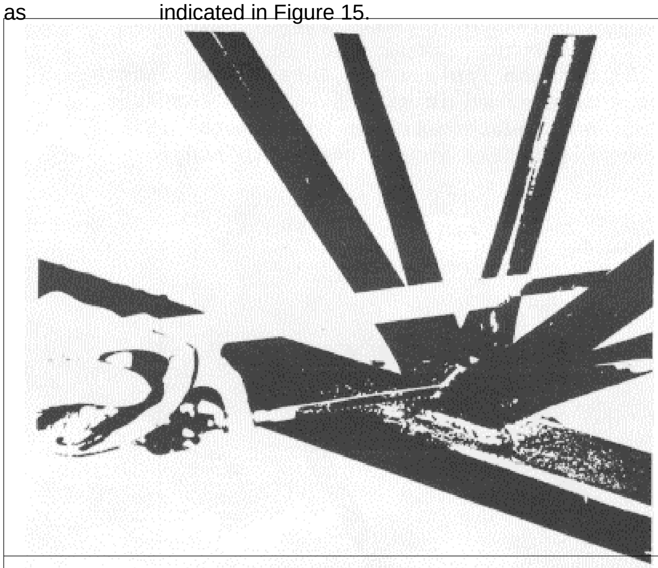


*Fig. 15*
*REMOVING THE LATTICE*

(2) Angle the cut to miss the diagonal. Note: This is a difficult cut to make. Use caution not to cut beyond the weld into the chord.
(3) Grind cut surface square, i.e. grind the angular hacksaw cut square with the lattice for a good welding fit-up. Take care not to damage adjacent parts.
(4) Check to see if replacement-tube will fit snugly onto stub and in the proper position and alignment. If necessary carefully shape or contour your replacement lattice for proper fit-up.

(5) Clean area to be welded to bright clean metal. See Figure 16.

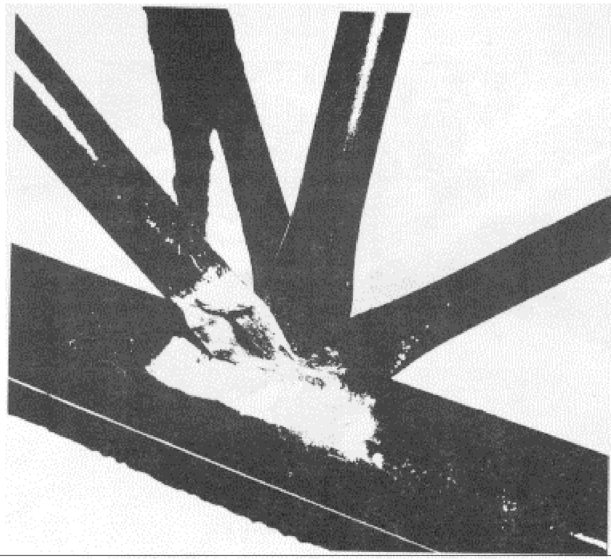


*Fig. 16*
*AREA CLEANED FOR WELDING*

(6) Align and clamp lattice Into position for welding. See Figure 17.

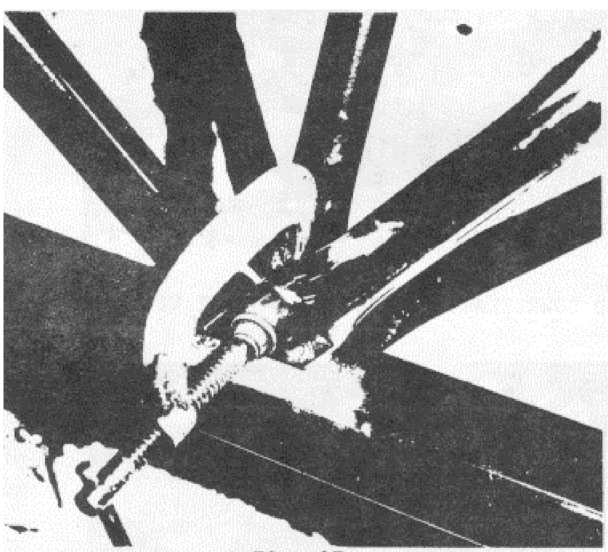


*Fig. 17*
*LATTICE CLAMPED IN PLACE*

(7) Weld all around each end. All weld sizes should be 3/16" Use an A.W.S. 1/8" E7018 electrode. (The amperes and voltage should be set within the ranges recommended by the electrode manufacture. See Appendix C).

(8) Inspect welds.

(9) Repaint.

2.10 REPLACEMENT OF LATTICE OR DIAGONALS BY COMPLETE REPLACEMENT - BOOM AND JIBS ONLY:

(a) Lattice or diagonals which are damaged too extensively to use the sleeve/tube splice repair or have the weld damaged which joins the lattice or diagonal to the chord (which does not enter the chord) are repaired by complete replacement. This procedure covers both lattice and diagonals of the flattened, pinched or coped type end connection.

(b) Complete replacement procedure.

(1) Remove the lattice or diagonal above the chord along section C-C in Figure 18.

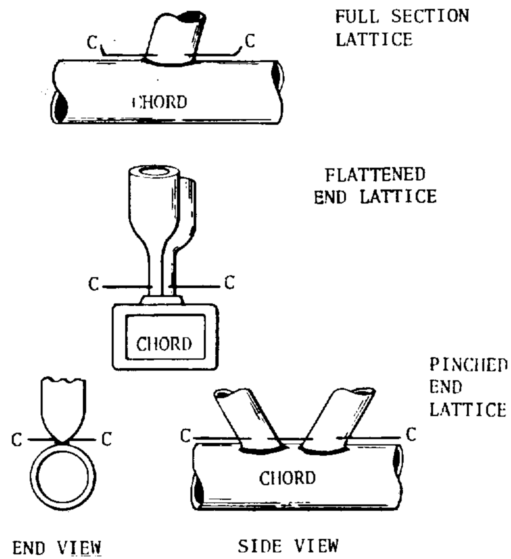



*Fig. 18*
*REMOVAL OF LATTICE*

(2) Removal of the lattice or diagonal is most easily accomplished on flattened diagonals, single flattened lattice, pinched lattice and pinched diagonals by cutting well above the weld and manually flexing the tube until it. separates Just above the weld. See Figure 19. For double lattice connections of the flattened type and for coped lattice and diagonals, a hack saw or similar cutting tool must be used. See Figure 20 and 21. Note: Be careful not to damage main chord member.

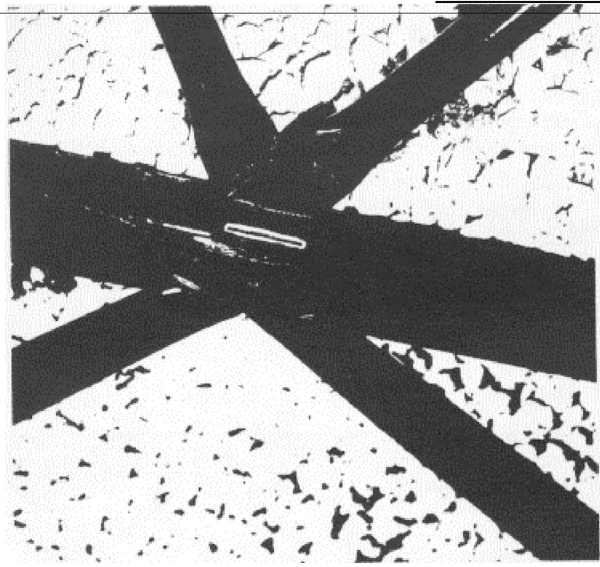


*Fig. 19*
*REMOVED SINGLE FLATTENED LATTICE*

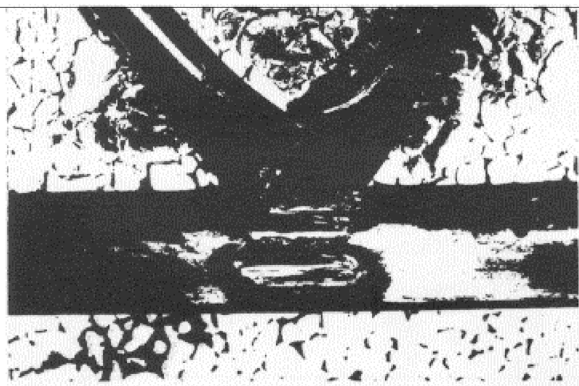


*Fig. 20*
*REMOVED FLATTENED DOUBLE LATTICE USING AN ABRASIVE CUT-OFF TOOL*

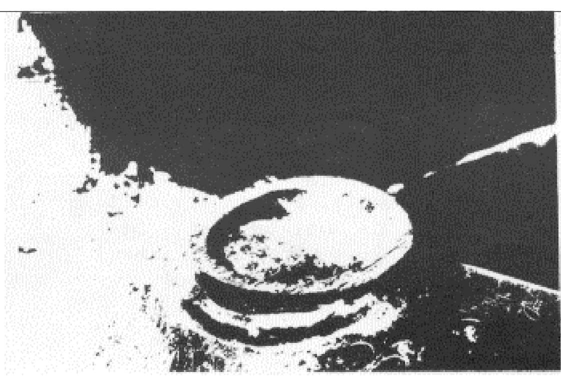


*Fig. 21*
*REMOVED COPED LATTICE USING A HACK-SAW*

(3) Carefully grind the weld down to within 0.010" to 0.020" of the chord surface as shown in Figures 22, 23 and 24.

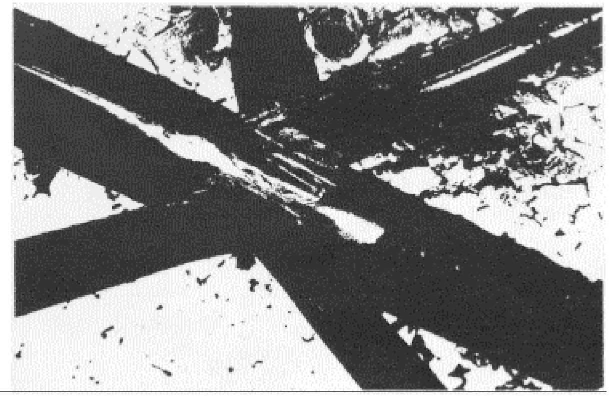


*Fig. 22*
*GROUND DOWN DIAGONAL WELD*

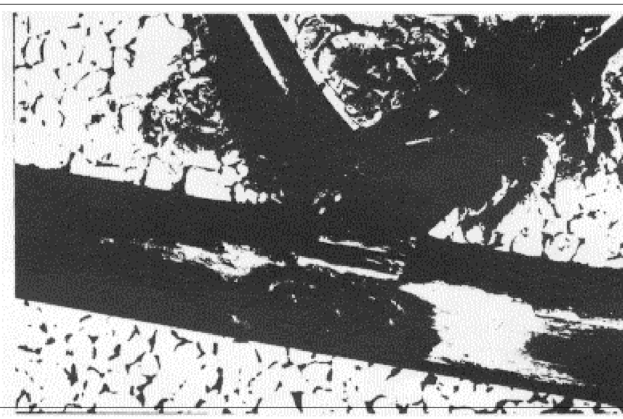


*Fig. 23*
*GROUND DOWN FLATTENED DOUBLE LATTICE WELD*

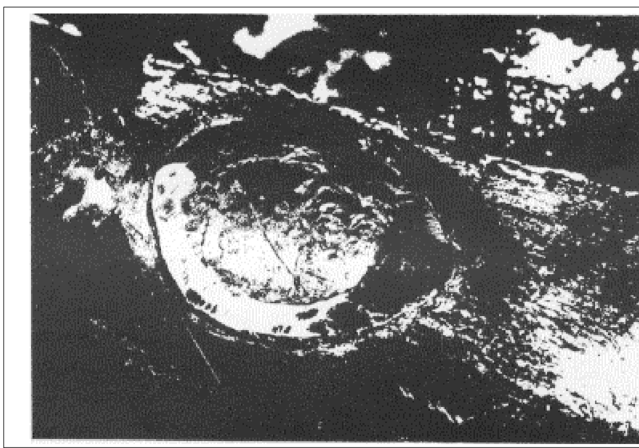


*Fig. 24*
*GROUND DOWN COPED WELD*

(4) Using a fine (80 - 100 grit) disc, polish the weld area to bright clean metal as In Figure 25.

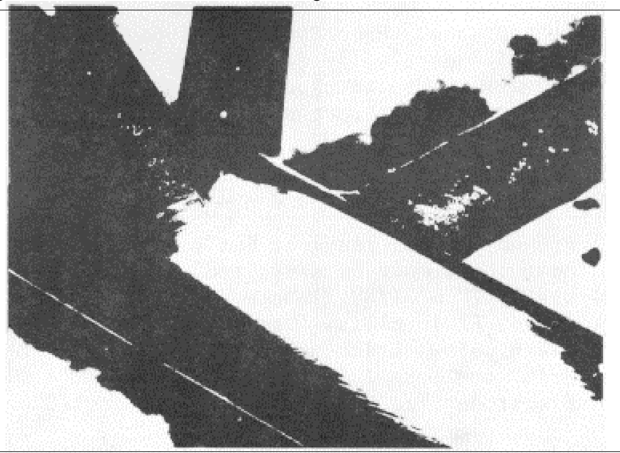


*Fig. 25*
*CHORD POLISHED CLEAN*

MOST OF THE POLISH MARKS SHOULD RUN PARALLEL TO THE CHORD LENGTH. CARE MUST BE TAKEN SO THAT NO GOUGING OR DEEP GRINDING IS DONE.

(5) Check to see that the replacement tube will fit snugly onto the chord and In proper position and alignment. If necessary, carefully contour or shape the replacement for a proper fit-up. A good fit-up will aid In proper heat and weld size control resulting in a better repair Job.

(6) Position the replacement tube to be welded Into the proper location and clamp Into place as shown In Figure 26 Do not tack weld. Check to Insure that all grease, oil and paint are removed from the area to be welded.

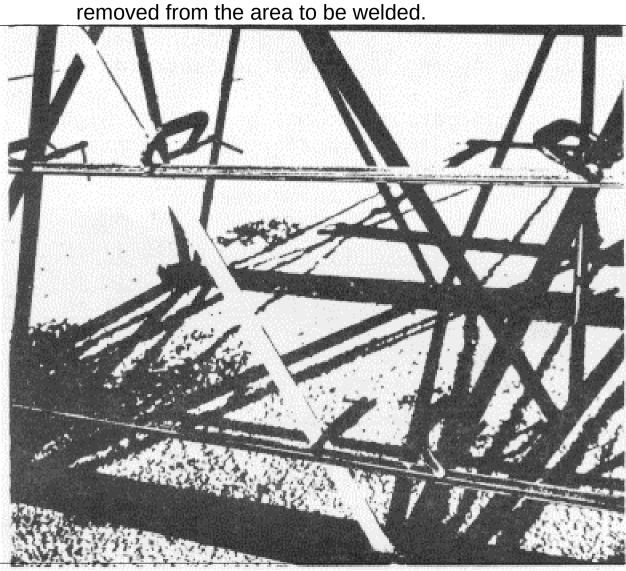


*Fig. 26*
*LATTICE ALIGNMENT*

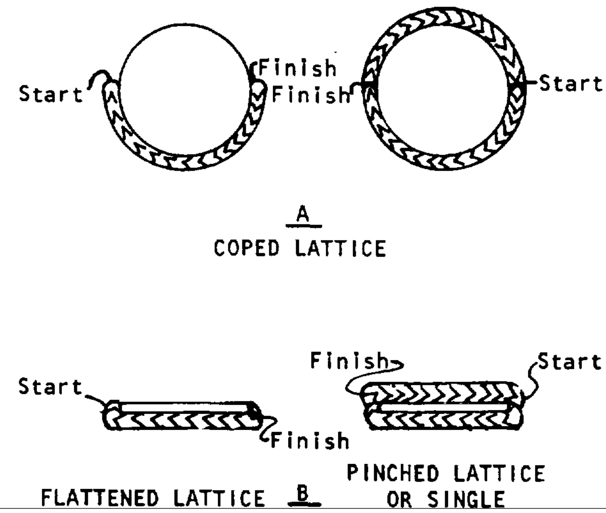



*Fig. 27*
*WELDING SEQUENCE*

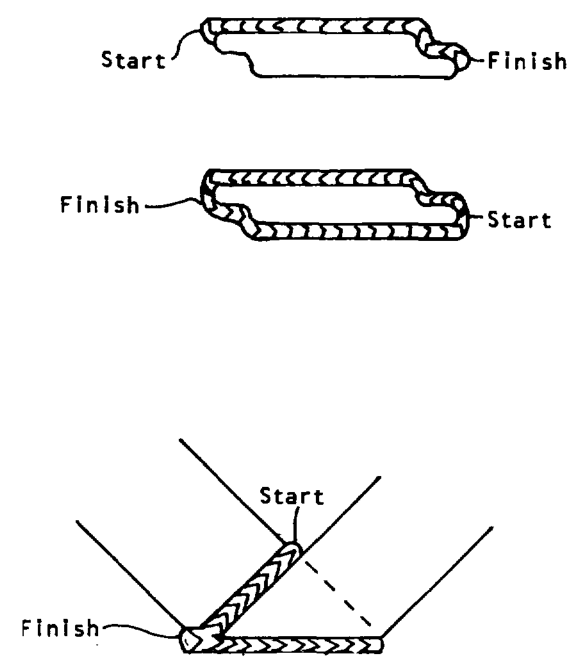



*Fig. 28*
*WELDING SEQUENCE FLATTENED LATTICE*

WELDING INSTRUCTIONS

7) Welding Instructions for type "A" and "B" material are the same. Procedures for type "C" material are different - In addition the type "C" jibs require particular close control. Therefore, we have listed three different sets of welding procedures to be used; Before proceeding, check the material type recorded in "PREPARATION FOR REPAIR" to insure that the proper Instructions are used.

"A" & "B" MATERIAL BOOMS & JIBS

(a) Preheat the chord and replacement tube In the area to be welded to 350°F. (minimum) to 5500F. (maximum). Tempilsticks 1 should be used to determine the temperature. DO NOT OVER OR UNDER HEAT.
(b) Use 3/32" or 1/8" diameter electrodes of A.W.S. E7018 class. Use the amperage, voltage and travel speed recommended by the electrode manufacturer to obtain a 1/8" to 3/16" one pass fillet weld. Some examples are given in Appendix C.
(c) Weld in replacement tube as shown in Figures:
Coped end connections -- Fig. 27a,29,30,31
Pinched end connections -- Fig. 27b,32,33,34
Figures:
Flattened end connections -- Fig. 28,35,36 &37

Note the starting and finishing positions and rod angle.
(d) The weld should be completed without delay. If the weld area cools below 350'F., preheat the area again.
(e) After welding, clean and Inspect the repair and repaint.

"C" MATERIAL BOOMS ONLY

(a) Preheat is not required but control of heat input must be exercised.
(b) Use 3/32" or 1/8" diameter electrodes of A.W.S. E7018 class. Use the procedures given below, which will produce a 1/8" to 3/16" one pass fillet weld.

| Electrode Size | 3/32" | 1/8" |
|---|---|---|
| Amperage, A | 60-100 | 90-135 |
| Voltage, V | 21-23 | 22-23 |
| Travel Speed, inches per minute | 7 | 8 |

(c) Weld In the replacement tube as shown in

Coped end connections -- Fig. 27a,29,30,31
Pinched end connections -- Fig. 27b,32,33, 34.

Note the starting and finishing positions and rod angle.
(d) Allow the weld area to cool to room temperature before welding the opposite side.
(e) After welding, clean and Inspect the repair and repaint.

**"C" MATERIAL JIBS ONLY**

(a) Because of the smaller size of the jib, repair must be performed with close control and special care. The welding procedures given below must be followed. If the welding machine used does not have reliable current and voltage Indicating devices, Appendix D gives guidance for properly setting the machine.
(b) Also due to the smaller size of the jib, welding requires a person who has acquired a high degree of skill and Is a conscientious workman. It is a must that practice welds be made duplicating as nearly as possible the welds to be made before starting the work.
(c) The welding on jibs must be performed with a small (250 amp maximum) AC welder.

NOTE: We have found that all small A-C welders don't perform equally when running E7018 3/32" dla. electrodes. If practice welds shown inability to hold an arc this may indicate instability of the welding equipment and a different machine should be tried. All values reported here have been obtained using a Hobart T-225 machine.

(d) Use 3/32" diameter electrodes of A.W.S. E7018 class. Use the procedures given below, dependin on jib chord size:

| | AMP. | VOLT. | SPEED OF TRAVEL INCHES PER MINUTE |
|---|---|---|---|
| OUTSIDE DIA. OF CHORD 1-1/4" | 85A | 23V | 9.5 I.P.M. |
| ALLLARGER JIB CHORDS | 85A | 23V | 8.5 I.P.M. |

(e) Weld In the replacement tube as shown In Figures: Flattened end connections -- Fig. 28, 35 36 & 37. Pinched end connections -- Fig. 27b,32,33, & 34.
(f) Allow the weld area to cool to room temperature before welding the opposite side.
(g) After welding, clean and Inspect the repair and repaint.

1Tempilsticks are temperature Indicating crayons and are available from local welding suppliers or Temoll Corp 132 West 22nd St., New York, N.Y., 10011.

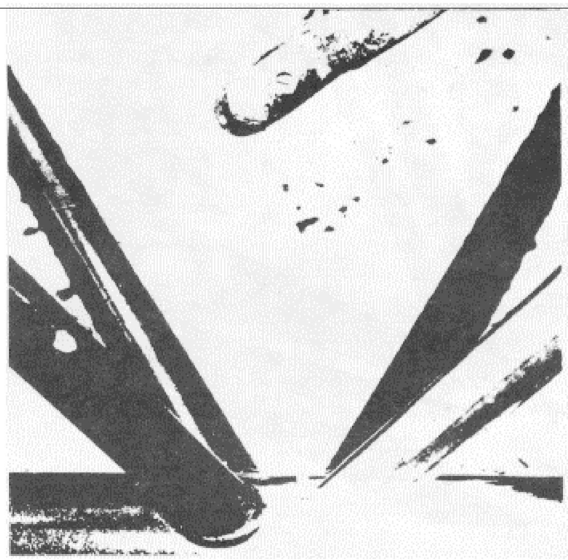


*Fig. 29*
*ROD POSITION AND ANGLE FOR START OF LATTICE WELD INSIDE OF BOOM (USE OPPOSITE POSITION AND ANGLE IF WELD IS STARTED ON OUTSIDE FIRST)*

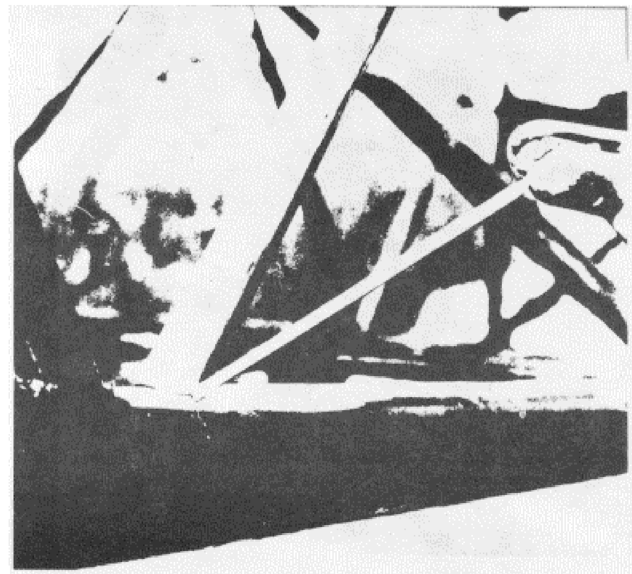


*Fig. 30*
*ROD POSITION AND ANGLE FOR LATTICE WELD OUTSIDE OF BOOM*

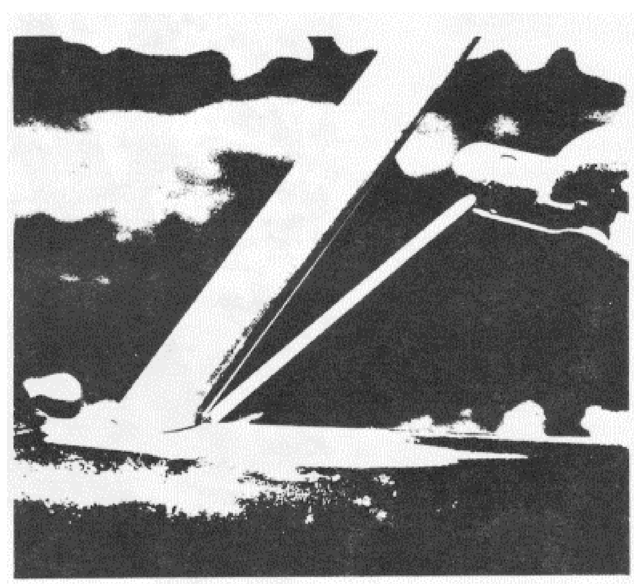


*Fig. 31*
*ROD POSITION AND ANGLE FOR END OF LATTICE WELD OUTSIDE OF BOOM. START POSITION FOR INSIDE WELD*

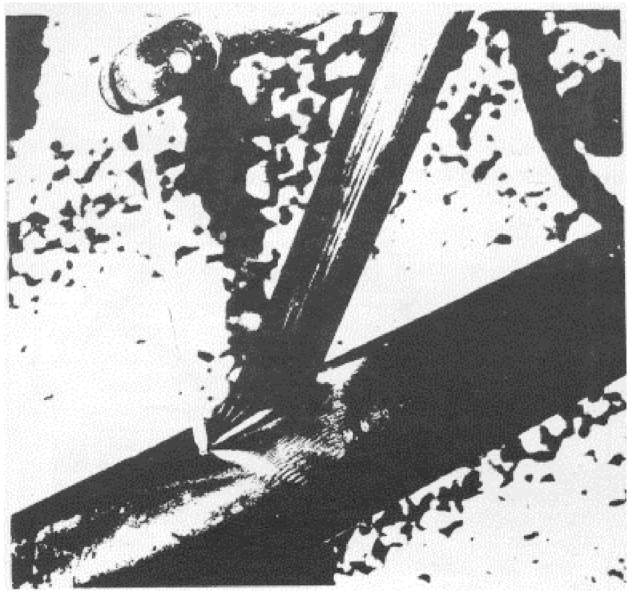


*Fig. 32*
*ROD POSITION AND ANGLE FOR START OF LATTICE WELD ON INSIDE OF BOOM (USE OPPOSITE POSITION AND ANGLE IF WELD IS STARTED ON OUTSIDE FIRST).*

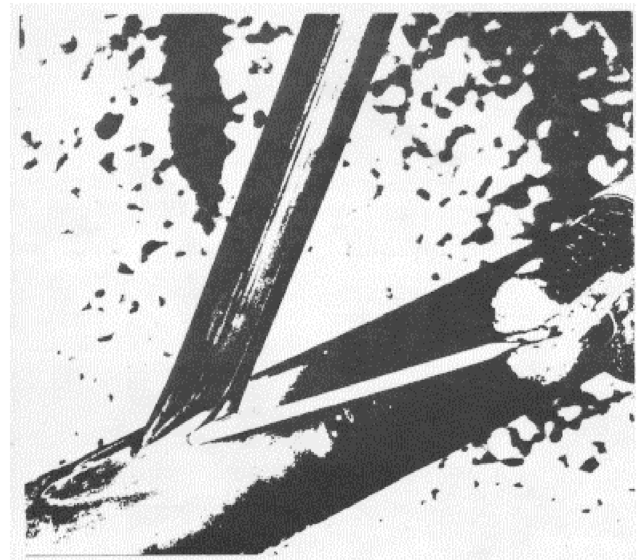


*Fig. 33*
*ROD POSITION AND ANGLE FOR LATTICE WELD OUTSIDE OF BOOM*

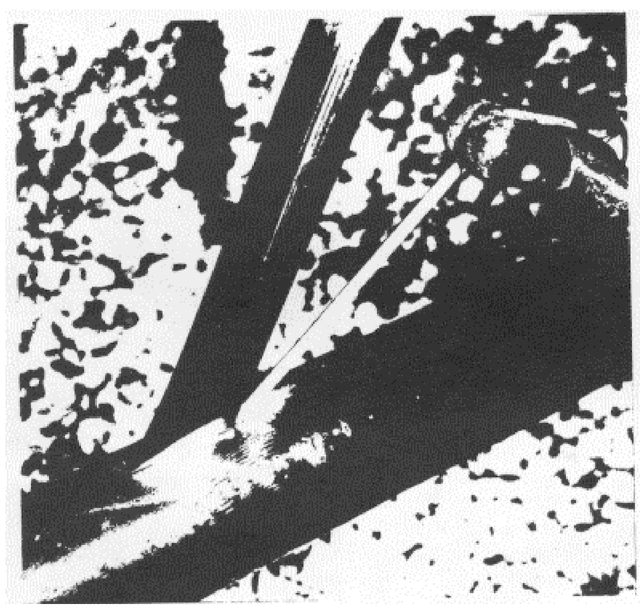


*Fig. 34*
*ROD POSITION AND ANGLE FOR END OF LATTICE WELD ON OUTSIDE OF BOOM*

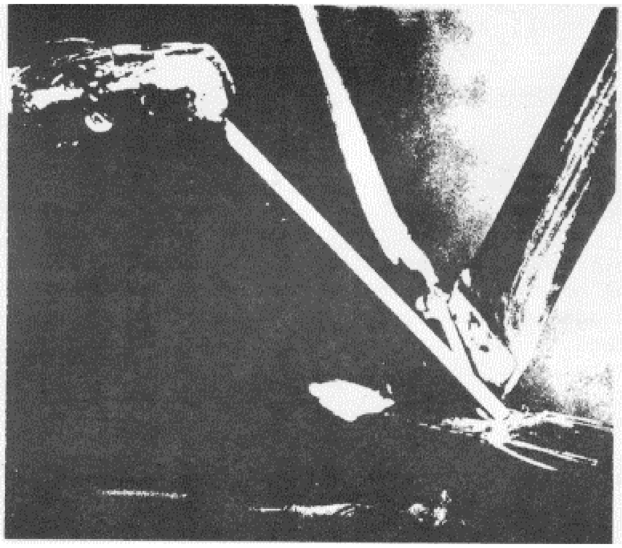


*Fig. 35*
*ROD POSITION AND ANGLE FOR START OF LATTICE WELD ON INSIDE OF BOOM*

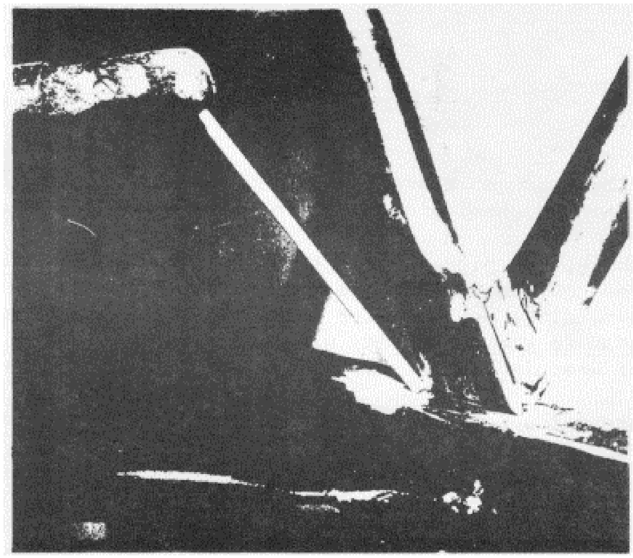


*Fig. 36*
*OD POSITION AND ANGLE FOR END OF LATTICE WELD*

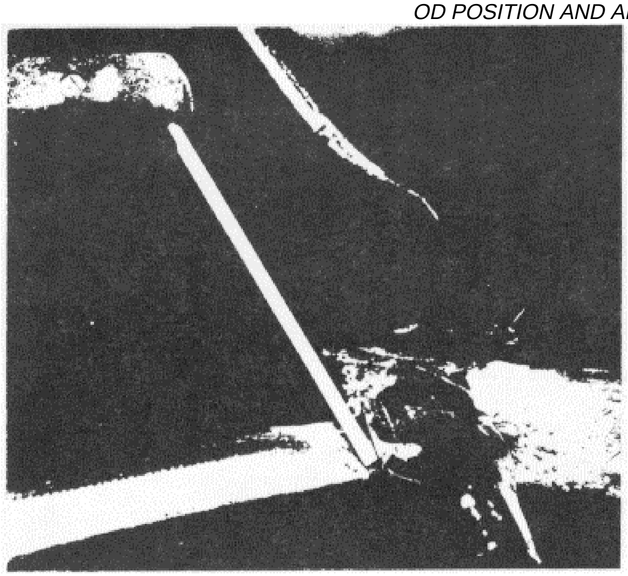


*Fig. 37*
*ROD POSITION AND ANGLE FOR START OF*

APPENDIX A

CARE OF ELECTRODES

The low-hydrogen characteristics of electrodes should not be taken for granted. Hydrogen Is an unwanted chemical element in welding most types of steels including all the alloy steels.

Normally, the higher-strength alloy steel low-hydrogen electrodes are packaged In hermetically sealed containers and have less than 0.2% moisture in the coating. Such electrodes are suitable for Immediate use provided the container has not been damaged and the electrodes have not been exposed to the air. Some electrodes, however, are packaged in cardboard containers with "moisture proof wrapping" which may or may not provide adequate protection.

To prevent under bead cracking In welds, the following steps are recommended for the conditioning and handling of low-hydrogen electrodes:

(1) As soon as an electrode container Is opened, the electrodes should be removed and placed Into a baking oven.

(2) Electrodes should be baked according to the manufacturer's Instructions (usually 800°F. For one hour). The electrodes should be put into the oven at 500' F. maximum and heated up to 800° F., with the electrodes placed no more than three layers deep on a tray. THIS BAKING HAY BE OMITTED ONLY IF THE USER WAS SATISFIED HIMSELF THAT THE ELECTRODE COATING, AS READY FOR USE, CONTAINS LESS THAN 0.2 PERCENT MOISTURE.

(3) Whether baked or not, the electrodes should be immediately transferred to a storage or holding oven at 250° + 25° F.

(4) Both the baking oven and the storage oven should be equipped with air-circulating systems and temperature Indicators with controls.

(5) Electrodes should not be placed In the storage oven unless sufficiently dry as received or properly baked.

(6) The welding electrodes should be used within one hour after removal from the storage oven.

(7) Electrodes removed from the storage oven and exposed in a clean, dry location for times longer than those specified should be rebaked as described under Item (2). Electrodes exposed to water, grease, or dirt should be destroyed.

(8) When welding is done In areas of high humidity, It Is advisable to store a suitable quantity of electrodes in a small portable oven from which electrodes may be drawn one at a time by the welder.

APPENDIX B

ORDERING MATERIALS

1. REPAIR OF DAMAGED LATTICE - BOOMS ONLY TUBE/SPLICE

A. Kits are available to repair damaged lattice in tubular booms. Eack kit contains a five foot length of tubing and two sleeves. The kits are as follows:

| KIT NO. | TUBING SIZE |
|---|---|
| (1) PX394 | (3/4") 0.750 O.D. X .065 wall X 5 ft. |
| (2) PX395 | (7/8") 0.875 O.D. X .065 wall X 5 ft. |
| (3) PX396 | (1") 1.00 O.D. X .083 wall X 5 ft. |
| (4) PX397 | (1-1/4") 1.250 O.D. X .095 wall X 5 ft. |
| (5) PX3968 | (1-3/8") 1.375 O.D. x .083 wall X 5 ft. |
| (6) PX399 | (1-1/2") 1.500 O.D. X .095 wall X 5 ft. |
| (7) PX400 | (1-5/8") 1.625 O.D. x .095 wall X 5 ft. |
| (8) PX401 | (1-7/8") 1.875 O.D. X .095 wall X 5 ft. |
| (9) PX402 | (2") 2.00 O.D. X .120 wall X 5 ft. |
| (10) PX403 | (2-1/4") 2.25 O.D. X .120 wall X 5 ft. |

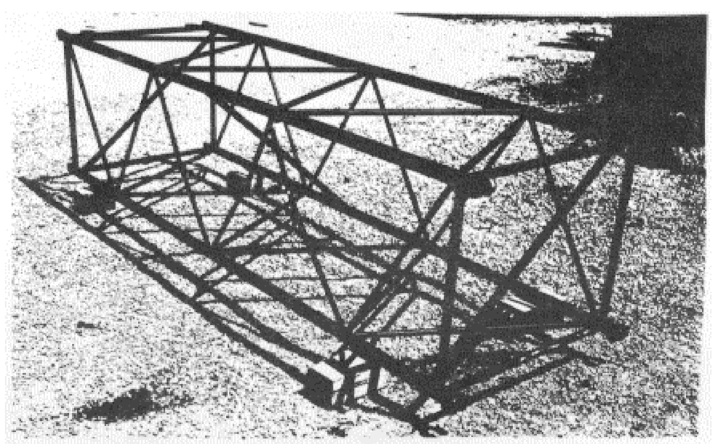
II. REPAIRS OF DAMAGED LATTICE - TOWERS ONLY - TUBE/SPLICE

A. Kits are available to repair damaged lattice In tower sections. Each kit contains a length of tubing and two sleeves. The kits are as follows:

| KIT NO. | | TUBING SIZE |
|---|---|---|
| PX404 | 218,238 | (2-5/8") 2.625 O.D. X .095 wall X 5 ft. |
| PX405 | | (3") 3.00 O.D. X .1875 wall X 5 ft. |
| PX406 | 108 | (2-3/8") 2.375 O.D. X .083 wall X 50 inches |
| PX407 | | (3") 3.00 O.D. X .095 wall X 50 Inches |

III. ALL OTHER BOOMS - FULL LATTICE REPLACEMENT

A. Draw sketch of the boom.



B. Indicate which lattice is damaged.

C. Record the Information on the I.D. plate and send it with the sketch for factory replacement lattice.

APPENDIX C

CURRENT TABLE* (USE AC OR DC REVERSE)

**Table 1**

| | | AMPS. FLAT | | AMPS. | AMPS. |
|---|---|---|---|---|---|
| SIZE | VOLTS | RANGE | OPTIMUM | VERTICAL | OVERHEAD |
| 3/32" | 21-24 | 70-110 | 100 | 70-100 | 70-100 |
| 1/8" | 21-24 | 90-160 | 140 | 90-135 | 90-160 |

* Hand Book for Welding Low Alloy, High Tensile Steels, Alloy Rods Company, Division of Chemetron Corporation, Copyright 1964 by Alloy Rods Company, AR-30 (Formerly HB-3) 5-769 Edition 3.

APPENDIX D

TRAINING INSTRUCTIONS REQUIRED BEFORE WELDING ON TUBULAR JIB STRUCTURES. SUPPLIES REQUIRED:

MATERIALS: 3/4" wide X 5-3/8" long X 12 gauge (0.109") thick steel, with bright finish on one side. (See Fig. 4).

The purpose of this test sample is to set the welding machine current (amps) and volt- age (volts) and arc travel speed to obtain the required heat input without the use of any meters. In effect, this sample serves as a known heat test. Heat Input is con- trolled by voltage, current, and arc travel speed.

In order to maintain the toughness of "C" type materials it is mandatory that heat Input be controlled.

We have shown In Section (I) the actual conditions used to weld each model lattice to chord connection. We used the same voltage and current In all cases and adjusted only the arc travel speed to obtain the correct heat input for the different models.

The test sample has been sized for the 23V, 85A, and 6.75 Inches per minute arc travel speed.

USE OF "HEAT INPUT TEST SAMPLES"

1. Run several passes on scrap material to adjust the welding machine for good electrode running performance. This may be considered "initial Coarse Adjustment".

2. Tack both ends of the " HITS " * to a scrap plate. Securely fasten the ground cable to the plate. Allow the tack welds to cool to room temperature. This assembly should be located In a draft-free area. If wind or draft is blowing over the "HITS"* shield it so that the draft condition Is removed.

3. Strike an arc at the extreme end of "HITS"* and weld bead to the other end. Someone must measure the time required to make this 3-3/8" long weld. The correct time Is 30 seconds. The correct result Is as follows:

   (a) A continuous, even weld must be made.
   (b) The weld must not melt through the strip at any point.
   (c) The time must be 30 seconds + 2 seconds.

   If all these conditions are met the heat Input is correct. If the arc is lost during the travel time, the test is not good. If the weld melts through, current, voltage or speed is wrong. Since the time is easily checked on a heavier plate the welder may want to practice speed control on heavier material before making test welds. Once speed is correct and melt through still occurs then the current setting must be reduced.

4. Once a successful "HITS"* is produced the welder Is ready to weld jibs "type C" materials.

5. This establishes the correct current and voltage settings and 6.75" per minute travel speed. However, these lighter members require a faster travel speed and further practice must be done to obtain the new correct speed. This speed can be established on any scrap material because the voltage and current have been set by producing a good "HITS"*.

* HEAT INPUT TEST SAMPLE

To weld at-9.50 in. per min. requires 3-3/8" of weld be made in 21 seconds.

To weld at 8.50 In. per min. requires 3-3/8" of weld be made in 24 seconds.

2.11 Repair Of Picture Frame Lattice

When lattice elements at the end of a boom section (picture frame members, see Fig. 1; description of terms) are damaged, several problems develop that hinder the use of "regular" lattice repair methods of this SM. Therefore, it is necessary to understand what is different about replacing picture frame elements and list those extra steps to be used for repair.

First: The most important part of this procedure is maintaining the alignment of the pin-connections during repair so that the section will properly pin- up when the repair work is completed. When a picture frame lattice is damaged it is likely that alignment, (squareness) and proper location of the pin connection is thrown off. Therefore, when replacing the lattice elements at the ends of the boom sections it is necessary to re-align the pin connections by pinning that section to a section in excellent condition;(which of course, would normally pin with it).

Second: To simply remove the entire damaged lattice and replace it with a full length new one while maintaining the pin-hole alignment is next to impossible. The reason for this is that the original picture frame lattice were factory welded when the boom was being built and while in a welding fixture that provided for a snug fit with proper pin-hole-alignment. Where- as, the "Sleeve/Tube Splice" procedure works nicely because it allows for ease of installation and final adjustment by means of the extended joint by virtue of the splice connection. The "Sleeve/Tube Splice" method for repair of picture frame lattice is covered this SM in either:

Part 1 Two Good Stud Areas
Part II One Good Stud Area
Part III Neither Stud Area Good

Third: It will be necessary to select a working site which is flat, level, and of a suitable surface for working. A size at least equal to the width of the section and the length of the two sections, one being repaired and the other being used to hold alignment.

Fourth: Set the sections (unpinned) on blocks (saw horses, or other suitable surface) at a good working height. The supports should be approximately 2 feet to 3 feet from the ends (4 places) of the sections.

Fifth: If the factory I.D. tag and other informational or cautionary tags are on the lattice being replaced, it will be necessary to replace them. The Stainless Steel I.D. tag can be removed by carefully cutting through the tack welds and relocating it on the replacement lattice. The other tags will have to be ordered from the factory. The Stainless Steel I.D. may be replaced in the same manner as they were.

2.12 Repair Work
Part 1: Sleeve/Tube Splice Procedure When Both Snub Ends (Approx. 4"-8") Of The Lattice Are Not Damaged

(a) Picture frame lattice or diagonals with curvature in excess of that given in "Straightening Of Lattice Diagonal & Round Picture Frame Tubes" Section C, or with kinks are to be repaired by the sleeve/ tube splice procedure as long as the lattice or diagonal to chord weld is sound.
(b) Sleeve/tube splice procedure.
  (1) Cut out the damaged area of the lattice making the cuts far enough away from the damaged area to insure a round section (so that the sleeve will fit over it). (See Fig. 11). Make the cut as square as possible (a tube cutter works nicely). Be careful not to cut too close to the chords, in which case there would not be enough room for the sleeve to fit properly or be welded properly. (Make the cut with a hacksaw or tubing cutter).
  (2) Pin the two sections together. If one or more of the connections will not pin where a lattice had been removed it will be necessary to move the ends into position (jack, come- along or other suitable means of adjusting the ends) to maintain alignment; pin sections, four places.
  (3) At this point check to see if that portion of the lattice remaining ("stub") is inline with the other lattice along that chord. To do this, lay a straight edge or pull a string along several lattice to check its alignment. It will be necessary to bring the "stub" into proper alignment. One way to straighten "stub" would be placing a 4 X 4 across the chords over the span where the lattice was cut away then clamp against the 4 X 4 and the "stub" until it is inline. Be careful not to crush or dent the "stub" with clamps. Re- inspect the lattice or diagonal to chord welds.
  (4) Measure the distance between the "stubs" for cutting the replacement tube to length. Sub- tract 1/4" from this measurement to allow 1/8" gap at each end of the tube.
  (5) Cut the replacement tube to the length deter- mined in Step 4. Clean the tube and stubs to bright clean metal (see Fig. 12) and de-burr each end. The replacement tube, prior to cutting, has coped ends for use in Parts II and III also. In this case they will be cut off and the remaining length is that deter- mined in Step 4.
  (6) Slip both sleeves onto the replacement tube and set it into place between the "stubs".
  (7) Position one sleeve so that it is midway over the gap. The other end should have approximately 1/8" gap. See Fig. 13.
  (8) Weld all around each end of the sleeve positioned per step 7. Use an A.W.S. E6013 or E7018, either 3/32" or 1/8" diameter. (The amperes and voltage should be set within the ranges recommended by the electrode manufacturer. (See Appendix C).
  (9) Repeat steps 6 and 8 for the sleeve at the opposite end.
  (10) Inspect welds.
  (11) Repaint.
  (12) Unpin.

## Part II: Sleeve/Tube Splice Procedure When One Stub-End Is Damaged

(a) It is necessary to remove and reweld to-the chord a new piece of lattice only on the end that is damaged. The other end, (that is undamaged stub end), is to be prepared by cutting off the damaged area, leaving a stub of about 4"-8" long (see Fig. 11). Prepare this end as follows:
  (1) Cut out the damaged area of the lattice making the cuts far enough away from the undamaged

stub end area to insure a round section (so that the sleeve will fit over it). (See Fig. 11). Make the cut as square as possible (a tube cutter works nicely). Be careful not to cut too close to the chord, in which case there would not be enough room for the sleeve to fit properly or be welded properly. (Make the cut with a hacksaw or tubing cutter).

(2) Pin the two sections together. If one or more of the connections will not pin where a lattice had been removed it will be necessary to move the ends into position (jack, come- along or other suitable means of adjusting the ends) to maintain alignment; pin sections, four places.

(b) Procedure for complete removal of the damaged end of the lattice from the chord.

(1) Remove the damaged stub from the chord by cutting just above the weld. See Fig. 18, 20, and 21.

(2) Carefully grind the weld down to within 0.010" to 0.020" of the chord surface as shown in Fig. 22, 23, and 24.

(3) Using a fine (80-100 grit) disc, polish the weld area to bright clean metal as in Fig. 25. MOST OF THE POLISH MARKS SHOULD RUN PARALLEL TO THE CHORD LENGTH. CARE MUST BE TAKEN SO THAT NO GOUGING OR DEEP GRINDING IS DONE.

(4) At this point you should have a snub on one and a removed tube from the chord on the other end. Cut the replacement tube to fit between the stub and the chord leaving about 1/8" gap at the stub end.

(5) Check to see that the replacement tube will fit snugly onto the chord and in proper position and alignment. If necessary, carefully contour or shape the replacement for a proper fit-up. A good fit-up will aid in proper heat and weld size control resulting in a better job.

(6) Position the replacement tube to be welded into the proper location and clamp into place as shown in Fig. 26. (The sleeve should be put on the replacement tube at this time).

(7) Weld the replacement lattice to the chord per Fig. 26, 27, 29, 30, 31 and the Welding Instructions per page 12.

(8) Position the sleeves so that it is midway over the gap. See Fig. 13.

(9) Weld all around each end of the sleeve positioned per step 8. Use an A.W.S. E6013 or E8018, either 3/32" or 1/8" diameter. (The amperes and voltage should be set within the ranges recommended by the electrode manufacturer. See Appendix C).

(10) Inspect welds.

(11) Repaint.

(12) Unpin.

Part III: Sleeve/Tube Splice Procedure When Both Stub-Ends Are Damaged.

(a) This procedure utilizes various steps already outlined in Parts I and II. That is, with both stubs damaged, both ends need to be removed from the chords and polished smooth.

(1) Remove the damaged stubs from the chord by cutting just above the welds. See Fig. 18, 20, and 21.

(2) Carefully grind the welds down to within 0.010" To 0.020" of the chords surface as shown in Fig. 22, 23, and 24.

(3) Using a fine (80-100 grit) disc, polish the weld area to bright clean metal as in Fig. 25. MOST OF THE POLISH MARKS SHOULD RUN PARALLEL TO THE CHORD LENGTH. CARE MUST BE TAKEN SO THAT NO GOUGING OR DEEP GRINDING IS DONE.

(4) Pin the two sections together. If one or more of the connections will not pin where a lattice had been removed it will be necessary to move the ends into position (jack, come- along or other suitable means of adjusting the ends) to maintain alignment; pin section, four places.

(b) The replacement tube must fit tightly in place so weld shrinkage will not draw the pin-connection out of alignment. This snugness of fit is best achieved by utilizing the "Sleeve/Tube Splice" procedure because of the ease of installation and final adjustment by means of extendable joint by virtue of the splice connection. Therefore, the replacement tube, as outlined below, is cut in two pieces, clamped in place, welded to the chords, and then welded at the splice.

(1) Cut the replacement tube in two pieces. The selection of "where to cut" in two pieces is left up to the repair person. However, a splice weld near the center of the tube would be the most convenient area for alignment and welding.

(2) Check to see that the replacement splice tube will fit snugly onto the chord and in proper position and alignment. If necessary, care- fully contour or shape the replacement for a proper fit-up. A good fit-up will aid in proper heat and weld size control resulting in a better job.

(3) Slide the splice ring on one of the tubes. Prepare a clamping - alignment set-up like that shown in Fig. 26. Clamp each half in place. Align the splice joint by laying a short angle-iron along the tube, and clamp it on each side of the splice. (Forget about having the sleeve in place at this time, but be sure it is on the tube, and that after the alignment angle-iron is removed it can be slid into place.)

(4) Weld both ends of the replacement lattice to the chords per Fig. 26, 27, 29, 30, 31 and the Welding Instruction per page 12.

(5) Remove the short angle-iron used for aligning the splice area and position the sleeve so that it is midway over the gap. See Fig. 13.

(6) Weld all around each end of the sleeve positioned per Step 5. Use an A.W.S. E6013 or E7018, either 3/32" or 1/8" diameter. (The amperes and voltage should be set within the ranges recommended by the electrode manufacturer. See Appendix C).

(7) Inspect welds.

(8) Repaint.:

(9) Unpin.

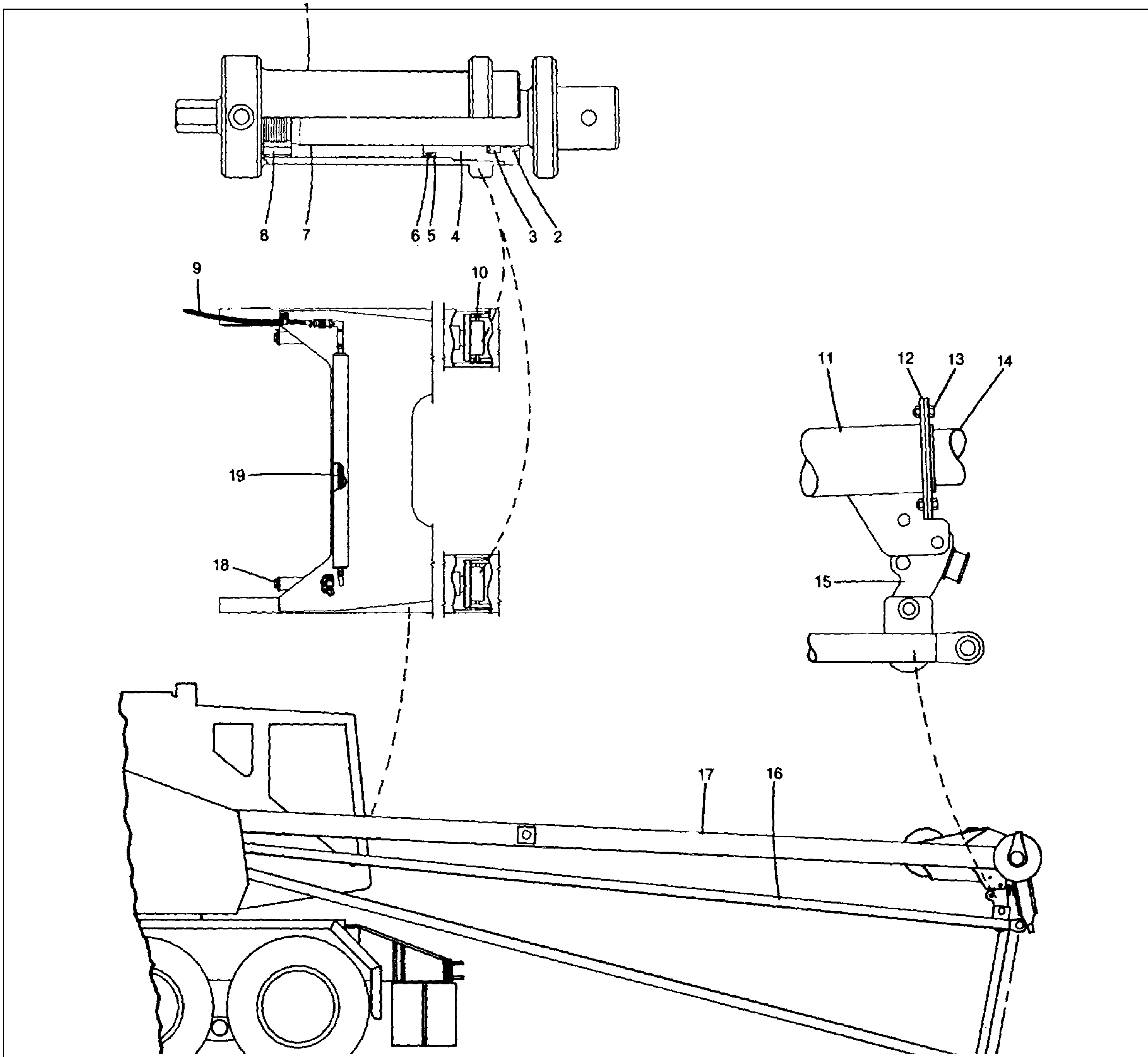



*Fig. 1* *NA241-D, 242-B, 288-D*

*Live Mast and Mast Cylinder Assemblies*

(1) Mast Cylinder ***(6)*** '0' Ring (11) Outer Mast Tubes (16) Boom
(3) 'U' Cup and '0' Ring 8) Rod Stop 13) Capscrew and Locknut (18 Cylinder Mounting
(4) Head (9) Hydraulic Line (14 Inner Mast Tube Capscrews
(5) Back-up Washer (10) Rollpin (15) Live Mast Stand Off (19) Hydraulic Line

HC238A

The live mast is hydraulically extended with pressure from the S-o-M system by means of a small hydraulic cylinder inside each leg of the mast, See Operators Manual Section 1 for operating instructions. The cylinder is designed to extend under pressure, but must be retracted manually as explained in the Operators Manual.

## 1.1 Live Mast Disassembly

The live mast may be disassembled to remove the hydraulic cylinders as follows:

(a) Lower attachment to ground. Lower live mast standoffs (see Operators Manual Section 1) and lower mast until standoffs contact lift shaft in boom and boom hoist ropes are slack.
(b) Remove main pendants, midpoint pendants, and boom hoist rope from machine.
(c) Remove cylinder mounting capscrews (18) from both cylinders.
(d) Disconnect all hydraulic lines from cylinders. Cap or plug all openings to prevent entry of foreign material.
(e) Remove pins from mast tubes. Unbolt end plates (12) from the top of each outer mast tube.
(f) Slide the inner mast tubes (14), with boom hoist bridle, spreader bar, and cylinders .attached out of outer mast tubes (11). Be careful not to damage boom during removal procedure.
(g) Remove rollpins (10) which attach cylinders to inner tubes. Remove cylinders from tubes.

## 1.2 Cylinder Disassembly

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(a) Thoroughly clean exterior of cylinder with kerosene or approved solvent.
(b) Unscrew head (4) from cylinder with a spanner wrench. Remove cylinder rod (7) and head (4) as a unit.
(c) Unscrew and remove rod stop (8) from cylinder rod.
(d) Slide head from cylinder rod.

## 1.3 Inspection and Parts Replacement

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

(a) Thoroughly clean all parts in approved solvent.
(b) Inspect parts for scratches, nicks, or other damage. Replace damaged parts.

## 1.4 Reassembly

(a) Lubricate the inner diameter of the head (4) and the 'U' cup seal lips (3).
(b) Slide head (4) onto cylinder rod (7).
(c) Thread rod stop (8) onto rod, and tighten down.
(d) Lubricate outer diameter of head. Slip the '0' ring (6) on the head carefully past the case threads to avoid damage to the '0' ring.
(e) After the head is in far enough for threads to mate, screw it in one full turn, then back off 1/4 turn. Follow this procedure until head is in place and tight. This procedure helps keep the '0' ring (6) and back-up washer (5) from wadding up in their groove.

Slide cylinder into end of inner mast tube (4). Install rollpin (10) through tube and cylinder.

## 1.5 Live Mast Reassembly

(a) Slide inner mast tubes with cylinders attached into outer tubes. Install and tighten down cylinder mounting capscrews (18).
(b) Bolt end plates (12) in place on outer mast tubes (11).
(c) Install hydraulic lines on mast cylinders.
(d) Reeve boom hoist ropes (see Operators Manual). Install main and mid-point pendants.
(e) Pin mast in extended position before use. Refer to Section 1 in the Operators Manual for mast operating instructions.

## 3.1 General

When engine disassembly is necessary - remove complete assemblies (tear down individual components like fuel pump, breaker mechanism, etc., as bench jobs). Use special tools available.

## 3.2 Disassembly

(a) Common sense will dictate proper order of disassembly. As disassembly progresses, the order may be changed, as will become self- evident.

(b) A suggested procedure would be as follows:

(1) Housinqs, shrouds, blower housing, air cleaner
(2) Flywheel - using puller or pry-bar method
(3) Gear Cover protect oil seal from key way damage.
(4) Crank Gear - use puller and gear puller ring.
(5) Loosen accessories such as fuel pumps, oil filter, starter, and generator.
(6) Control box and generator (lift all generator brushes) tag all wires for identification.
(7) Drain oil - discard oil removed.
(8) Cylinder head
(9) Valves, springs, rocker arms
(10) Camshaft and gear, rear bearing plate, oil pump
(11) Piston, connecting rod bearings
(12) Crankshaft
(13) Try to analyze reasons for any parts failure and necessity of the repair.
(14) Cleanliness and neat orderly work area makes the job easier to do.
(15) Use proper meters and gauges. Observe if cylinder requires boring, crankshaft needs grinding, or other major shop work necessary.
(16) Check qenerator. Use growler, test light (buzzer), or ohmmeter for armature or field coil shorts, grounds, or opens. Determine if commutator or slip rings need turning by lathe to true them up. Under-cut mica if necessary.

## 3.3 Assembly

(a) Engine assembling procedure is normally the reverse of disassembly - observing proper clearances of bearings, connecting rod, pro- per fitting and sizing of piston, rings, etc.

(b) Follow proper recommended procedure for fit of valves, adjusting clearances, and torque of all special items. Use a torque wrench to assure proper tightness without danger of stripping threads.

(c) As each internal engine part is assembled, use crank (or wrench) and turn over engine, making certain it turns freely. If tightness is noted after any operation you then know your last step is responsible.

(d) As each internal engine part is assembled, coat it heavily with oil (the same grade to be used in the crankcase). During the first few critical moments of operation the engine will depend on this lubrication.

(e) After you have the internal engine parts re-assembled, the engine should turn over freely when cranked. If reasonable care and atten- tion has been given, the engine will operate efficiently.

(f) At this point, it is a matter of mechanically adding the outside accessory items to the block assembly. Order of assenibly is reverse of disassembly.

(g) When engine is complete, install generator and plant control. Check the tagged wires. Use wiring diagram to connect generator leads to control, and, from control to engine leads. All wires are marked for correct indentifica- tion. If plant is to work properly, wires must be connected correctly.

(h) The engine-generator is now ready for testing. Follow suggestions given on Testing and Ad- justing Plants. Before final test and ad- justments, run the plant about 15 minutes under light load to reach normal operating temperature.

## 3.4 Assembly Suggestions (Things to keep-in mind during engine assembly)

(a) Wet holes in crankcase (holes through crankcase) always use copper (gasket) washers.

(b) Nuts, bolts and screws that do not require exact torque should be tightened snugly, then 1/4 extra turn.

(c) Select proper length of any screw or bolt and position in hole. Make sure they do not bot- tom.

(d) Gasket kits sometimes cover more than (1) engine. Therefore, select gasket of correct size and shape for part being used. Always use new gaskets.

(e) When disassembling engine, mike bearing plate gasket thickness. Then select proper gasket thickness for correct end play.

(f) When assembling crankshaft, make sure bearing thrust washers are in proper position support- ed by bearing stop pins. Use cup grease to hold in place.

(g) When installing gearcase cover, put a dab of grease on roll pin so governor cup can be aligned.

(h) Crank gears are easier to remove and install if heated.

(i) Service manual (for any specific model) should be read carefully for correct timing.

(j) Allow some gear lash (approximately .005 in.) in oil pump. Do not install gears tightly against each other!

## 3.5 Testing And Adjusting Plants Preparation Check the following:

(1) Put proper oil in crankcase.
(2) Service the air cleaner.
(3) Connect the fuel line.
(4) Connect the load.
(5 Connect fully-charged battery.
(6 Check ventilation for proper cooling.

## 3.6 Operation

(1) Start engine.
(2) Check oil pressure, adjust brush rig.

(3) Run plant 15 minutes to bring up to operating temperature.
(4) Check for oil leaks, loose electrical connections. tight fuel lines and tight exhaust connections.

## 3.7 Adjustments

(1) Adjust governor for speed and sensitivity.
(2) Make sure meters are connected.
(3) Check the output; volts, amps, watts, frequency.

Important: For complete customer satisfaction repaint unit (Onan Green, spray can 525P137, or Onan White, spray can 525P216) and apply instruc- tions from Vitt8-l100C.

If engine disassembly is necessary, observe the following order (i.e. Flywheel, Gear Cover...). As disassembly progresses, the order may be changed somewhat as will be self-evident. The engine assembly procedure is the reverse of dis- assembly. Any special assembly instructions for a particular group are included in the appli- cable section. When re-assembling, check each section for these special assembly instructions or procedures.

4.1 Flywheel

Remove the blower housing. The flywheel is a tapered fit on the crankshaft. Improvise a puller, using at least a 7/16 in. bar, and drill two 7/16 in. holes 2-7/8 in. between centers. Loosen the flywheel mounting screw a few turns. Place bar against the flywheel screw and attach bar, using two 3-8/16 thread screws in the holes provided in flywheel. Alternately tighten the screws until flywheel is free.

Replacement flywheels are supplied without the timing markings because each flywheel must be fitted to its engine. The only accurate method of determining the top dead center (TDC) and port closing points is to measure the piston travel. This is a critical measurement and should be attempted only with accurate, dependable equipment.

With the flywheel mounted, remove the head and install a depth qauge over the piston. Rotate the flywheel to find the TDC position on the compression stroke and mark this point on the flywheel. Next, turn the flywheel counterclock- wise until the piston drops exactly .102 in. from TDC. This is the port closing piont, 170 BTDC. Mark it on the flywheel.

4.2 Gear Cover

To remove the qear cover, detach the upper governor ball joint. Remove the governor speed adjustment nut and governor spring bracket.

Remove the screws holding the gear cover to the crankcase. To loosen the gear cover, tap it with a soft hammer.

Governor Shaft: The governor shaft is supported by two sets of need e bearings. mo remove the shaft, remove the yoke and pull the shaft from the gear cover. If the shaft is binding, clean the bearings, if loose, replace the bearings. To remove the larger bearing, drive both bearing and oil seal out from the outside of the gear cover. Remove the smaller bearing with an Easy- Out or similar tool. Press new bearings and oil seal into place.

Gear Cover Oil Seal: Replace the oil seal if damaged or worn. Drive the old seal out from in- side the gear cover. Lay the cover on a board so the seal boss is supported. Using an oil seal driver, insert the new seal from the inside with rubber lip toward outside of gear cover (open side of seal inward) and drive it flush with the outside surface. During gear cover installation, use the driver to protect the oil seal. See Fig. 2.

4.3 Assembly, Gear Cover

(1) Work the governor shaft to check for binding and see that the governor-shaft-end-thrust ball is in place (Fig. 1).
(2) Turn governor yoke so the smooth side is toward governor cup.
(3) Turn the governor cup so the stop pin in the gear cover will fit into one of the holes in the cup surface (Fig. 1). Measure the distance from the end of the stop pin to the mounting face of the cover. It should be 25/32 in.. If it is not, replace the pin. Pin should be positioned with open end facing crankshaft seal.
(4) Coat the oil seal lip with oil or grease. Set a piece of shim stock over the crankshaft keyway to protect the seal and install the gear cover. Torque the mounting screws to 15 to 20 foot pounds. Before tightening screws, be sure the stop pin is in the governor hole.

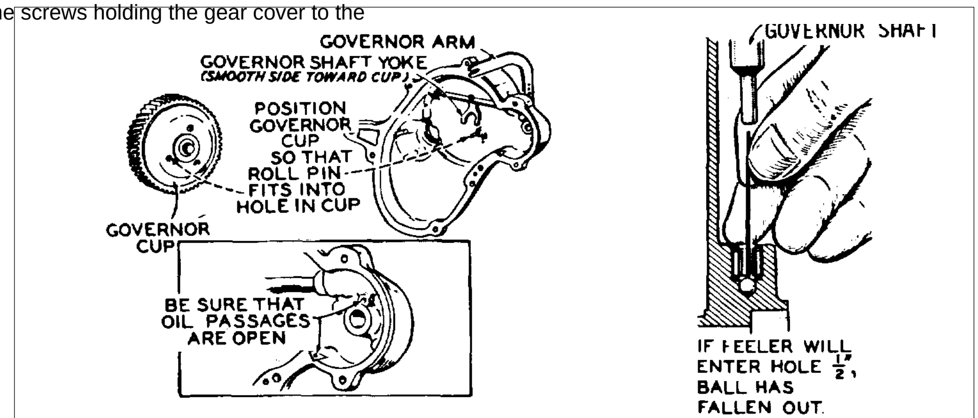



*Fig. 1 Gear Cover Assembly*

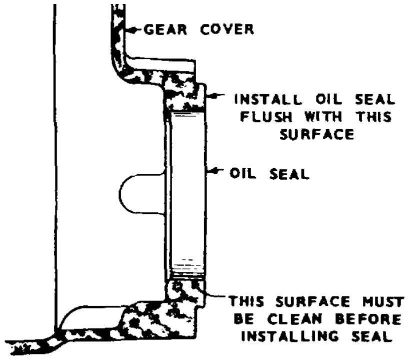



*Fig. 2 Gear Cover Oil Seal*

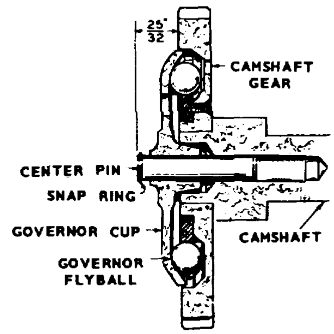



*Fig. 3 Governor Cup*

## 4.4 Governor Cup

To remove the governor cup, remove the snap ring from the camshaft center pin and slide the cup off.

Note: <u>Be sure to catch the ten flyballs that will fall out when the cup is removed.</u>

4.5 Repair

Replace any flyballs that have flat spots or grooves. Replace the cup if the race surface i! grooved or rough. The governor cup must be a free spinning fit on the camshaft center pin, but should be replaced if excessively loose or wobbly.

Check the distance the center pin extends from the camshaft gear; this distance must be 25/32 in. to give the proper travel distance for the cup. (Fig. 3). If it is less, the engine may race; if more, the cup will not hold the balls properly. If the distance is too great; drive or press the center pin in. If it is too small replace the pin; it cannot be removed without damaging the surface.

In some cases, if the distance is too small, the head of the governor cup can be ground to give the necessary 7/32 in. travel distance.

4.6 Installation

To install the governor assembly, tip the front of the unit upward. Set the flyballs in their recesses and position the governor cup on its shaft. Finally, brush with heavy grease and install the snap ring on the center pin.

4.7 Camshaft

The camshaft is a one-piece machine casting, driven through gears by the crankshaft. It rides on sleeve bearings pressed into the crank case.

In addition to providing a means of opening and closing the valves, the camshaft operates the injection pump and fuel transfer pump.

4.8 Removal

(1) Remove the rocker arms and push rods from the valve chambers.
(2) Remove the injection pump and fuel transfer pump from the engine.
(3) Remove the crankshaft gear retaining washer by removing the lock ring on the crankshaft.
(4) Lay the engine on side to avoid dropping tappets and remove the camshaft assembly as a group. If necessary, pry it out with a screwdriver between the camshaft gear and crankcase.
(5) Remove the valve tappets. These can be re- moved only from the camshaft end of the push rod holes.

4.9 Repair

If a lobe has become slightly scored, dress it smooth with a fine stone. If the camshaft is badly worn or scored, replace it. After installing a new camshaft, retime the injection pump to the engine.

Camshaft Gear: This gear is a pressed fit on the camshaft and drives it at 1/2 the crankshaft speed. To remove the gear, use a hollow tool or pipe that will fit inside the gear bore and over the center pin. Press the camshaft out of the gear bore. Be careful not to damage the center pin.

Camshaft Bearings: The camshaft bearings should be replaced if the clearance to the camshaft is greater than specified, the bearings show cracks, breaks, burrs, excessive wear, or other defects. The camshaft-to-bearing clearance should be .0012 in. to .0037 in.. To check the rear bearing, remove the expansion plug at the rear of the crankcase.

Press new bearings into place (Fig. 4). Press the rear bearing flush with the bottom of the expansion plug recess. Press the front bearing in flush with the crankcase front surface so the oil passages are aligned. Do not attempt to ream the bearings, as they are a precision type. After the rear bearing is installed, insert a new expansion plug in the recess, using sealing compound, and expand it into place with sharp blows at its center.

4.10 Installation, Camshaft Assembly

(1) Install the key and press the camshaft gear on its shaft.
(2 Install the governor components.
(3) Slide the thrust washer onto the shaft. Measure camshaft end play; it should be .007 in. to .039 in. (Fig. 5).
(4) Lay the engine on side or end and insert the push rod tappets.
(5) Install the camshaft assembly in the engine. Align the timing marks on the camshaft gear and crankshaft gear (Fig. 6).
(6) Replace the push rods and fuel transfer pump.
(7) When the engine is reassembled, install the injection pump, following the steps of Injection Pump Installation. This step is critical.

4.11 Crankshaft

These engines use a counter-balanced, ductile iron crankshaft. To increase the shaft fatigue durability, all crankpin fillets are shot-peened during manufacture. The crankshaft rides on two lead-bronze bearings; the front one housed in the crankcase and the rear one in the bearing plate.

4.12 Removal

(1) Remove the lock ring and retaining washer in front of the crankshaft gear.
(2) Pull off the crankshaft gear. It has 2-1/4- 20 UNC tapped holes for attaching a gear pul- ling ring. Use care not to damage teeth if the gear is to be re-used. (Fig. 7).
(3) Remove the oil pan, piston, and connecting rod.
(4) Remove the rear bearing plate from the crankcase.
(5) Remove the crankshaft through the rear opening in the crankcase.

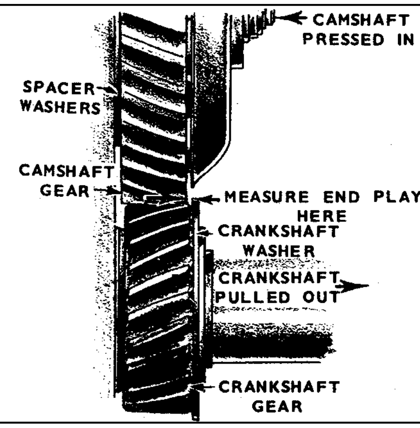



*Fig. 5 Camshaft End Play*

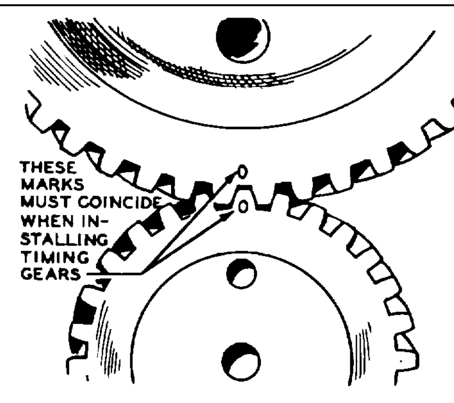



*Fig. 6 Timing Marks*

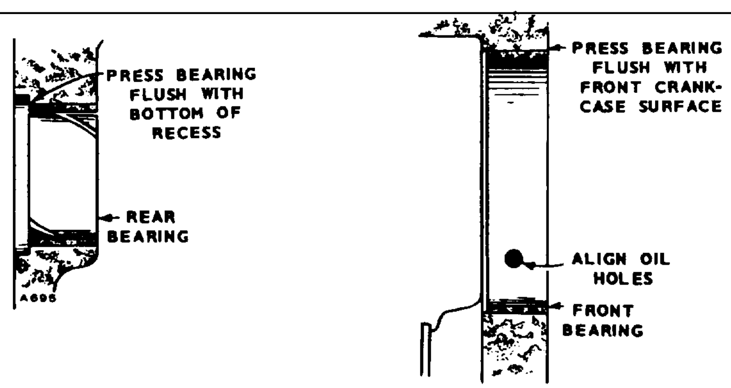



*Fig. 4 Camshaft Bearings*

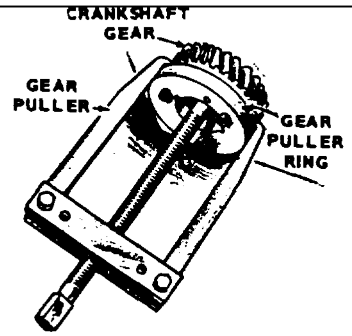



*Fig. 7 Removing Crankshaft Gear*

## 4.13 Inspection

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

Clean the crankshaft and blow out all oil pas- sages. Check journals for out-of-round, taper, grooving or ridges. Pay particular attention to ridges or grooves on either side of the oil hole areas. Unusual conditions here often point to previous neglect of oil changes. If journal dimensions are not within limits, or if the journals are scored, regrind the crank- shaft.

Crankshaft Regrinding: Crankshaft grinding re- quires a trained, experienced operator working with precision equipment. Procedures which may be satisfactory for some spark-ignition engines may well be unsatisfactory for diesel applications, resulting in expensive failures. Onan emphasizes that if facilities or trained personnel are not available, the crankshaft may be sent to the factory.

Special procedures must be observed when re- working diesel crankshafts. In addition to machining, the crankshaft must be "shot-peened" and super-finished. Failure to "shot-peen" the crankpin fillets is likely to cause early failure. When the shaft is machined, follow this data and Fig. 8 to "shot-peen" each crank pin fillet.

(1) Almen gauge reading, .012 A.
(2) Peen with .019 in. diameter cast steel shot.
(3) Peen for 15 seconds on each crankpin fillet.
(4) Mask off connecting rod bearing areas.

Undersize bearings and connecting rods are available to rework the shaft to .010 in., .020 in. and .030 in. undersize.

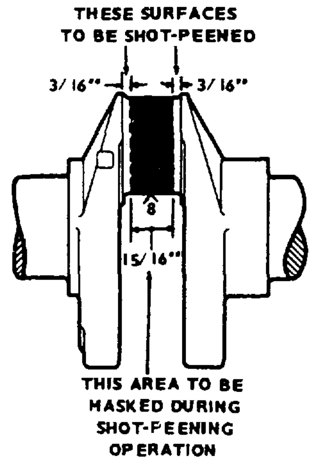



*Fig. 8 Shot-peening Crankshaft*

Main Bearings: Replace main bearings if clearances are greater than limits, or if the bearings are worn, grooved or broken. Precision re-placement bearing inserts and thrust washers are available for all main bearings. Do not ream the bearings. Align the oil holes and press the new bearings into the front and rear housings.

Rear Oil Seal: The rear oil seal is in the rear bearing plate. If damaged, drive it out from the inside of the plate. Using the oil seal installing tool, install a new seal with the rubber lip facing outward (open side of seal inward) Fig. 4. Drive the new seal flush with the rear surface of the bearing plate. Leave the seal installer on during bearing plate installation to protect the oil seal.

## 4.14 Installation

After each installation step, check the crankshaft to be sure it is not frozen into place.

(1) Press the front and rear main bearings into place, aligning the bearing and bearing housing oil holes. Do not attempt to drive a bearing into a cold block or rear bearing plate. (Fig. 9).
(2) Install the thrust washers and locking pins.
(3) Oil the bearing surfaces and install the crankshaft from the rear of the crankcase through the rear bearing plate hole.
(4) Mount and secure the rear bearing plate.
(5) Heat the timing gear on an electric burner or oven to about 3500 F. Install the key on the crankshaft, then drive the gear into place. Install the retaining washer and lock ring.
(6) Check the crankshaft end play. Use enough rear bearing plate gaskets-or shim and gaskets to provide .010 in. to .015 in. end play. If gaskets of more than .015 in. total thickness are required, use a steel shim of proper thickness and a thin gasket on each side of shim.- This avoids excessive gasket compression and maintains bolt torque.
(7) Install the piston assembly.

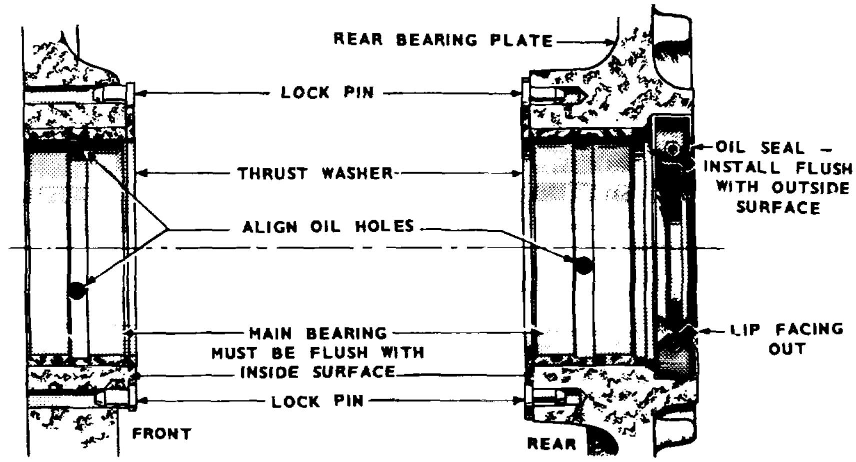



*Fig. 9 Main Bearing Installation*

4.15 Crankcase

If the crankcase is replaced, a new set of injection pump shims will be furnished with the new crankcase. These must be used and, in addition, the injection pump must be retimed to the engine. See Fuel System (SM18-10-8.0).

The cylinder head assembly has alloy-hardened faced valves, release-type rotators, alloy-hard- ened inserts, guides, rocker arms, injection nozzle and glow plug. The push rods run through shields. The head assembly contains a decompression mechanism.

5.1 Maintenance

Check the valve clearances at regular intervals. (See Operators Manual). In addition, clean the combustion chamber and valve seats at regular intervals. Readjust decompression mechanism after adjusting valves.

5.2 Testing

The cylinder compression test can be used to determine the condition of valves, the piston, piston rings and cylinder.

To check compression, run the engine until thoroughly warm. Stop it and remove the injection nozzle. Insert the compression gauge in the injection nozzle hole, crank the engine and note the reading. To check for piston blow-by, squirt a small amount of SAE 50 oil into the cylinder and repeat the check. An increase in compression with oil in the cylinder indicates piston blow-by.

Another quick check of valve condition is to listen at the intake manifold (air cleaner re- moved) and the exhaust outlet while the engine is turned over by hand. A hissing sound indicates a leaking valve. Be careful when using this test because there will always be a slight hissing during the start of each compression stroke as the intake valve finished closing.

5.3 Valve Clearance

Check valve clearance when the engine is at room temperature (about 70°F). Allow at least two hours for engine to cool after operation.

(1) Turn the flywheel until the cyinder is on its compression stroke. Use a socket wrench on the flywheel screw hex head.

To determine if the cylinder is in its compression stroke, observe the action of the push rods as the engine is rotated in a clockwise direction. The exhaust valve push rod will be in its lowest position and the intake valve push rod will be moving downward. As the piston reaches top dead center, the flywheel timing mark should be aligned with the timing pointer and the valve push rods stationary.

(2) Now turn the flywheel clockwise an additional 10 to 45 degrees. There is no timing mark for this position, so it must be estimated. With the piston located in this position, it will be in its power stroke with both valves completely closed.

(3) To change the setting of valve clearance, ad- just the locknut which secures the rocker arm to the cylinder head (See Fig. 1). Loosen the locknut to increase clearance and tighten it to reduce clearance.

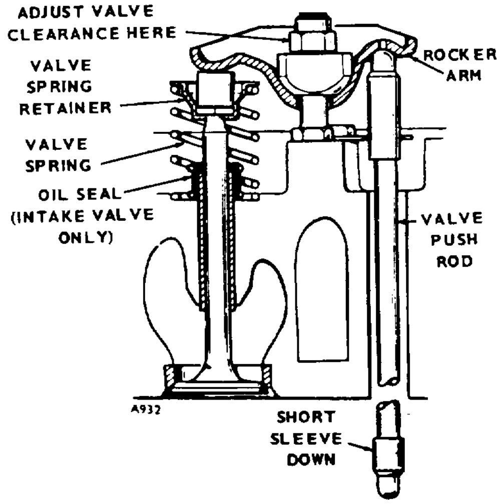



*Fig. 1 Setting Valve Clearance*

(4) After allowing engine to cool, check the clearance with a feeler gauge between the rocker arm and the valve (See Fig. 2). Increase or reduce the clearance until the proper gap is established. Correct valve clearance is .011 in. intake and .008 in. exhaust.

Compression reading will deviate from the above readings because of differences in cranking speed, altitude and ambient temperature conditions. Therefore, the specification is given only as a guide.

5.4 Disassembly

(1) Remove the decompression solenoid.
(2) Remove the rocker box cover, fuel nozzle and connecting oil lines to the cylinder head.
(3) Remove the intake and exhaust manifold. Remove capscrews holding the cylinder head to the cylinder block.
(5) Remove the head. If it sticks, rap it sharply with a soft hammer. Do not use a pry.
(6) Remove the rocker arms and push rods.
(7) Use a valve spring compressor, disassemble the valve assemblies.

5.5 Repair

Thoroughly clean all components of the cylinder head assembly. Remove all the carbon deposits from the intake and exhaust ports and clean all gasket surfaces.

Valves: Remove all carbon and check each valve for burning, pitting or warped stem. Refinish valves that are slightly pitted or burned on an accurate valve grinder. Refinish intake valves to a $^{42'}$ angle and exhaust valves to a 450 angle. If they are badly pitted or have a thin edge when refacing, replace them.

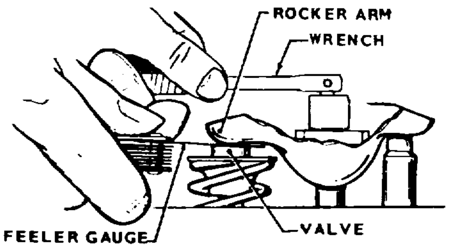



*Fig. 2 Checking Valve Clearance*

Check refinished valves for a tight seat to the valve seat with an air-pressure-type testing tool, or by applying Prussian Blue to the valve face and rotating it against the seat.

Valve Guides: Check valve guide to valve clear- ance, (See SM18-10-13.0, Table of Clearances). If the proper clearances cannot be obtained by replacing the valves, replace the valve guides. Drive the old valve guides into the valve cham- bers. Drive new guides in until they protrude 11/32 in. from the rocker box side of the head. Ream the new valve guide to obtain the proper clearance.

Valve Seats: If the valve seats are pitted, re- finish them. Using conventional seat grinding equipment, reface each seat to a **450** angle and a seat width of 3/64 in. to 1/16 in.. You should be able to reface each seat several times before it becomes necessary to replace it. If, however, the valve seats are loose or cannot be refaced, replace them.

Use Onan tool #420B272 in a drill press (Fig. 2) to remove each valve seat. Adjust the tool to cut 1/64 in. from the edge of the seat. Oil the pilot to prevent it from seizing in the valve guide. Cut each seat down to a narrow rind on edges and bottom and break it out with a sharp tool. Be careful not to cut into the counter- bore bottom.

Thoroughly clean the valve seat counterbore and remove any burrs from the edges. If the counter- bore is damaged, it will have to be remachined for an oversize seat. Oversize seats are avail- able in .002 in., .005 in., .010 in. and .025 in.. Otherwise, install new standardsize seat inserts.

Drive the new valve seat inserts into place. Be certain that each seat rests solidly on the bottom of the counterbore at all points. To make installation easier, heat the cylinder head in an oven at 3250F for about 30 minutes and cool the valve seats in dry ice.

Face each new seat to a 450 angle and width of approximately 3/64 in.. The finished seat face should contact approximately center of the valve face. Use Prussian Blue on each valve face to check this. Make any corrections on the seat, not the valve face.

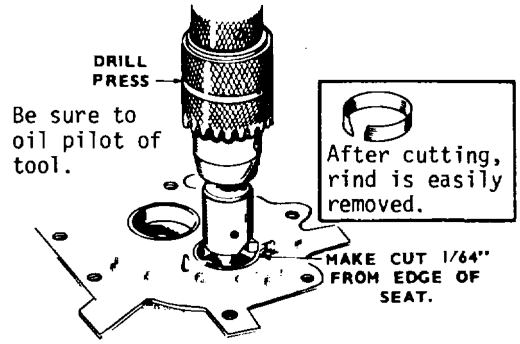



*Fig. 3 Removing Valve Seats*

When the new seats are installed and faced, in- sert the valve into each and check the clearance from valve head to the face of the cylinder head. This must be at least .030 in.. If it Is not, regrind the seat.

Valve Springs: Check the valve springs on an accurate compression scale. The valve spring load should register 45-49 lbs. closed; 83-93 lbs. open. Replace any weak, cracked or pitted spring, or one that has out-of-square ends.

5.6 Installation

(1) Push a valve stem oil seal onto the intake valve guide and clamp in place. Then oil the inside surface of the seal.
(2) Oil the stem of each valve lightly and insert into its own guide.
(3) Check each valve for a tight seat with an air pressure type tester. If a tester is not available, make pencil marks at intervals on the valve face and observe if the marks rub off uniformly when the valve is rotated part of a turn in the seat. If the seat is not tight, regrind the valves.
(4 Using a valve spring compressor, compress each valve spring and insert the valve spring retainer and retainer locks.
(5) Install the head assembly and gasket to the cylinder block. Tighten the head bolts evenly to 44 to 46 ft/lbs. See Fig. 4 for proper tightening sequence.
(6) Install the exhaust manifold, nozzles, glow plugs and oil lines. Tighten manifold nuts evenly to 13-15 lbs.
(7) Install the valve stem caps.
(8) Install the push rods, rocker arms and rocker arm nuts.
(9) Set the valve clearance. Intake is .011 in.; exhaust is .008 in..
(10) Install and adjust the decompression mechanism.
(11) Install the rocker cover. Remove the solenoid, dip plunger "0O" ring in oil and rein- stall when cover is on engine.

Important: <u>After the first 50 hours of operation, retighten the cylinder head bolts and check valve clearance. See Fig. 4.</u>

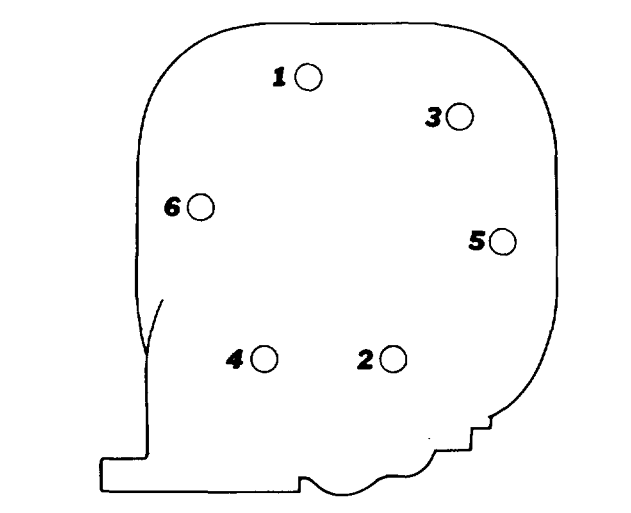



*Fig. 4 Bolt Tightening Sequence*

5.7 Decompression Release

The decompression release mounts on the cylinder head with a solenoid on the rocker box cover. It holds the exhaust valve open to allow the en- gine to build up speed during starting before compression occurs, and to stop the plant. The mechanism holds the exhaust valve open when the solenoid is de-energized. If the release is defective, replace any worn parts; otherwise, adjust it, following the instruction below.

Note: Before adjusting the decompression mechanism the valves must be set for the correct clearance.

Figure 5 shows the decompression release in de- tail. It must operate properly for dependable engine starting and stopping.

(1) With the piston $10^{\circ}$ to $45^{\circ}$ past TDC on the power stroke, hold the arm in the decompression position (tension against spring). Turn the set screw so it just touches the exhaust rocker arm. The release arm must be tight against the snap ring during adjustment. Then turn the screw exactly one revolution clockwise. The original factory setting is marked with white or yellow paint.

Note: If the screw is tightened more than one turn, the exhaust valve could hit the piston.

Hold the set screw and lock it into position with the attached nut. Turn the nut hand tight plus 1/4 to 1/2 turn to lock the mechanism.

(2) Release the mechanism to allow compression. Check the clearance between the screw and rocker arm. Insert a .008 in. feeler gauge between valve and rocker arm to take up valve clearance for this check. If there is no clearance, back off the set screw until it just clears the rocker arm.

When reassembling the rocker cover, remove the solenoid, dip the plunger "O" ring in oil and reinstall when cover is on the engine. Align solenoid so terminal "SW". is above terminal "IGN".

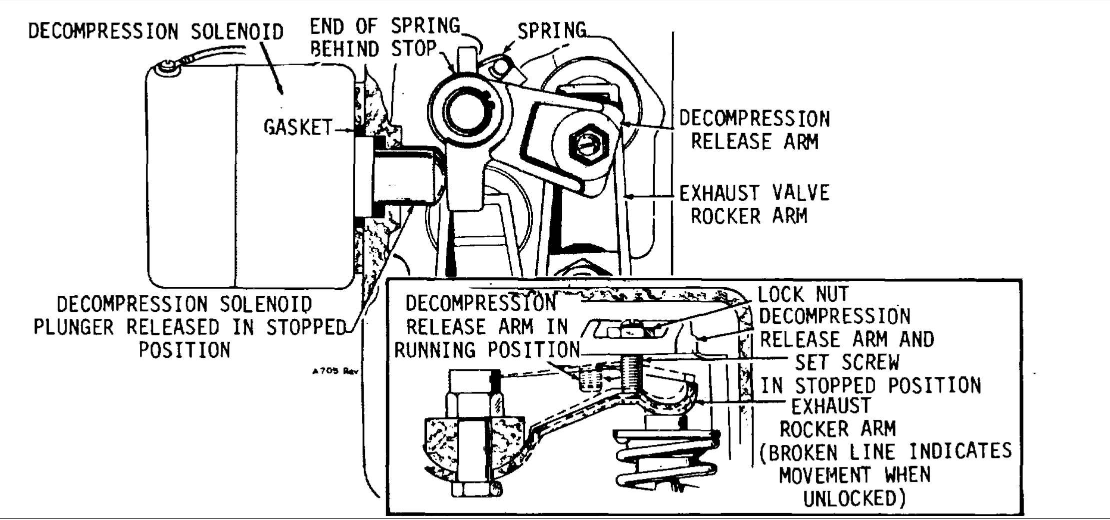



*Fig. 5 Decompression Release*

This engine uses a cam-ground aluminum piston, tapered and fitted with three compression rings and an oil control ring. A full-floating piston pin connects the piston to its connecting rod. The pin is held in place with a snap ring at each end. The lower end of the connecting rod contains half-shell, precision bearings, and the upper end, semi-finished bushings.

Important: Some engines are fitted with a .005 in. oversize piston and rings at the factory. These engines are marked with an E following the engine serial number.

## 6.1 Removal And Disassembly

(1) Drain the crankcase oil and remove the oil base.
(2) Remove the cylinder head.
(3) Remove the cap from the connecting rod and push the assembly through the top of the cy- linder bore. Replace the cap and bearing inserts in the assembly.
(4) Using a ring expander, remove the rings from the piston.
(5) Remove the two retaining rings and push the piston pin from the piston.

## 6.2 Cylinder

The cylinder wall should be free of scratches, pitting and scuffing. Check cylinder with an inside-reading micrometer for out-of-round and wear. The bore should measure between 3.2495 in. and 3.2505 in. and be less than .001 out-of-round.

If necessary, rebore the cylinder to fit the next available oversize piston. Pistons and rings are available in .005 in., .010 in., .020 in., .030 in. and .040 in. oversize. If the cy- linder does not need refinishing, remove any existing ridge from the rop of the wall with a fine stone.

## 6.3 Piston

Clean thoroughly and inspect the piston. Clean the carbon from the ring grooves and be sure all oil holes are open. If the piston is badly scored or burred, loose in the cylinder, has bad- ly worn ring grooves or otherwise is not' in good condition, replace it.

Check the clearance 900 from the axis of the pis- ton pin and below the oil control ring. Clear- ance should be .0055 in. - .0075 in.. If not, replace the piston and check the cylinder for possible reconditioning.

## 6.4 Piston Pin

The piston pin should be a thumb push fit into the piston at room temperature. If the pin is excessively loose, install a new one. If the condition is not corrected, install the next oversize pin. If the n4itnn is worn enough that the oversize pin will not fit, replace it.

## 6.5 Rings

Inspect each ring carefully for fit in the piston grooves and seating on the cylinder wall (Fig. 1). Fit each ring to the cylinder wall at the bottom of its travel, using the piston to square the ring in the bore. Check the gap with a feeler gauge. It'should be .010 in. to .020 in.. If the gap is too small, file the butt ends of the rings. Do not use rings that need a lot of fil- ing, as they will not seat right on the cylinder wall. If an oversize piston is used, use the correct oversize rings.

## 6.6 Connecting Rod

Clean the connecting rod and check for defects. Check the connecting rod bushings for proper clearance with the piston pin. Clearance should be .0002 in. to .0007 in.. If the bushings are excessively worn, press them out and install one new bushing from each side of the bushing bore. Press the new bushings only until flush with the sides of the rod to leave 1/16 in. to 7/64 in. oil groove in the center (Fig. 2).

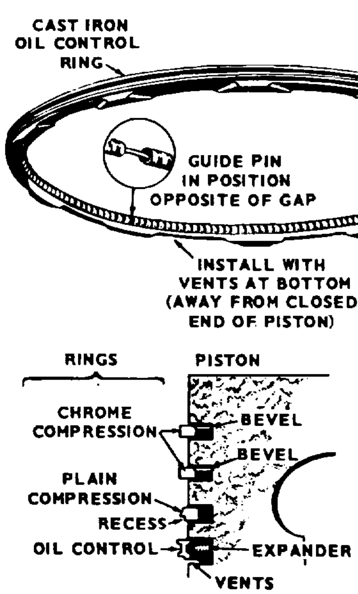



*Fig. 1 Piston Rings*

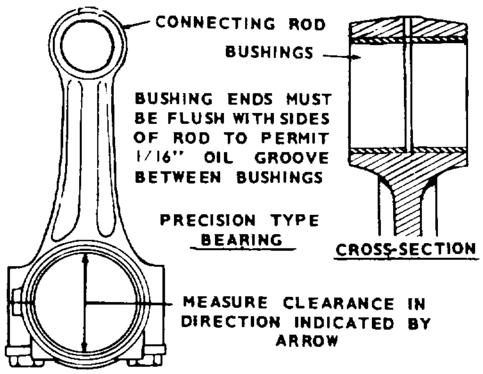



*Fig. 2 Connecting Rod Bushings*

## 6.7 Connecting Rod Bearings

Inspect the connecting rod bearings for burrs, breaks, pitts and wear. Measure the clearance between bearings and the crankshaft journal. The clearance should be .001 in. to .0033 in.. If necessray, replace with new standard or over-size precision bearings.

For information about the crankpin journals, see SM18-10-4. 0.

## 6.8 Assembly And Installation

(1) Install the connecting rod on the piston with the pin and retaining rings. If new bushings were installed, make certain the ends are flush with the connecting rod to provide for the oil recess in the center.
(2) Install the rings on the piston. Rings will be marked top, or identified in some manner. Place this mark toward the closed end of the piston. Space the ring gaps one fourth of the way around the piston from one another. No gap should be in line with the piston pin. Oil the rings and piston. Gap in oil ring expander must be approximately 1800 from gap in oil ring.
(3) Position a bearing half in the connecting rod. Be sure there is no dirt under the bearing. This could cause high spots and early bearing failure.
(4) Oil the cylinder wall. Install the piston in the cylinder, using a suitable installer. The assembly should be installed with the stamp on the piston facing in the same direc- tion as when removed. The notch on the piston should be on the front of the engine.
(5) Position the connecting rod on the crank- shaft, oil the journal and install its rod cap with bearing half. When installing the rod cap, position so the raised witness mark on the forging matches the mark on the connecting rod;
(6) Tighten the capscrews to the specified torque.
(7) Crank the engine over by hand to see that the bearings are free.
(8) Install the oil base with a new gasket. (9) Install the cylinder head using an even bolt-tightening sequence and specified torque.
(10) Replace oil.

## 6.9 Break-In Period

Whenever a new piston or rings are installed or the cylinder refinished, the engine must be run-in before regular operation can be resumed. Run the engine for 15-20 minutes at no load, about 30 minutes at 1/3 load and 2 to 3 hours at 2/3 load. Regular operation can then be resumed. Avoid light load operation during the following several hours for best ring seatinq to control oil.

To remove the heat produced during operation, DJA generating plants use a pressure air cooling system. Blades on the engine flywheel draw air into the front of the engine housing and force the air past the cylinder and out the right side of the engine. A separate blower on the generator rotor draws air into the rear of the generator and forces it out through openings near the engine.

From the engine outlet, air can be ducted out of the area. An optional shutter assembly can be installed on the air outlet to improve engine temperature control.

## 7.1 Maintenance

With a properly installed engine, maintenance should consist of cleaning the engine cooling area (fins on cylinder head) at regular intervals, normally every 1,000 hours but more often under dirty operating conditions.

## 7.2 Overheating

The first sign is usually a dark exhaust smoke and loss of engine power, which results in a speed loss. This happens before the engine seizes, and results in a seized piston, or worse. At the first sign of speed or power loss the plant should be stopped, if possible, and the cause found.

The most probable causes of overheating are dirty cooling surfaces, operating without the engine air housing, poor air circulation, improper lubri- cation, wrong injection timing or engine over- loaded.

Piston rings and nozzles will generally stick before the piston seizes.

**CAUTION**

The Air Housing, Including The Door, Must Be On When Operating The Engine. Overheating And Permanent Damage Can Result From As Little As One Minute Of Operation Without It.

Common installation problems leading to overheating are as follows:

(1) Installation with duct size too small for sufficient air flow.

(2) Installation in small room with no ducts and insufficient air ventilation in the room.

(3) Installation of air inlet and outlet ducts so air outlet feeds back to the inlet.

The diesel fuel system provides a means of fil- tering, transporting and delivering fuel in a fine spray to the engine cylinder at the correct time for ignition. The system consists of a primary fuel filter, fuel transfer pump, secon- dary fuel filter, injection pump and an injec- tion nozzle. Fig. 1 shows the fuel system.

The diaphragm fuel transfer pump which operates directly off the engine camshaft, draws fuel from a supply tank and delivers it through two filter to the injection pump. The injection pump meters fuel and delivers it at high pres- sure to the injection nozzle at the correct time for ignition.

The injection nozzle opens at a set pressure, delivering fuel in a fine spray to the precom- bustion chamber for ignition.

Excess fuel is returned to the tank after each injection cycle by a fuel return line from the nozzle. An adapter combines the leak-off fuel with the flow-through fuel from the injection pump. A return line connected at this point returns the combined fuel back to the fuel sup- ply tank.

**CAUTION**

A Diesel Engine Cannot Tolerate Dirt In The Fuel System. It is One Of The Major Causes Of Diesel Engine Failure. A Tiny Piece Of Dirt In The Injec- tion System May Stop Your Unit. When Opening Any Part Of The Fuel System Beyond The Secondary Fuel Filter, Place All Parts In A Pan Of Clean Diesel Fuel As They Are Removed. Before Installing New Or Used Parts, Flush Them Thoroughly, And Install While Still Wet.

8.1 Maintenance

8.2 Fuel Filters

Fuel filters are required for protection of the

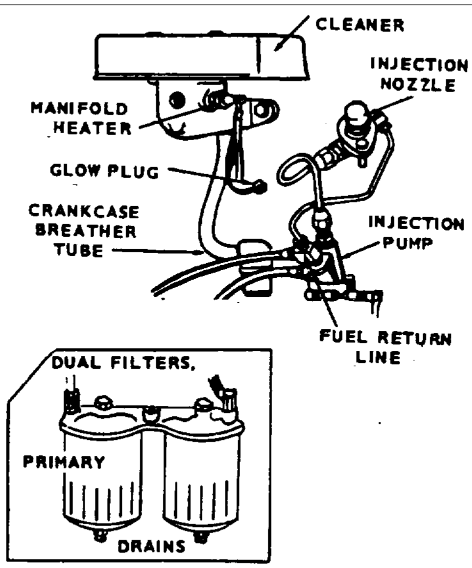



*Fig. 1 Diesel Fuel System*

fuel injection system, even though good fuel handling practices are followed. It is absolute- ly necessary to use filters capable of removing micron-size particles from the fuel.

(1) Two-stage filtration is supplied with Onan diesels.
(2) The first stage of filtration is a 10-micron filter which has a replaceable cartridge, air bleed and drain valve. This filter is installed on the suction side of the fuel transfer pump and provides protection for the pump as well as the injection system when extremely adverse conditions are en- countered, such as mobile installations or construction sites.
(3) Fuel transfer pumps have a glass sediment bowl which traps water and sediment. If water or sediment are seen at this point (in continuing amounts), an additional fil- ter and water trap should be installed at the supply outlet.
(4) The final stage of filtration is accomplish- ed with a 2-to-5 micron filter (Particle sizes from .00080 to 0.000200 inch). Parti- cles larger in size would eventually damage the injection equipment.

8.3 Air Cleaner

**WARNING**

Use Diesel Fuel, Fuel Oil, Or Solvents In A Well Ventilated Area, Away From Flames.

Check the air cleaner after each 50 hours of operation. Wash the filter element in diesel fuel. Moisten with clean oil of the same viscosity and grade as is in the crankcase. Dip and then squeeze dry. Replace element if it is damaged.

The fuel filtration system accommodates both primary and secondary fuel filters on a common mounting casting which is bolted to a oil fill tube. The engine cannot be run with either filter loose or missing, thus ensuring proper lubrication at all times.

The drains are located on the bottom of each filter housing. A damaged fitting may cause fuel leakage. To avoid damage, use two wrenches on each fitting when draining the filters. This will avoid the possibility of the upper drain fitting nut twisting away from the sheet metal housing.

In addition to regular service periods, change the secondary fuel filter cartridge if the engine shows signs of starving from lack of fuel. Remove the secondary filter *by* removing the large screw in the center of the filter cover. Use care when replacing the filter cartridge to avoid getting dirt into the injection pump passages.

When replacing or cleaning filters, bleed the fuel system. Do this by opening the air bleed screw located on top of the secondary filter removal capscrew. Operate the hand priming lever on the transfer pump until no air bubbles

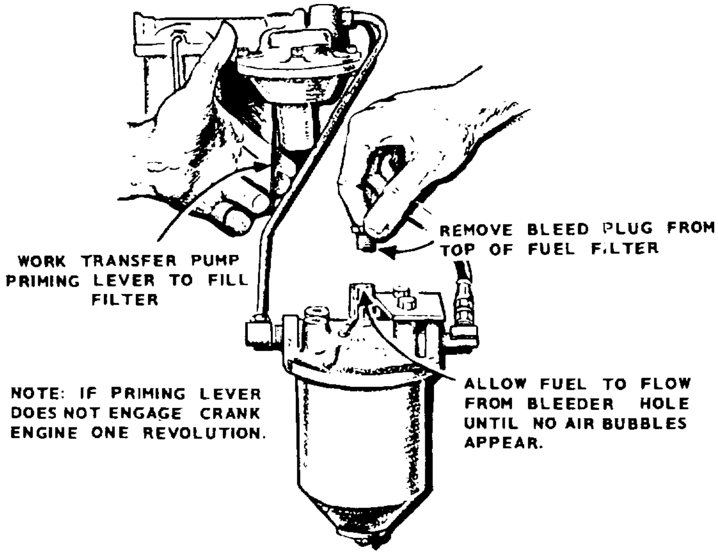



*Fig. 2 Bleeding Fuel System*

flow from the bleed screw hole, then tighten the bleed screw. Return the priming lever to its original position (Fig. 2).

Important: <u>If the transfer pump cam lobe is on the high side, the priming lever will not operate the pump. Turn the engine one revolution before operating the priming lever.</u>

8.4 Fuel Transfer Pump

Fuel transfer pumps are automotive type, incorporating a diaphragm and check valves. These pumps are operated by a rocker arm which rides on an eccentric camshaft lobe. The diaphragm spring maintains required fuel pressure to the injection pump. Fuel pressure should be 3-1/4 to 4-1/2 psi.

If fuel does not reach the secondary filter, make the following checks before removing the pump.

(1) Check the fuel tank and see that the shut off valve is open.
(2) Remove the fuel line from the transfer pump outlet and work the priming lever on the pump. Fuel should spurt out of the pump. If not, remove the pump for repair or replacement.

<u>Testing:</u> If the transfer pump delivers fuel, test it with a pressure gauge or manometer. Perform these tests before removing the pump from the engine. Remove the pump outlet and install the pressure gauge (Fig. 3). Run engine at governed speed with fuel supplied by gravity feed. The pressure gauge should show 3-1/4 to 4-1/2 psi, with the gauge 16 in. above the fuel pump. A low pressure reading indicates extreme wear in one part or some wear in all parts, and the pump should be overhauled or replaced. If the reading is above maximum, the diaphragm is probably too tight or the diaphragm spring too strong. This can also be caused *by* fuel seeping under the diaphragm retainer nut and between the diaphragm layers causing a bulge in the diaphragm. Overhaul the pump and replace the defective parts. Low pressure, with little or no pressure leak after pumping stops, indicates a weak or broken spring or worn linkage, and in most cases the pump should be replaced. Figure 4 shows the fuel transfer pump. Refer to it for disassembly/assembly.

8.5 Fuel Pump Removal And Disassembly

(1) Remove the pump inlet and outlet lines. Remove the two capscrews holding the pump to the engine and lift it off.
(2) Notch the pump cover and body with a file so they can be reassembled in the same relative positions and remove the six screws holding them together.
(3) Tap the body with a screwdrive to separate the two parts. Do not pry them apart; this would damage the diaphragm.
(4) Lift out the diaphragm assembly and diaphragm spring.

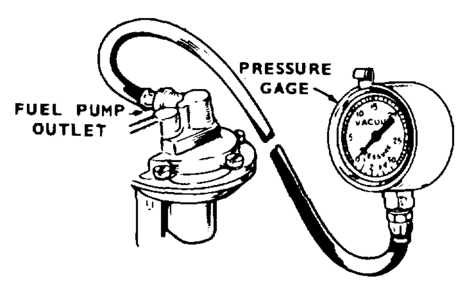



*Fig. 3 Fuel Pressure Gauge*

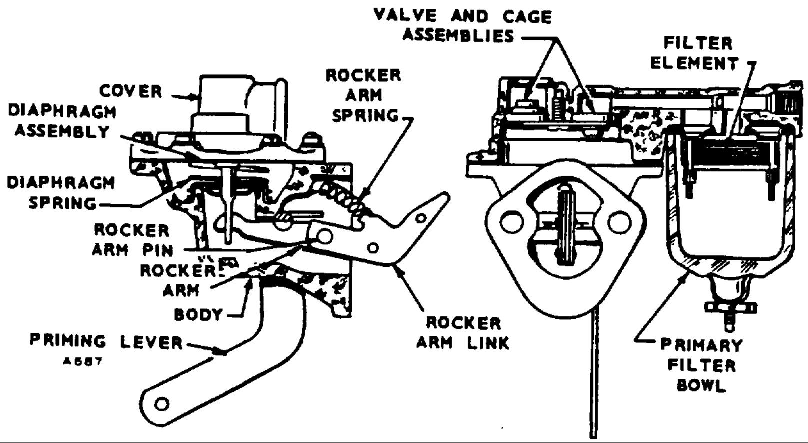



*Fig. 4 Fuel Transfer Pump*

Repair: Transfer pump failure is usually due t a leaking diaphragm, valve or valve gasket. A kit is available for replacement of these parts Because the extent of wear cannot be detected b the eye, replace all parts in the kit. If the diaphragm is broken or leaks fuel, check for diluted crankcase oil and replace.

Occasionally, failure is due to a broken or weak spring or wear in the linkage. In this case, replace the worn parts or install a new pump. Obtain replacement parts other than the repair kit from an original equipment parts distributor.

8.6 Assembly

(1) When installing a new diaphragm, soak it in fuel before assembling. Insert the diaphram spring and soaked diaphragm into the pump body.
(2) Insert the link and rocker arm into the body and hook it over the diaphragm pull rod. Align the rocker arm with the rocker arm pi hole and drive in the pin. The priming lever must be In its lowest position, as shown in Fig. 3, when installing the rocker arm.
(3) Compress the rocker spring and install between the body and rocker *arm.*
(4) Insert the valve cages, gaskets and valve cover plate. Position the inlet valve with spring showing and the outlet valve with spring in the cover recess (if valves were removed.)
(5) Assemble the cover to the body with notch marks lined up. 'Install the screws but do not tighten.
(6) Push the rocker arm in full stroke and hold in this position to flex the diaphragm.

Important: <u>The diaphragm must be flexed or it will 'deliver too much fuel pressure</u>.

(7) Tighten the cover screws alternately and securely, then release the rocker arm.
(8) Install the pump on the engine and repeat the pressure test.

8.7 Nozzle

The injection nozzle is the conventional inward- opening, hydraulically-operated pintle type with adjustable opening pressure. It is factory adjusted to open at 1,900 to 1,950 psi. After several hundred hours of operation the nozzle pressure will decrease to approximately 1750 psi. Do not disassembly the nozzle or adjust nozzle pressure without proper test equipment. A nozzle pressure tester is essential to do this work.

8.8 Operating Principle

Figure 5 shows the parts of the injection nozzle. Nozzle operation is as follows:
(1) High pressure fuel from the injection pump enters the fuel inlet stud (5), flows down the drilled passage in the body of the noz- zle holder (4).
(2) Fuel enters the fuel duct and pressure cham- ber of the nozzle assembly. When the fuel pressure overcomes the pre-set pressure of the adjusting sprinq (6), the pintle is forced upward off its seat and a fine mist of fuel is injected into the pre-combustion chamber.

Note: <u>Do not disturb the pressure adjust- Lng spring (6 ) as it cannot be reset with out proper equipment.</u>

8.9 Trouble Shooting

If the cylinder is misfiring, it is reasonable to suspect that its nozzle is not operating properly.

Inspection: To inspect the nozzle spray pat- tern, remove the nozzle from the cylinder head. Crank the engine, let the nozzle spray into the air and watch the pattern. The spray should be cone shaped, with a solid-appearing center surrounded by clouding fog in which the spray is evenly atomized (Fig. 6). An apparent chattering of the nozzle is normal.

1. PROTECTION COVER
2. PRESSURE ADJUSTING SCREW
3. GASKET
4. NOZZLE HOLDER
5. FUEL INLET STUD
6. PRESSURE ADJUSTING SPRING
7. LOCKNUT
8. SPINDLE ASSEMBLY
9. NOZZLE CAP NUT

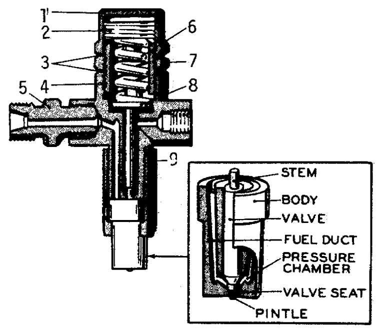



*Fig. 5 Injection Nozzle*

If streamers are visible, the pattern is badly distorted or the nozzle drips before it reaches opening pressure, It is defective, and must be cleaned or replaced.

**WARNING**

Do Not Let The Nozzle Spray Against Your Skin. The Fuel Can Penetrate Flesh And Cause A Serious Infection.

If the spray pattern of the nozzle appears to be satisfactory, other areas should be explored, such as compression pressure, etc.

8.10 Injection Nozzle Testing And Adjustment

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Testing and adjustment can be performed only with a nozzle tester such as shown in Figure 7. Clean procedure is extremely important when disassembling injection equipment. Always rinse in clean fuel before reassembling.

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Opening pressure, leakage and spray pattern can be checked using this tester. If, when checking nozzles, any of the above malfunctions appear (except opening pressure), the nozzle valve and seat can be inspected with a magnifying glass for erosion, scoring, etc. If these conditions are present, and cleaning with solvent does not correct them, a new nozzle tip will be required.

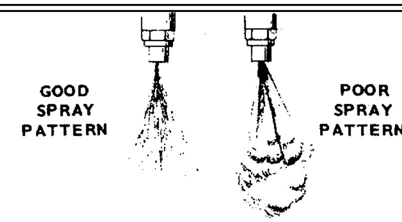



*Fig. 6 Nozzle Spray Pattern*

The opening pressure can then be set and spray pattern checked (See Fig. 6).

The nozzle opening pressure on a used nozzle should be set at 1750 psi. The nozzle tester and nozzle assembly cleaning kit listed in SM18- 10-15.0.

Never use hard or sharp tools, emery paper, grinding powder or abrasives of any kind.

Soak each nozzle in fuel to loosen dirt. Then clean the inside with a small strip of wood soaked in oil and the spray hole with a wood splinter. If necessary, clean the outer surfaces of the nozzle body with a brass brush, but do not attempt to scrape carbon from the nozzle surfaces. This can severely damage the spray hole. Use a soft oil-soaked rag or mutton tallow and felt to clean the nozzle valve.

Adjustment: To adjust the opening pressure, remove the nozzle from the engine. Remove the cap nut over the adjusting screw of nozzle and install the nozzle on a static fuel nozzle testing fixture. Following the tester instructions, adjust the opening pressure to 1,750 psi by turning the adjusting screw (Fig. 8). Turning it clockwise increases the pressure and turning counterclockwise decreases it. Do not try to adjust the pressure without a testing fixture.

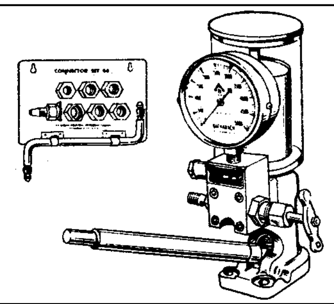


*Fig. 7 Nozzle Tester And Cleaning Kit*

8-11 Disassembly

When removing and disassembling nozzles, separate and label all nozzle components. Never interchange components between nozzles.

(1) Remove nozzle assembly from the engine and remove the fuel inlet and return lines.
(2) Clamp the nozzle holder body in a vise and remove the nozzle cap nut and nozzle.
(3) Install the nozzle cap nut loosely to protect the lapped surface for the holder body.
(4) If necessary to further disassemble the nozzle, reverse the pressure adjusting screw and lift out the spring and spindle assembly.

8.12 Cleaning

**WARNING**

Use Diesel Fuel, Fuel Oil, And Solvents In A Well Ventilated Area, Away From Flame.

Cleanliness is essential in cleaning nozzles. Work only in a clean room, on a clean work bench. Keep a pan of clean diesel fuel handy and have a supply of clean, lintfree wiping rags available.

8.13 Repair

If cleaning will not eliminate a nozzle defect, replace the nozzle or take it to an authorized service station. Do not attempt to replace nozzle parts, except for the nozzle and pintle assembly.

8.14 Assembly

Rinse both the valve and nozzle thoroughly before assembly and coat with oil. The valve must be free in the nozzle. Lift it about 1/3 out of the body. It should slide back to its seat without aid when the assembly is held at a 45° angle. If necessary, work the valve into its body with clean mutton tallow.

(1) Remove all pressure on the nozzle spring by adjusting the pressure adjusting screw.
(2) Clamp the nozzle holder body in a vise.
(3) Set the valve in the body and set the nozzle over it.

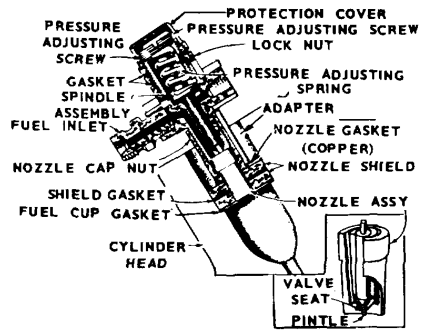



*Fig. 8 Nozzle Assembly*

(4) Install the nozzle cap nut loosely.
(5) Place the centering sleeve over the nozzle (Fig. 9) for initial tightening. Then re- move the centering sleeve to prevent it from binding between nozzle and cap nut and tighten the nozzle cap nut to specified torque.

8.15 Installation

Before installing the *injection nozzle in* the engine, thoroughly clean the mounting recess.

A dirty mounting surface could permit blow-by, causing nozzle failure and a resulting power loss.

(1) Install a new heat shield to head gasket in the cylinder head recess.
(2) Install the heat shield, a new gasket and the nozzle adapter.
(3) Insert the nozzle assembly into the recess, Do not strike the tip against any hard sur- face.
(4) Install the nozzle flange and two capscrews. Tighten the capscrews alternately to avoid cocking the nozzle assembly. Tighten each capscrew to 20-21 ft/lbs.

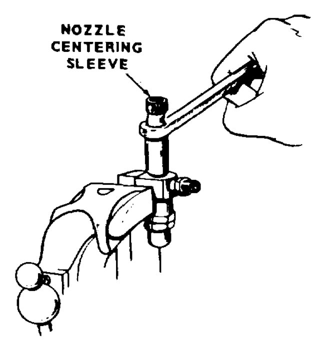



*Fig. 9 Tightening Nozzle Cap Nut*

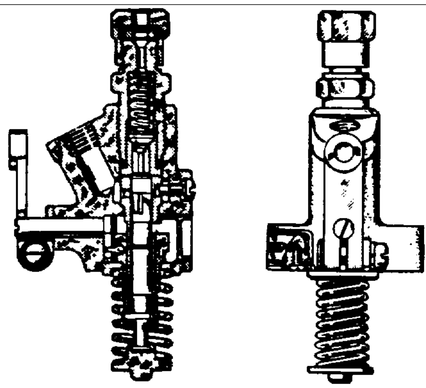


*Fig. 10 Injection Pump*

8.16 Injection Pump

The single-outlet pump is mounted on the left side of the engine crankcase. The camshaft operates the pump plunger, producing pressure to deliver fuel and open the injection nozzle. A control sleeve in the pump meters fuel by controlling the length of time the plunger port is closed in each stroke.

(1) Figure 10 illustrates the injection pump cross section. When the piston is nearing the end of the compression stroke, the plun- ger has moved upward (lower line, Fig. 10) closing the ports trapping fuel and forcing the delivery valve off its seat. The fuel flow is up past the delivery valve and de- livery valve spring to the high pressure line leading to the injection nozzle. Injection continues until the helix passes and spills, which drops the pressure rapid- ly. Delivery valve action is to aid in dropping line pressure and keep fuel from draining out of the line, allowing a void between the injection pump and nozzle which would cause the nozzle not to open on the next firing cycle.

Figure 11 shows the helix on the plunger. The amount of fuel delivered is controlled by rotating the plunger, thus changing the length of its effective pumping stroke. The distance the plunger travels is always the same because the cam lift never varies.

Field repair of the injection pump is discouraged, because of the exceptionally close tolerances between parts, and the specialized equipment necessary for repair. The injection pump is an expensive part of the unit and even a particle of dirt as fine as talcum powder could score its working surfaces. If the rest of the fuel system is in working order and fuel delivery is abnormal, remove the pump for replacement.

Removal: Remove the pump inlet and outlet lines. Remove the two capscrews holding the pump to the engine and lift it off. Don't lose the shims. They time the injection pump to the engine. Cap all openings in the pump and fuel lines to keep dirt out of the fuel system.

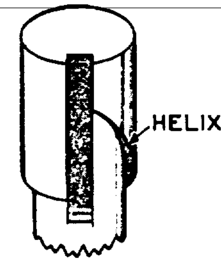



*Fig. 11 Plunger Helix*

Timing: Pump timing procedures determine the correct thickness of shims between pump and engine so port closing occurs at 170 BTC (before top center), and is marked PC on the flywheel. The control sleeve position controls port open- ing and is, in turn, controlled by the throttle setting.

Repair: Most fuel system troubles are not due to a faulty injection pump. Test the rest of the fuel system before condemning the injection pump.

8.17 Pump Timing

The most accurate method of injection pump timing is with a depth micrometer (Method 1). However, if a depth micrometer isn't available, time it by Flowing the pump (Method 2).

Note: The injection pump must be timed on the compression stroke, not the exhaust stroke.

Method 1 Depth Micrometer Method:

(1) Install pump tappet in its recess and position flywheel on the port closing mark (PC) of the compression stroke.
(2) Using a depth micrometer, measure the distance from the pump mounting pad on the crankcase to the tappet center (Fig. 12).
(3) Subtract from the port closing dimension of the pump (1.670 in.) the depth obtained in Step 2. The result is the thickness of shims necessary to correctly time the pump.

Note: Shims thickness may vary from .006 in. to ,052 in,. If it does not fall within these limits, check camshaft and tappet for excess wear or improper assembly.

(4) Select the correct shims for the required thickness.
(5) Install the pump.

Method 2 Flowing The Pump:

(1) Install pump with .006 in. shims between pump and pad.
(2) Loosen the delivery valve holder to relieve pressure on spring (Fig. 13).
(3) Rotate the flywheel to about $15^{\circ}$ before the port closing (PC) point. Blow in the pump inlet and rotate the flywheel slowly clock- wise until air stops coming out of the pump outlet. This is the port closing point.
(4) Measure the distance from the point where

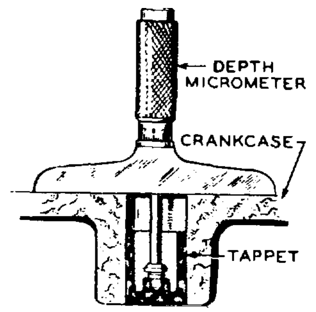



*Fig. 12 Depth Micrometer*

port closing occurs to the PC mark on the flywheel. The Shim Thickness Chart shows the thickness of shims to be added.

(5) Install the pump.

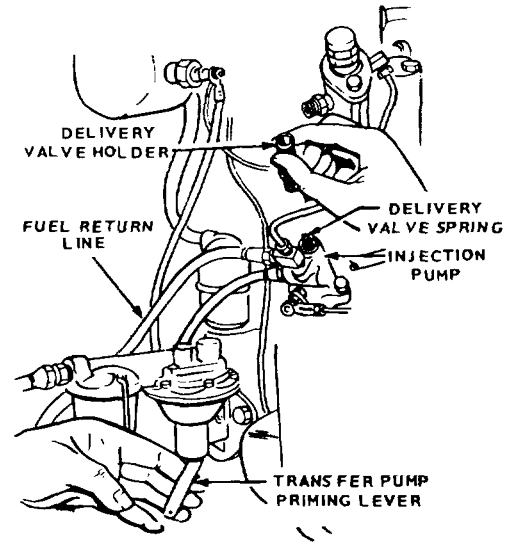
8.18 Installation

Prior to mounting the injection pump to the cylinder block, follow steps 1 through 3.

(1) Slide the shim or shims (Using proper thickness of shims for correct timing) over the pilot until they are flat on the pump flange (Fig. 14).
(2) Dip the Seal ("0" ring) in engine lubricating oil.
(3) Slide the seal over the pilot until tight against the shim or shims.

With shims and seal in place insert the pump into cylinder block mounting pad, and insert mounting screws. Torque the mounting screws (tighten alternately) to 18-21 ft/lbs.

Install the fuel inlet line and governor linkage. Bleed the pump and then install the fuel outlet line.




*Fiq. 13 Loosening Delivery Valve Holder*

**METHOD 2. SHIM THICKNESS CHART**

| Distance Measured Step 4 | Add These Shims | Distance Measured Step 4 | Add. These Shims |
|---|---|---|---|
| .1." | .004 | .7" | .028 |
| .2" | .008 | .8" | .032 |
| .3" | .012 | .9" | .036 |
| .4" | .016 | 1.0" | .040 |
| .5" | .020 | 1.1" | .044 |
| 1.3" | .052 | | |
| .6" | .024 | 1.2" | .048 |

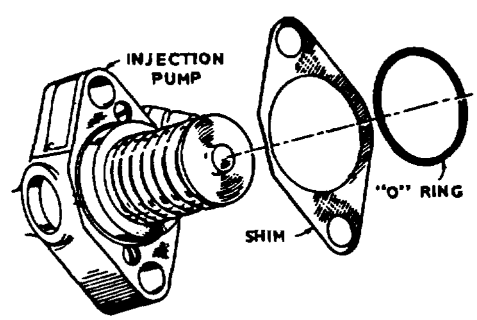



*Fig. 14 Shimming The Pilot*

These engines have pressure lubrication to all working parts. The oil system includes oil in- take cup, gear-type oil pump, by-pass valve, oil pressure gauge, full-flow oil filter, and block passages and drillings to deliver oil throughout the engine (Fig. 1). Oil is held in the oil base, drawn by the pump and delivered through the oil filter. Lines leading to the rocker housing, drillings through the block to crank-shaft bearings and to front camshaft bearing, crankshaft passages to connecting rod bearings, and connecting rod passages to piston pin bushings complete the oil system plumbing.

The crankcase breather is included in this system because it aids oil consumption control.

Oil pressure should be 25 psi or higher when the engine is at normal operating temperature. If pressure drops below 20 psi at governed speed, inspect the oil system for faulty components.

9.1 Maintenance

Periodic oil system maintenance should include changing crankcase oil, cleaning the crankcase breather, cleaning rocker box oil lines, and re- placing the oil filter. Consult the periodic service chart for service periods.

9.2 011 Pump

The oil pump is mounted on the front of the crankcase behind the gear cover and is driven *by* the crankshaft gear.

9.3 Removal

(1) Remove the gear cover and oil base. (See SM18-10-4.0).
(2) Unscrew the intake cup from the pump.
(3) Remove the crankshaft lock ring and gear retaining washer.
(4) Loosen the two capscrews holding the pump and remove pump .

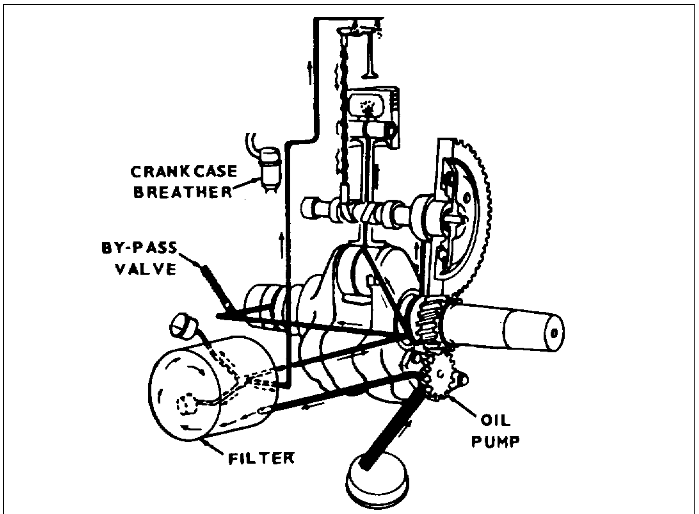



*Fig. 1 Pressure Oil System*

9.4 Repair

Except for the gaskets, component parts of the pump are not individually available. If the pump is defective or excessively worn, replace it. Disassemble the pump *by* removing the two capscrews holding the pump cover to the body. Inspect for excessive wear in gears and shafts. To improve pump performance, adjust the gear end- clearance by changing the gasket thickness be- tween the pump body and cover. Use the thinnest gasket that permits free movement of the pump shaft. Oil. all parts when assembling the pump.

9.5 Installation

Before installing, fill the pump intake and out- let with oil to be sure it is primed. Mount the pump in the engine and adjust for 005" lash between the pump gear and crankshaft gear. Mount the intake cup on the pump so it is parallel to the bottom of the crankcase.

9.6 By-Pass Valve

Located on the outside of the rear bearing plate, the by-pass valve (Fig. 2) controls oil pressure by allowing excess oil to flow directly back to the crankcase. Normally the valve begins to open at about 25 psi. It is not adjustable and normally requires no maintenance.

To determine if high oil pressure is caused by the plunger sticking closed or low oil pressure by the plunger sticking open, clean and inspect the valve.

To remove the valve, unscrew the recessed plug in the rear bearing plate and lift out the spring and plunger assembly. Determine proper valve operation by checking the spring and plun- ger against the values given below:

| | |
|---|---|
| Plunger Diameter | .3365 in. to .3380 in |
| Spring Free Length | .2-5/16 - 1/6 in. |

2.25 lb ± .11 lb at 1-3/16 in. (Compressed)

9.7 Oil Lines

**WARNING**

Warn Personnel In The Immediate Area Before Using Compressed Air For Cleaning. Wear Safety Glasses. Compressed Air, Coming Into Contact With The Human Skin Or Causing Flying Metal Chips Can Cause Injury.

At overhaul time the rocker box oil line should be flushed with fuel and a fine wire used to clean the small holes (Fig. 3). Clean out all other oil lines and drillings with compressed air whenever the engine is disassembled or over- hauled. Reach the oil gauge passage by removing the oil filter mounting plate.

External oil lines, the rocker box oil line and the internal oil line to the rear bearing are replaceable, if damaged.

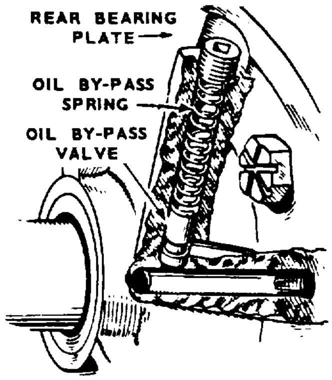



*Fig. 2 By-Pass Valve*

9.8 Gauge

The oil pressure gauge is located on the lower front corner of the cylinder block. Remove it with a wrench and screw in a new gauge if it is faulty. Before replacing, check for clogged oil passage behind the gauge.

9.9 Oil Pressure Switch

The non-adjustable oil pressure switch controls and decompression solenoid in the starting system, allowing it to energize only when the switch closes. This allows the engine to build up speed during starting before compression occurs. The switch closes at about 5 psi under increasing oil pressure.

Note: <u>This switch is not designed to be used as low oil pressure protection. It will not pro- tect the engine against slowly decreasing oil pressure. The engine can be equipped with low oil pressure protection. See Low Oil Pressure Circuit. If the decompression solenoid won't energize, check switch operation by shortinq oil pressure switch terminal to qround when en- gine has built up speed during starting. The solenoid should energize immediately and the engine should start.</u>

If The Engine Starts, Check Immediately FONr Oil If The Engine Starts, Check Immediately For Oil Pressure And Shut The Engine Down If Oil Pressure Doesn't Build Up Within A Few Seconds. In This Case It Is Lack Of Oil Pressure That Is Causing Faulty Operation, Not The Switch.

Centrifugal Switch: This switch is mounted on the gear cover backplate and operates directly off the camshaft gear. Normally open, the switch closes when engine speed builds up to about 900 rpm. This allows engine to build up sufficient oil pressure and unit can be started.

For correct operation maintain the switch gap at .020 in.. See Figure 4.

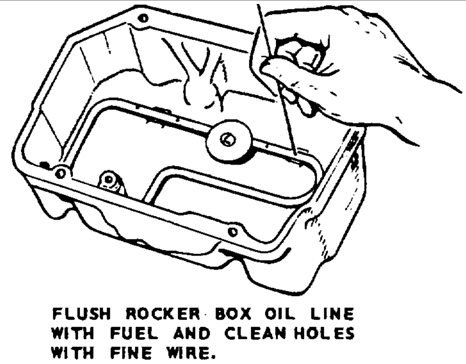



*Fig. 3 Cleaning Rocker Box Oil Line*

Check the contacts for dirt or pitting when adjusting the gap. Clean the contacts with paper, or replace them if badly pitted.

9.10 Disassembly

Figure 5 will aid in disassemblinq the switch.

(1) Disconnect the battery to prevent accidental shorts.
(2) Remove the switch cover, revealing the point set.
(3) Remove the point set assembly by removing the screws holding it to the plate. Pull out the plunger and plunger diaphragm.
(4) Remove the centrifugal switch plate, revealing the cam and weight assembly.
(5) Pull out the cam and weight assembly.

**CAUTION**

Be Careful Not To Lose The Spacer Mounted On The Gear Shaft Behind The Gear.

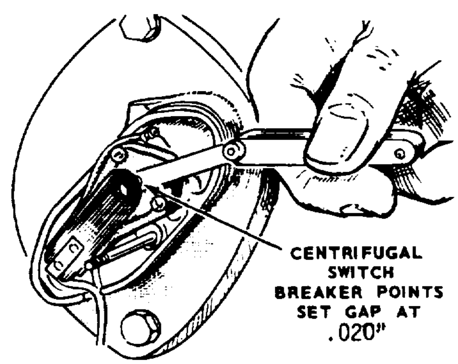



*Fig. 4 Breaker Points*

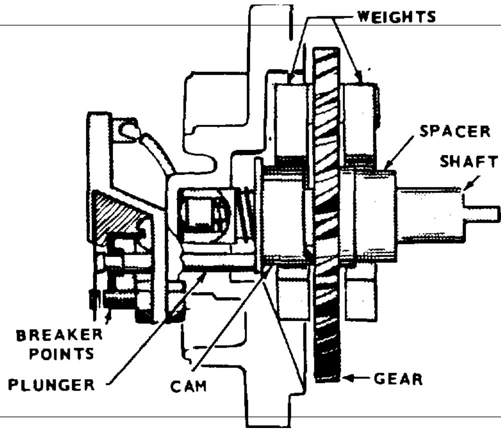



*Fig. 5*
*Centrifugal Switch Assembly 9.11 Repair*

9.11 Repair

Thoroughly clean the gear and cam assembly, the bearing surfaces in the gear case and breaker plate, and oil trickle holes to these bearings. Check the oil spray hole in the gear case to be sure it is open.

Check for wear in the spacer, fibre plunger and the spring loaded shaft plunger. The spacer must be at least .35 in. long. If not, replace it immediately. Push the weights outward; they should move freely. If they don't, or if any part of the assembly is sticking or worn, replace the-cam and weight assembly. If the cam is loose on the gear shaft, replace the assembly.

If the breaker cap cannot be maintained at .020 in., check the fibre plunger and spacer for wear.

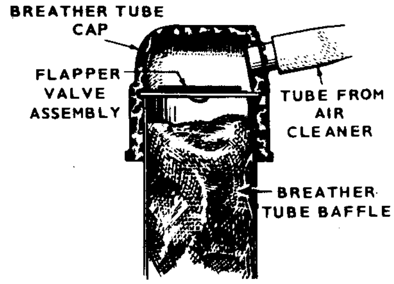
9. 12 Assembly

(1) Install the spacer on the shaft and install the shaft assembly into the gear case. Match it with the cam gear.
(2) Install the spring and plunger into the end of the shaft.
(3) Install the breaker plate.
(4) Install the plunger and diaphragm.
(5) Install the breaker points on the breaker plate and set the gap at .020 in
(6) Install switch cover and reconnect battery.

9.13 Crankcase Breather

The crankcase breather is located in the left rear corner of the crankcase, and maintains a partial vacuum in the crankcase during engine operation. Its purpose is to ventilate the crankcase and control oil loss. It consists of a metal filter packed into the tube on-the crankcase, a rubber cap with flipper valve, and a hose connecting it to the engine air horn.

To disassemble, remove the rubber cap from the crankcase tube and pry the valve out of the cap. Wash the valve in fuel at regular intervals and, if defective, replace it. At the




Remove breather cap. Remove valve from cap. Wash valve in fuel. Dry and install with perforated disc toward engine. If faulty, install new valve.

*Fig. 6*
*Crankcase Breather*

same time, pull the baffle out of the breather tube and clean it. Install the valve with the perforated disk toward the engine. Figure 6 shows the crankcase breather.

Crankcase Breather Valve: This valve requires cleaning only. To clean, remove hose clamp, breather valves (air cooled units only) to release breather cap and valve assembly. Wash the baffle in fuel, and re-install. Figure 3 shows the breather valve assembly.

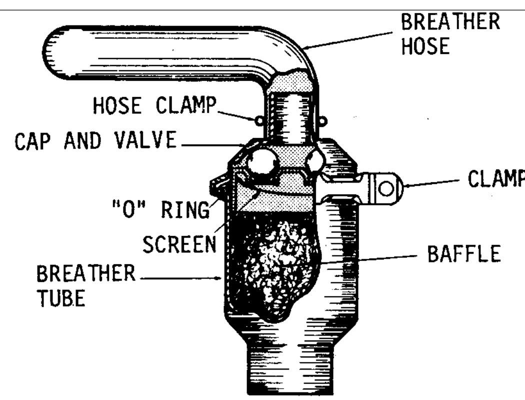



*Fig. 7*
*Breather Valve Assembly*

**Service Manual** SM18-10-10.0 Governor System

The purpose of a governor is to maintain a nearly constant engine speed during changes in power demands. A governor responds to these power demand changes by varying the throttle position.

10.1 Governors

The constant speed governor maintains engine speed up to 1800 rpm. The speed-sensing device is a ball and cup mechanism on the camshaft gear. A yoke, resting on the cup, is connected to the governor arm which, in turn, is connected to the throttle lever. Any change in engine speed is transmitted from the cup to the yoke and on to the throttle.

Tension on the governor spring determines the speed at which the engine is governed.

10.2 Maintenance

Periodically lubricate the governor linkage with lubricating graphite or light non-gumming oil. During servicing, inspect the governor linkage for binding, or excessive slack or wear.

10.3 Adjustment

Adjust engine speed (rpm) by turning governor speed adjusting nut (Fig.1). Turn nut clockwise to increase speed, counterclockwise to decrease speed.

Sensitivity (no load to full load speed drop) is adjusted by turning the sensitivity adjusting ratchet nut accessible through hole inside of blower housing. If speed drops too much when full load is applied, turn the ratchet nut counterclockwise to increase spring tension and compensate for reduced rpm. An over-sensitive adjustment, approaching no speed drop when load is applied, may result in a hunting condition (alternate increase and decrease in speed). Adjust for maximum sensitivity without hunting. The use of a reed-type frequency meter will give the most accurate results. A mechanical tachometer can be used on the generator thru stud, but this is not generally as accurate. It should be possible to adjust for a sensitivity of less than 3 cps, and 2 cps is usually attainable.

After adjusting speed and sensitivity, secure speed stud locknut and replace dot button in blower housing.

The governor cup disassembly and assembly is discussed in SM18-10-4.0.

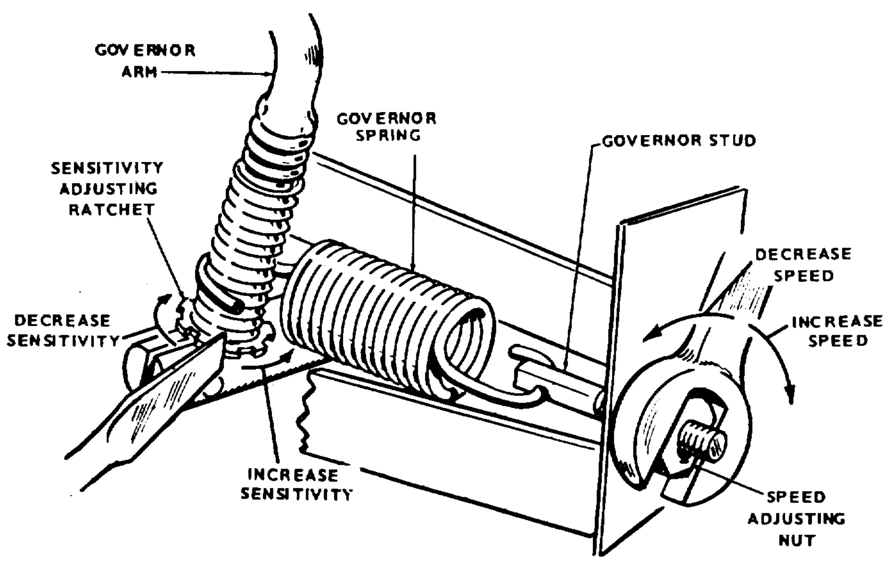



*Fig. 1*
*Governor Adjustments*

The revolving armature generator is used on DJA generating plants. It is a 4-pole, self-excited generator with inherent regulation. The qenerator serves as a starting motor and furnishes dc current to recharge the batteries during operation. This section covers ac plants and serves as a guide for dc battery charging plants.

11.1 Maintenance

Normal maintenance procedures include periodic inspection of the armature, ball bearing, collector rings and commutator, and the brushes, normally every 500 hours.

Brushes: To examine the brushes, remove the end-bell band and cover (Fig. 1). Replace the brushes when they wear down to the Onan name and part number. At this point there is about 5/8 in. of brush remaining. If the brush is not replaced, the slip rings or commutator will be damaged. All brushes must have at least a 50 percent seat. If they don't, sand as illustrated in Fig. 2.

Generator Bearing: The generator bearing is prelubricated for its life and sealed. It requires no servicing.

Commutator and Collector Rings: The commutator must be clean and in good condition. If it is dirty, clean with paper or cloth. Do not use a cleaning solvent because it will destroy the film.

Check the mica between the commutator bars. If it is above the level of the bar, undercut it.

Anti-Flicker Points And Resistor: The antiflicker breaker points are located on the left corner of the engine crankcase. The camshaft opens these points on every power stroke to add a resistor in series with the generator field windings. To adjust the points, crank the engine until the points are at full separation. Adjust the stationary contact to .025 in. gap.
Retiqhten and check the gap. When breaker plunger guide and "0" ring are removed, dip "0" ring in oil before reinstalling. Tighten guide to 25 to 28 foot pounds. Figure 3 shows breaker point adjustment.

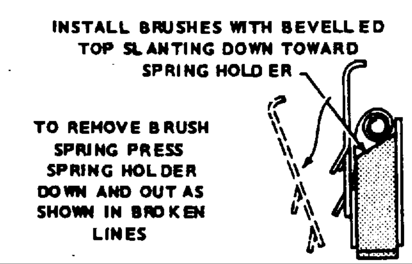



*Fig. 1*
*Brush Installation*

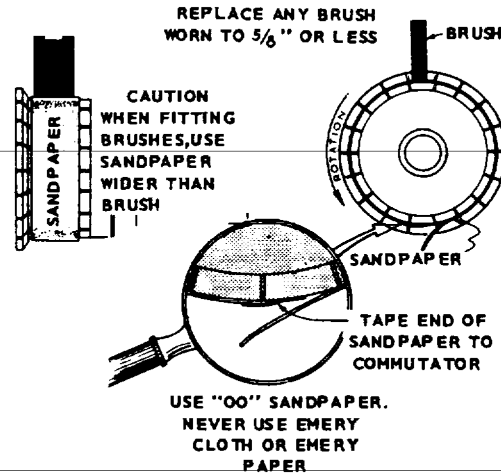



*Fig. 2*
*Seating Brushes*

The adjustable flicker resistor is located on the right side of the control box. If flicker becomes excessive, adjust the resistor by moving its slider. Adjust resistor for minimum flicker with the average load on the plant.

11.2 Testing And Repair

Most of the following tests can be performed without disassembling the generator. Clearly mark all leads disconnected, together with the point taken from.

11.3 Armature Testing

Before testing, remove all brushes from their holders.

(1) Using a test lamp or ohmmeter, check the ac winding for an open circuit between the slip rings. If an open circuit is found, replace the armature.
(2) Test both the slip rings and commutator for grounding to the shaft.
(3) To test the armature for an open circuit in the dc windings, check continuity between all adjacent bars of the commutator. Open circuit problems can be seen because they cause bar burring, arcing and poor cranking. Touch the probes to two adjacent bars and check for continuity. Move each probe over one bar and check again. Continue around the commutator. Any adjacent bars that don't show continuity indicate an open armature winding.
(4) This test can only be performed with the generator disassembled and requires a growler. To test for shorts in the dc winding, place the armature in the growler. Operate the growler and pass a steel strip back and forth over and above the armature windings (Fig. 4). If the strip is magnetically attracted to the armature at any point, a short is indicated. After testing in one position, rotate the armature slight-

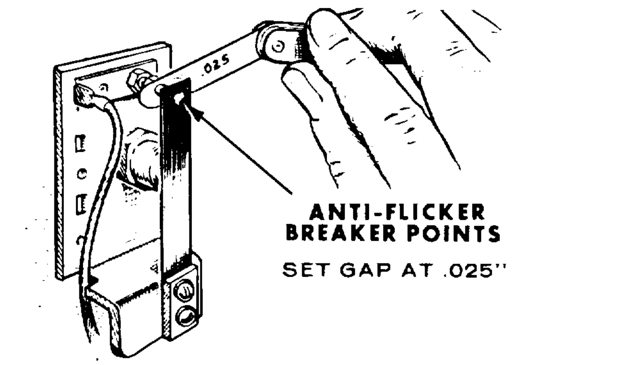



*Fig. 3*
*Setting Breaker Points*

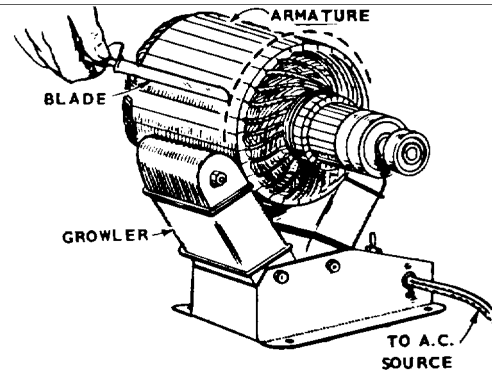



*Fig. 4*
*Testing With Growler 11.5 Commutator Repair*

ly and repeat the test. Do this for one complete revolution.

If the test indicates a short circuit in the dc windings, be sure the Eommutator is clean. Carbon dust, dirt or grease between the bars or slip rings can cause a short.

If the test show that the armature is defective, replace it.

11.4 Field Winding Tests

The following tests can be performed without disassembling the generator, but the field coil leads must all be disconnected from their terminal points; brush rig, control box, and external connections. If a defective coil is found, disassemble the generator and replace the defective coil.

(1) With an ohmmeter or continuity lamp, check for grounding to the generator frame. Touch one prod to the coil terminals and the other to a clean, paint-free part of the frame. If grounding is indicated, separate the windings and check each.
(2) Check the field winding resistance from $F_2$ in the control box to the F + connection on the generator (F + is connected to the positive brushes). Resistance should be 1.46 ohms on standard ac models.

If the winds are warm from running, the resistance will be slightly higher. If the resistance is high, check for an open circuit in one of the parallel windings, step 3, otherwise yo to step 4.

(3) Separate the parallel field windings (F+) and check each for open circuit.
(4) Check for open circuit in the series winding with ohmmeter. Touch probes to lead $S_1$ and connection F +. If there is an open circuit, isolate each coil and check it.
(5) Test for short circuit between the starter windings and the shunt windings. Before doing this, separate all windings at F +.

The commutator bars wear down with use, so eventually the mica between them extends over the tops of the bars and causes sparking and noisy brushes. When the mica on any part of the commutator is touching the brushes, it must be undercut. A suitable undercutting tool can be made from a hacksaw blade (Fig. 5). Be careful not to injure the bars. After undercutting, remove any burrs formed on the bars. Cut the mica to about 1/32" under the bars.

If the commutator is grooved, out-of-round, or otherwise damaged, refinish it. Turn it in a lathe and undercut the mica as described above. Shield the ball bearing during refinishing. Do not use turning centers on shaft because they probably have been damaged and are no longer true centers. Commutator and slip ring run-out should be less than .002 in

Collector Rings: If the collector rings are qrooved, out-of-round or rough, so good brush seating can't be maintained, remove the armature and refinish the rings in a lathe. Shield the ball bearing during refinishing.

Ball Bearing: If the ball bearing becomes noisy, worn or otherwise defective, replace it. Remove the old ball bearing with a gear puller and drive or press a new one into place.

11.6 Brush Rig Alignment

The brush rig must be aligned in the neutral position. If it isn't sparking will occur. Normally the neutral position is identified by a yellow mark extending from the brush rig to the endbell. If the mark is lost, or a new brush rig installed, follow these instructions to find the neutral position:

(1) With the end cover and band removed to allow access to the rig.
(2) Start the unit.
(3) Apply full rated load.
(4) Allow unit to reach full operating temperature.

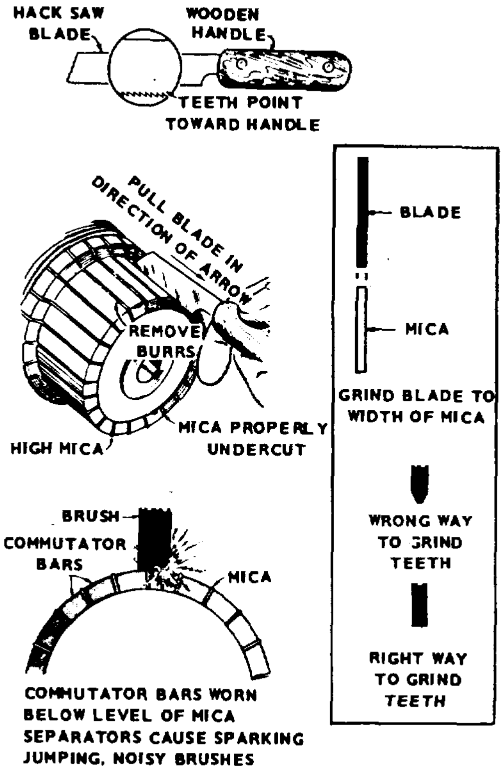



*Fig. 5*
*Undercutting Commutator' Mica*

(5) Inspect brushes; they must be seated across the brush face if we are to have an accurate setting.
(6) Connect a voltmeter across the dc terminals.
(7) Loosen the brush riq mounting screws and rotate the rig to get the highest voltage with full load.
(8) Rotate the rig in one direction until the voltmeter reading starts to decrease. Mark this point. See Fig. 6.
(9) Repeat Step 8 in the other direction.
(10) Half the distance between the two marked points is the neutral position.

Note: If a voltmeter is not available, use the above procedure, but mark the point where arcing begins in each direction and set it at one half the distance. (This procedure is not as accurate as the procedure above.)

11.7 Generator Assembly Procedures

**WARNING|**

Do Not Tighten The Armature Or Rotor Thru Stud Before Mounting The Frame And Bearing Support. If This Procedure Is Not Followed, Misalignment May Occur, Shortening The Life Of The Rear Main And Out-board Bearings. Also, Cranking Torque Requirements Could Be Doubled, Resulting In Damage To The Commutator And dc Brushes On Revolving Armature Units.

11.8 Disassembly

(1) The first step is to remove generator band and end bell cover. Remove all brush sprinqs and lift the brushes from their holders.
(2) Remove generator thru-stud nuts. Hold both the end bell and frame assembly, since they are separate parts, and remove them as one assembly from the adapter. Screwdriver slots in the adapter provide for prying the frame loose. Be careful not to let the frame assembly rest or drag on the armature.
(3) Remove baffle ring from adapter. Turn armature thru-stud nut out to the end of the thru-stud. While pulling the armature outward with one hand, strike a sharp end-wise blow on the nut with a heavy soft-faced hammer to loosen the armature. If the armature does not come loose, strike the armature with a sharp downward blow in the center of the lamination stack with a lead or plastic hammer. Rotate the armature and repeat. Be careful not to hit the collector rings, commutator, bearing or windings.
(4) Upon disassembly, all parts should be wiped clean and visually inspected.

11.9 Assembly

(1) Clean and inspect all mating surfaces. Surfaces should be free of nicks and dirt.
(2) Clean mating area between the generator shaft and the engine crankshaft with a thin film of lubricating oil molycoat, or equal.
(3) Assemble the armature thru stud to the engine crankshaft with required-torque.
(4) Check to see that the key is in the crank-shaft.
(5) Slide armature over the thru stud and onto the crankshaft, being careful not to let the weight of the armature rest on the thru stud.
(6) Install baffle ring, when used.
(7) Assemble generator thru studs to the adapter with required torque.
(8) Install the frame and bearing support. Tighten frame to required torque.
(9) NOW torque down the armature thru-stud nut. Because you have tightened the frame and bearing support before tightening the armature, you have the armature

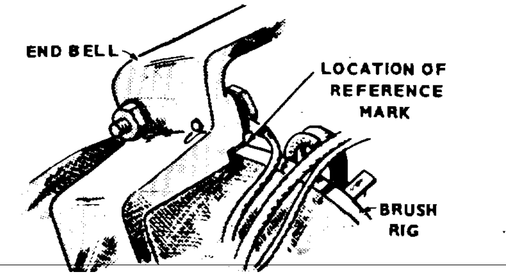



*Fig. 6*
*Brush Rig Alignment*

and frame in alignment.

(10) Tap the bearing support in the horizontal and vertical plane with a lead hammer to relieve stresses on the components and then recheck the torque.

(11) Reconnect the decompression solenoid and other leads to the engine.

(12) Reinstall the battery cables.

(13) Align the brush rig.

12.1 Maintenance

Reliable operation of the electric plant depends heavily upon the performance of the controls, as they are the "brains" of the plant, and must function properly to give dependable service. Connections should be periodically checked for tightness, as a loose connection can cause erratic performance.

The plant control system functions to control starting, stopping and battery recharging. It also provides emergency automatic stopping and engine pre-heating. The control system and control system defects can best be analyzed with the aid of the proper wiring diagram.

The generator is used as a starting motor and a decompression solenoid on the engine rocker box is used to control the engine. The control system includes the starting circuit, a battery-charging circuit with a reverse current relay, a pre-heating circuit, and the optional high air temperature cutoff. Figure 1 shows the starting cycle in pictorial form.

The oil pressure switch on this model is used as part of the starting system.

If any component of the control circuit fails, replace it. Normally, it isn't worthwhile to attempt repairs on individual relays, etc.

12.2 Control Components

Starting and Stopping System: The starting system includes the start solenoid, decompression solenoid and oil pressure switch: To stop the engine, the switch grounds the decompression solenoid relay, releasing the decompression solenoid which holds the exhaust valve open.

Decompression Solenoid: Mounted on the engine rocker box, the decompression solenoid controls a lever that holds the exhaust valve open. The solenoid contains 2 windings. Both are used to pull the plunger into the solenoid body. When the plunger hits bottom, it opens a set of contacts, de-energizing one coil while the other coil holds it in the energized position.

To test the solenoid operation, check plunger operation and current draw with 12-volt input to the solenoid. Current draw should be about 1 amp with the plunger fully in the solenoid body.

Decompression Solenoid Relay: This single-pole normally-open relay controls the decompression solenoid. It energizes during the engine starting cycle when the oil pressure switch closes, and is de-energized by pushing the stop switch. This is not a 12-volt relay, and is wired in
series with a 15-ohm resistor.

To test the relay, check the contact operation with a lamp or ohmmeter as indicator and check the coil continuity. The relay should energize with 5 volts input.

Oil Pressure Switch: The non-adjustable oil pressure switch controls the decompression solenoid, allowing it to energize only when the switch closes. This allows the engine to build up speed during starting before compression occurs. The switch closes at about 5 psi under increasing oil pressure.

Note: This switch is not designed to be used as low oil pressure protection. It will not protect the engine against slowly decreasing oil pressure.

To check oil pressure switch operation, if the decompression solenoid won't energize, short to ground when engine has built up speed during starting. The solenoid should energize immediately and the engine should start.

**CAUTION**
If The Engine Starts, Check Immediately For Oil Pressure And Shut The Engine Down If Oil Pressure Doesn't Build Up Within A Few Seconds. In This Case It Is Lack Of Oil Pressure That Is Causing Faulty Operation, Not The Switch.

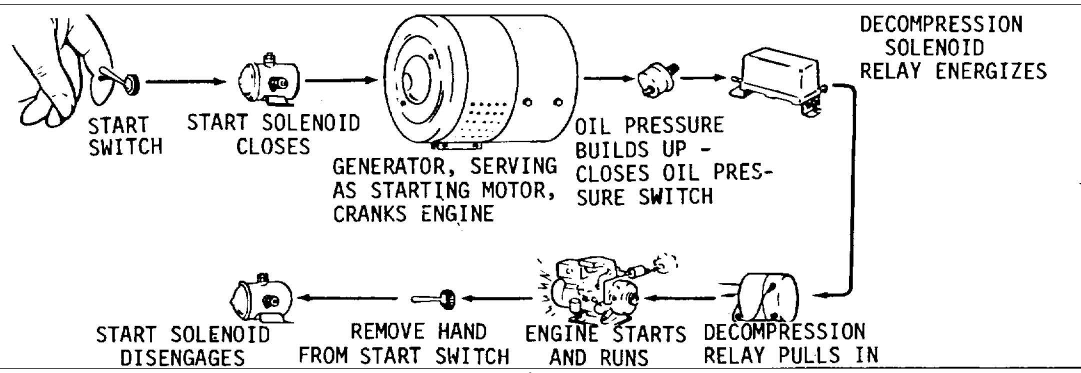



*Fig. 1*
*DJA Starting Cycle*

Starting Solenoid: The starting solenoid controls the heavy currents required by the exciter starting motor. Test this solenoid for welded contacts across the main terminal or an open circuit in the coil.

Improper Use: If the start switch is released when an engine slows at the peak of the first compression stroke, the very large current passing through the solenoid may burn or weld the contacts. Be sure the engine is revolving when the START switch is released. Momentary flips of the START switch in an attempt to "jar" the engine over compression will only result in damage to the starting solenoid.

Battery Charging Circuit: Adjust the charge rate between 2 to 5 amps by moving the slider on the charge resistor.

The generator dc winding supplies current for the battery charging circuit. The current flows through the charge rate resistor, reverse current relay and charge ammeter to the battery.

Reverse Current Relay: This relay allows current flow only from the generator to the battery, and opens when current attempts to flow in the other direction. To test the relay, isolate it by removing the generator connection (GEN). Check for continuity between the battery and generator terminals. Continuity here indicate that the relay contacts are welded together. Measure the resistance from the generator terminal to ground. This should be approximately 112 ohms.

Preheating Circuit: This circuit consists of a manifold heater to heat the engine intake air in the intake manifold and a glow plug to heat the pre-combustion chamber. Used for engine starting, the manifold heater and glow plug are wired in parallel and controlled by a pre-heat switch.

Check the heater by removing its lead, operating the preheat switch, and touching the lead to its terminal. If it sparks, there is continuity and the heater is working. If any components of this circuit fail, replace them. Do not attempt repairs on individual components. If there is still a question, check the component for heating.

| | 3DJA |
|---|---|
| Nominal dimension of plant (inches) | |
| Height | 26-3/16 |
| Width | 19-7/16 |
| ***Length | 28-11/16 |
| Approximate weight (pounds) | 350 |
| Number cylinders (vertical inline) | 1 |
| Displacement (cubic inch) | 30 |
| Cylinder bore (inches) | 3-1/4 |
| Piston stroke (inches) | 3-5/8 |
| BHP at 1800 rpm | 5.7 |
| RPM (60-cycle) | 1800 |
| Compression ratio | 19:1 |
| Governor (internal flyball type - externally adjustable) | Yes |
| Governor Regulation % | 5 |
| Battery Voltage (ac Plant) | 12-V |
| SAE Group 1H, 6 volt | Two |
| *Amp/Hr. SAE 20 hour | 105 (minimum) |
| Starting by exciter-cranking generator windings | Yes |
| Battery charge rate, amperes | 2-5 |
| **Oil capacity in U.S. quarts (refill) | 2.5 qts. |
| Ventilation required (cfm at 1800 rpm) | |
| Engine (pressure cooling) | 440 |
| Generator | 75 |
| Combustion | 16 |
| Output rated at unity power factor load | 1 - phase |
| Rating (output in watts) | |
| 60 - cycle ac service | 3000 |
| AC voltage regulation ± % | 10 |
| AC frequency regulation in % | 5 |
| Revolving armature type generator | Yes |
| Rotating type exciter | Yes |

*Mobile or outdoor operation during ambient temperatures below O' F, use 120 amp/hr rating.
**Plus 1/2 quart for new filter.
***2 - wire models (length of 3 - wire and 4- wire models is 30-5/16 inches)

## 13.1 Table of Dimensions, Clearances

All values in inches unless otherwise specified.

| | | | |
|---|---|---|---|
| CAMSHAFT | | Ring Width | |
| Bearing journal diameter, front | 2.500-2.505 | Top | .0925-.0935 |
| Bearing journal diameter, rear | 1.1875-1.1880 | 2nd | .0925-.0935 |
| Bearing clearance limit | .0012-.0037 | 3rd | .0925-.0935 |
| End play, camshaft | .007-.039 | Ring end gap | .010-.020 |
| Cam tappet hole diameter | .8755-.8765 | | |
| Cam tappet diameter | .8725-.8730 | VALVE, INTAKE (Chrome-Cobalt Alloy Facing) | |
| | | Stem diameter | .3405-.3410 |
| CONNECTING RODS | | Clearance in guide | .0015-.0030 |
| Large bearing bore diameter | | Valve clearance | |
| (w/o bearing) | 2.1871-2.1876 | Seat angle | 42° |
| (w/o bushing) | 1.044-1.045 | VALVE, EXHAUST (Chrome-Cobalt Alloy Facing) | |
| Small bushing bore diameter | | | |
| to small bushing bore | 5.998-6.002 | Stem diameter | .3405-.3415 |
| Distance, center of large bearing bore | | | |
| Piston pin bushing inside diameter | Clearance in guide | .0030-.0050 | |
| (bushing reamed) | .9903-.9906 | Seat angle | 45° |
| Valve clearance | | | .008 |
| Cylinder bore | 3-1/4 | VALVE GUIDE | |
| Outside diameter | .4690-.4695 | | |
| Cylinder diameter limits | 3.2495-3.2505 | Length | 1-25/32 |
| Cylinder head bore diameter | | .467-.468 | |
| CRANKSHAFT | Inside diameter (after reaming) | | |
| Main bearing journal diameter | 2.2437-2.2445 | Exhaust | .3445-.3455 |
| Connecting rod journal diameter | 2.0597-2.0605 | Intake | .3425-.3435 |
| Connecting rod bearing clearance | .001-.0033 | | |
| End Play, crankshaft | .010-.015 | VALVE SEATS (Chrome-Cobalt Alloy) | |
| Valve seat bore | | | |
| PISTON | | Diameter | 1.361-1.362 |
| Piston clearance to cylinder wall* | .0015-.0075 | Depth (from cylinder head face) | .433-.439 |
| Ring groove width, top | .097- 098 | Seat outside diameter | 1.364-1.365 |
| Ring groove width, 2ntop | .09765-.09875 | Seat width | 3/64-1/16 |
| Ring groove width, 3rd | .0965- 0975 | Available oversizes | .002,.005,.010,.025 |
| PISTON PIN | | VALVE SPRINGS | |
| Length | 2.753-2.738 | Free length | 1-7/8 |
| PISTON RINGS | | | |
| Ring Type | | | |
| Top | Compression | | |
| 2nd | Compression | | |
| 3rd | Compression | | |
| 4th | Oil Control | | |

* Clearance measured 90 from axis of piston pin and immediately below the oil ring groove.

13.2 Assembly Torque

The assembly torques given here will assure proper tightness without danger of stripping threads. If a torque wrench isn't available, estimate the degree of tightness necessary for the stud, or screw. Be careful not to strip threads. Use reasonable force only, with a wrench of normal length.

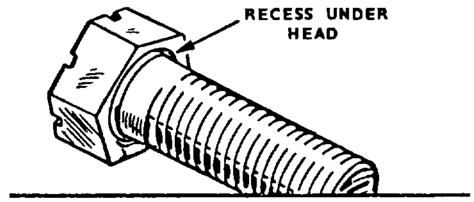


*Fig. 1*
*Place Bolts*

Specially designed place bolts (Fig. 1) don't require a lockwasher or gasket. Don't attempt to use a lockwasher with these bolts; it will defeat their purpose. Check all studs, nuts and screws often and tighten as needed to keep them from working loose.

TORQUE SPECIFICATIONS (Foot Pounds)

| | |
|---|---|
| Connecting Rod Bolt | 27-29 |
| Cover-Rocker Box | 8-10 |
| Cylinder Head Bolt | 44-46 |
| Exhaust Manifold Nuts | 13-15* |
| Flywheel Mounting Screw | 65-70 |
| Fuel Pump Mounting Screws | 15-20 |
| Gear Case Cover | 15-20 |
| Glow Plug | 10-15 |
| Injection Nozzle Mounting Screws | 20-21 |
| Injection Pump Mounting Screws | 18-21 |
| Intake Manifold | 13-15 |
| Oil Base Mounting Screws | 32-38 |
| Oil Filter | Hand Tight Plus 1/4 to 1/2 turn |
| Oil Pump Mounting Screws | 15-20 |
| Rear Bearing Plate | 40-45 |
| Rocker Arm Nut | 4-10** |
| Thru-Rotor-Stud Nut | 30-40 |
| Rocker Arm Stud | 35-40 |
| Flicker Plunger Guide | 25-28 |

* Exhaust nuts must be tightened evenly.
** This torque is due to friction between the threads only and locks the nuts in place. Use the rocker arm nut to adjust valve lash.

## 14.0 Trouble-Shooting Chart

### 14.1 Starting

| Possible Cause | Remedy |
|---|---|
| **Engine Will Not Turn Over** | |
| Defective switch. | Replace. |
| Internal seizure | Turn engine over by hand, check, disassemble and repair. |
| Loose connections, | Tighten connections. |
| Engine oil too heavy for low temperature. | Change oil. |
| Battery discharged. | Recharge. |
| **Engine Cranks Too Stiffly** | |
| Oil in crankcase too heavy for low tempera-true. | Check oil specifications, change oil. |
| Load connected. | Disconnect load. |
| Defective decompres-sion release. | Check and adjust. |
| **Engine Turns But Will Not Start** | |
| Defective glow plug | Repair or replace. or preheater. |
| Defective fuel sys-tem. | See Fuel System Section. |
| Air in fuel system. | Bleed fuel system. |
| Faulty injection caused by dirty fuel or clogged fuel fil-ter. | Replace with clean fuel, clean primary fuel fil-ter and replace secondary fuel filter. |
| Poor compression. | See poor compression section . |
| Wrong timing. | Correct timing. |
| Poor quality fuel. | Drain, fill with fresh fuel. |

| Possible Cause | Remedy |
|---|---|
| **Engine Hard To Start** | |
| Restricted air intake. | Clean air cleaner. |
| Poor fuel. | Check fuel specification, change if necessary. change e if necessary. |
| Incorrect timing. | Retime. |
| Worn or damaged fuel transfer pump. | Replace or |
| Air leak in fuel lines | Tighten all connections, check for defects in lines. |
| Clogged fuel lines. | Clean fuel lines. |
| secondary fuel fil-ter. | replace secondary filter cartridge. |
| Fuel tank too far below engine. | Fuel tank must be no more than 6 ft. below engine |
| **Defective Battery** | |
| Hardened plates (sulfa-tion) due to low charge tion) due to low charge after long period. | |
| Shorted c, | Replace battery, check new battery charge con-dition at frequent in tervals. |
| Loss of active ma-terial. | |
| Broken terminals. | |
| **Battery Discharged** | |
| Defective starting cir-cuit | Check starter circuit. |
| Excessive use of start-er. | Adjust starting proce-dures, check for causes |
| Poor compression. | See poor compression of hard starting. |
| Dirt and electrolyte on top of battery causing constant drain. | Clean battery up. |

**Service Manual** SM18-l0-14.0 Trouble-Shooting Chart

14.2 Operation

| Engine Misfires At All Loads | |
|---|---|
| Poor compression. | See Poor Compression. |
| Broken valve spring. | Replace. |
| Defective or dirty nozzle. | Clean nozzle or replace. Clean fuel system. |

| Engine Misfires At Light Load | |
|---|---|
| Faulty injection. | Inspect fuel system. |
| Poor compression | See Poor Compression. |
| Poor fuel. | Replace with correct fuel. |

| Engine Misfires At Heavy Load | |
|---|---|
| Faulty injection. | Inspect fuel system |
| Dirty air cleaner. | Clean. |
| Dirty fuel filter. | Clean primary filter, replace secondary filter cartridge. |

| Low Engine Power | |
|---|---|
| Restricted air intake. | Clean air cleaner. |
| High exhaust back pfPs sure. | Inspect exhaust line for restrictions. |
| Thin air at high altitude or in hot weather. | Normal under these conditions. |
| Poor fuel. | Change to correct fuel. |
| Fuel line leaks. | Inspect fuel system. |
| Poor compression. | See Poor Compression. |
| Incorrect timing. | Adjust injecting timing. |

Defective Nozzle

| (Usually Indicated by Defective Spray Pattern) | |
|---|---|
| Dirt in nozzle. | Clean nozzle. |
| Possible Cause | Remedy |
| Externally carboned nozzle. | Clean outside surface. |
| Worn nozzle or valve. | Replace or repair injection nozzle. |
| Incorrect nozzle opening pressure. | Using proper equipment, adjust nozzle pressure. |
| Dribble below opening pressure. replace nozzle. | Clean nozzle and recheck. If it still dribbles, |

| Fuel Knock | |
|---|---|
| Injection nozzle sticking. | Clean nozzle. |
| Injection nozzle spring broken. | Replace complete nozzle. |
| Air leaks in fuel lines. | Repair or replace. |
| Poor fuel. | Change to proper fuel. |
| Water in fuel. | Change fuel. |
| Sticking nozzle Valve (usually caused from fuels. | Clean nozzle - check filters and fuel quality. by dirt or corrosion |

14.3 Oil System

| Diluted Oil | |
|---|---|
| Leaky fuel transfer pump diaphragm | Rebuild or replace pump. |
| Faulty cylinder oil control. | Inspect rings and cylinder walls. |

**Service Manual** SM18-10-14.0 Trouble-Shooting Chart

| Possible Cause | Remedy |
|---|---|
| **Crankcase Sludge** | |
| Dirty oil filter. | Replace oil filter, adjust oil filter service periods. |
| Run for long idle periods. | Correct running procedures. |
| Sticking compression ring. | Replace. |
| **Low Oil Pressure** | |
| Worn bearings. | Rebuild engine. |
| Oil by-pass stuck open. | Clean by-pass valve. |
| Oil supply low. | Add oil.Check cause of oil consumption. |
| Worn oil pump. | Replace pump. |
| Defective oil gauge. | Replace gauge. |
| **High Oil Pressure** | |
| Oil by-pass stuck closed. | Clean. |
| Oil too heavy. | Replace with lighter oil. |
| Clogged oil passages. | Clean all lines and oil passages. |
| **Excessive Oil Consumption, Light Blue Smoky Exhaust** | |
| Worn or sticking piston rings. | Check compression. Clean or replace rings. |
| Defective breather valve. | Clean or replace. |
| Oil too light or diluted. | Replace with proper grade of oil. If diluted, check for cause. |
| Engine overheating. | See Cooling System. |
| **Excessive Oil Consumption, No Change in Exhaust** | |
| Leaking oil seals. | Inspect crankshaft front and rear oil seals. |
| Leaky oil base gasket. | Check for leaks around gasket. Replace if necessary. |
| Defective breather valve. | Clean the valve or replace it. |

14.4 Governor

| Possible Cause | Remedy |
|---|---|
| **Engine Races (Stop Engine Immediately By Pushing Throttle Lever)** | |
| Governor incorrectly adjusted. | See Governor System. |
| Linkage binding. | Clean or replace linkage. |
| **Engine Speed Too low** | |
| Governor incorrectly adjusted. | Adjust for proper speed. |
| Low engine power (will not reach governed speed). | Check for other causes. |
| **Hunting Condition** | |
| Governor spring sensitivity too great. | Adjust sensitivity. |
| **Poor Sensitivity** | |
| Excessive wear in linkage. | Replace governor linkage. |
| **Governor Acts Slowly** | |
| Binding in linkage. | Clean and lubricate linkage. |
| **No Governor Control** | |
| Linkage disconnected. | Reconnect linkage. |

14.5 Fuel System

| Possible Cause | Remedy |
|---|---|
| Black Smoky Exhaust, Excessive Fuel Consumption | great. |
| The brown or black color in the exhaust is minute solid particles of pure carbon. A darker exhaust indicates a higher carbon content. The exhaust color may vary from a very light gray haze to a brown or black, which indicates incomplete combustion. Since combustion is never absolutely complete, the exhaust gases will never be invisible, but an increase may indicate trouble, especially if there is no apparent change in engine condition. | |
| Engine overloaded (a normal condition under over-load). | Reduce load |
| Poor compression. | See Poor Compression. |
| Poor grade or dirty | Replace fuel. |
| Poor grade or fuel,. | |
| Dirty air cleaner, | Clean. |
| Faulty injection timing. | Check timing. |
| Faulty injection pump or nozzle. | Check and rebuild, or replace as necessary. |

| Excessive Fuel Consumption | |
|---|---|
| Engine overloaded. | Reduce load |
| Poor compression. | See Poor Compression. |
| Defective injection pump or nozzles. | Repair or replace. |

14.6 Miscellaneous

| Dull Metallic Thud, If Not Bad, May Disappear After Few Minutes Of Operation | |
|---|---|
| Loose crankcase bearing. | Replace bearing. |

| Sharp, Metallic Thud, Especially When Cold Engine First Started | |
|---|---|
| Low oil supply, | Add oil. |
| Oil badly diluted | Replace oil. |

| Tapping Sound, Clacking, Light Clicking | |
|---|---|
| Valve clearance too | Check valve clearance. |
| Broken valve spring. | Replace valve spring. |

| Metallic Knock Under Load Conditions And When Stopping | |
|---|---|
| Worn connecting rod bearings. | Replace bearings. |

| Hollow Clicking Sound With Engine Cool And Underload | |
|---|---|
| Loose piston. | Check piston |

| Light Pounding Knock | |
|---|---|
| Loose connecting rod bearing. | Replace bearings. |
| Low oil supply | Add oil - check for cause. |
| Oil badly diluted. | Replace oil - check |

| Poor Compression | |
|---|---|
| Loose cylinder head. | Tighten. |
| Sticking rings or worn rings. | Replace rings, check cylinder condition. |
| Worn cylinder wall and piston. | Refinish cylinder and replace piston. |
| Leaky head gasket. | Replace head gasket. |
| Valves sticking. | See Sticking Valves. |
| | check valve condi- |
| Broken valve spring. | Replace spring, tion. |
| Leaky nozzle gasket | Replace gasket. |
| Leaky valves. | Regrind valves. |
| Burned valves and seats. | Regrind valves and seats. Replace if necessary. |
| In sufficient valve clearance. | Adjust clearance. |

| Possible Cause | Remedy |
|---|---|
| **Sticking Valves** | |
| Incorrect valve clearance. | Adjust valve clearance. |
| Weak or broken springs. | Replace springs. |
| Dirty, scored or gummy guides. | Clean or replace valves and guides. |
| Incorrect clearance between valve guidbe | Correct clearance. |

| | |
|---|---|
| **Valve Burning** | |
| Close valve clearance. | Re-adjust valve clearance. |
| Weak springs. | Replace springs. |
| High temperatures, causing valve stretch. | Check for engine over-heating. |
| Valve seat or face off center. | Reqrind seat, replace valve. |
| Loose valve seat inserts. | Replace seats. Rebore and use over size if necessary. |
| Coked or gummed oil on stem. | Clean or replace valve. |

| | |
|---|---|
| **Valve Breakage** | |
| Weak valve springs. | Replace weak springs. |
| Excessively strong valve springs. | Replace springs. |
| Worn guides which set up thrust action. | Replace guides. |
| Excessive valve clearance. | Adjust valve clearance. |

| | |
|---|---|
| **Worn Connecting Rod, Busings And Bearings** | |
| Plant run with low oil | Add oil, check cause of oil loss. |
| Badly diluted, dirty or wrong oil. | Change oil. cause of dilution. If dirty, check service periods. |
| Clogged oil passages. | Clean oil passages and drillings. |

| | |
|---|---|
| **Piston, Cylinder And Ring Wear** | |
| Operated with dirty air cleaner, | Change air cleaner service periods. |
| Air leak between the air cleaner and engine. | Repair leaks. |
| Faulty cylinder oil control. | Check rings. |
| Engine run on low or dirty oil. | Add or replace oil. Check cause of loss. If dirty, adjust service periods. |
| Overheating. | See Cooling System. |

14.7 Generator

| | |
|---|---|
| **Voltage Low At Far End Of Line, But** | |
| Too small line wire for load distance. | Install larger or extra wires or reduce load. |

| | |
|---|---|
| **Electric Motor Runs Too Slowly And Over-Heats At Far End Of Line But OK If Used Near Power Unit** | |
| Too small line wire for load distance. | Install larger or extra wires or re- |

| | |
|---|---|
| **Voltage Unsteady, But Engine Not Misfiring** | |
| | correct speed. |
| Loose connections. | Tighten connections. |

| | |
|---|---|
| **Generator Overheating** | |
| (Approximately 160° F higher than ambient) | |
| Overloaded. | Reduce load. |

| | |
|---|---|
| **Voltage Drops Under Heavy Load** | |
| Engine lacks power. | See remedies of Engine Misfires At Heavy Load. Inspect. repair as necessary. |
| Check Faulty injection. | Clean the fuel system. Clean, adjust or replace parts |
| Dirty air cleaner. | Clean. |
| Restricted exhaust line. | Clean or increase size |

**Service Manual** SM18-10-14.0 Trouble-Shooting Chart

| Possible Cause | Remedy |
|---|---|
| **Engine Runs; Voltage Won't Build Up** | |
| Poor brush contact. | Be sure brushes seat their holders, are not worn too short, and have good spring tension. |
| Open circuit, short circuit or ground in generator. | Replace necessary parts. |
| Residual magnetism lost. | Remagnetize the field. |

| Possible Cause | Remedy |
|---|---|
| **Noisy And Excessive Arcing Of Brushes** | |
| Rough commutator. | Turn down. Undercut mica between bars. |
| Dirty coimmutator. | Clean. |
| Brushes not seating properly. | See Poor Brush Contact. |
| Brush rig out of position. | Line up properly. |

| Possible Cause | Remedy |
|---|---|
| **Unsteady Voltage With Steady- Running Engine** | |
| Speed too low. | Adjust governor to correct speed. |
| Poor brush contact. | See that brushes seat well on commutator, are free in holders, are not worn too short and have good spring tension. |
| Loose connections. | Tighten connections. |
| Fluctuating load. | Correct any abnormal load conditions causing trouble. |

| Possible Cause | Remedy |
|---|---|
| **Flickering Lights** | |
| Defective anti-flicker breaker points. | Check point gap and inspect points. |
| Anti-flicker resistor out of adjustment. | Adjust slider for minimum flicker at average load. |

15.0 Special Tools

These tools are available from ONAN to aid service and repair work.

| | |
|---|---|
| Crankshaft Gear Pulling Ring | 420A248 |
| Diesel Nozzle Tester | 420P184 |
| Diesel Pintle, Nozzle Cleaning Tool Set (Includes injection nozzle centering tool) | 420P208 |
| Driver, Front Camshaft Bearing | 42OA252 |
| Driver, Rear Camshaft Bearing | 420B250 |
| Driver, Rear Camshaft Bearing (JA) | 420B264 |
| Driver, Main Bearing Front and Rear | 420B269 |
| Driver, Valve Seat | 420B270 |
| Oil Seal Guide and Drive | 420B250 |
| Valve Seat Remover | 420B272 |
| Replacement Blades for 420B272 | 420B274 |
| Wrench, Oil Filter - (For Purolator full flow filter) | 420B268 |

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# THE METRIC SYSTEM AND EQUIVALENTS

### LINEAR MEASURE

1 Centimeter = 10 Millimeters = 0.01 Meters = 0.3937 Inches
1 Meter = 100 Centimeters = 1.000 Millimeters = 39.37 Inches
1 Kilometer = 1.000 Meters = 0.621 Miles

### SQUARE MEASURE

1 Sq Centimeter = 100 Sq Millimeters = 0.155 Sq Inches
1 Sq Meter = 10.000 Sq Centimeters = 10.76 Sq Feet
1 Sq Kilometer = 1.000.000 Sq Meters = 0.386 Sq Miles

### CUBIC MEASURE

1 Cu Centimeter = 1.000 Cu Millimeters = 0.06 Cu Inches
1 Cu Meter = 1.000.000 Cu Centimeters = 35.31 Cu Feet

### LIQUID MEASURE

1 Milliliter = 0.001 Liters = 0.0338 Fluid Ounces
1 Liter = 1.000 Milliliters = 33.82 Fluid Ounces

### TEMPERATURE

5/9 (°F -32) = °C
212° Fahrenheit is equivalent to 100° Celsius
90° Fahrenheit is equivalent to 32.2° Celsius
32° Fahrenheit is equivalent to 0° Celsius
9/5 C° +32 = F°

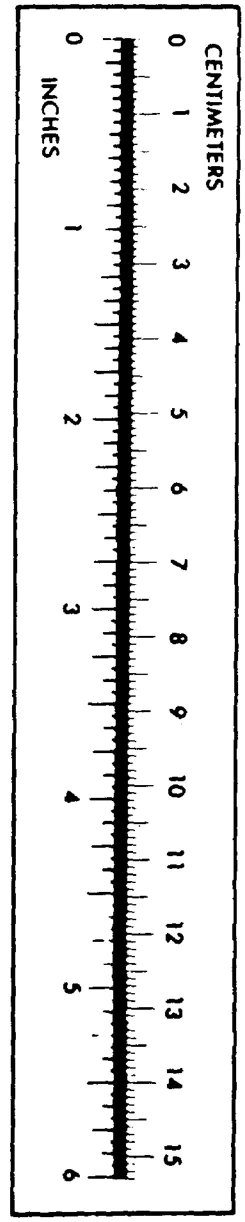
### WEIGHTS

1 Gram = 0.001 Kilograms = 1.000 Milligrams = 0.035 Ounces
1 Kilogram = 1.000 Grams = 2.2 Lb.
1 Metric Ton = 1.000 Kilograms = 1 Megagram = 1.1 Short Tons

## APPROXIMATE CONVERSION FACTORS

| TO CHANGE | TO | MULTIPLY BY |
|---|---|---|
| Inches | Centimeters | 2.540 |
| Feet | Meters | 0.305 |
| Yards | Meters | 0.914 |
| Miles | Kilometers | 1.609 |
| Square Inches | Square Centimeters | 6.451 |
| Square Feet | Square Meters | 0.093 |
| Square Yards | Square Meters | 0.836 |
| Square Miles | Square Kilometers | 2.590 |
| Acres | Square Hectometers | 0.405 |
| Cubic Feet | Cubic Meters | 0.028 |
| Cubic Yards | Cubic Meters | 0.765 |
| Fluid Ounces | Milliliters | 29.573 |
| Pints | Liters | 0.473 |
| Quarts | Liters | 0.946 |
| Gallons | Liters | 3.785 |
| Ounces | Grams | 28.349 |
| Pounds | Kilograms | 0.454 |
| Short Tons | Metric Tons | 0.907 |
| Pound-Feet | Newton-Meters | 1.356 |
| Pounds Per Square Inch | Kilopascals | 6.895 |
| Miles Per Gallon | Kilometers Per Liter | 0.425 |
| Miles Per Hour | Kilometers Per Hour | 1.609 |

| TO CHANGE | TO | MULTIPLY BY |
|---|---|---|
| Centimeters | Inches | 0.394 |
| Meters | Feet | 3.280 |
| Meters | Yards | 1.094 |
| Kilometers | Miles | 0.621 |
| Square Centimeters | Square Inches | 0.155 |
| Square Meters | Square Feet | 10.764 |
| Square Meters | Square Yards | 1.196 |
| Square Kilometers | Square Miles | 0.386 |
| Square Hectometers | Acres | 2.471 |
| Cubic Meters | Cubic Feet | 35.315 |
| Cubic Meters | Cubic Yards | 1.308 |
| Milliliters | Fluid Ounces | 0.034 |
| Liters | Pints | 2.113 |
| Liters | Quarts | 1.057 |
| Liters | Gallons | 0.264 |
| Grams | Ounces | 0.035 |
| Kilograms | Pounds | 2.205 |
| Metric Tons | Short Tons | 1.102 |
| Newton-Meters | Pound-Feet | 0.738 |
| Kilopascals | Pounds Per Square Inch | 0.145 |
| Kilometers Per Liter | Miles Per Gallon | 2.354 |
| Kilometers Per Hour | Miles Per Hour | 0.621 |



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