TECHNICAL MANUAL

ORGANIZATIONAL, DIRECT SUPPORT AND
GENERAL SUPPORT MAINTENANCE MANUAL
(INCLUDING SUPPLEMENTAL OPERATING,
MAINTENANCE AND REPAIR PARTS
INSTRUCTIONS
FOR

40 TON CRANE
CRAWLER MOUNTED

HARNISHCFEGER CORPORATION
MODEL 5060

NSN 3810-01-145-8288

HEADQUARTERS DEPARTMENT OF THE ARMY

13 AUGUST 1984

WARNINGS, CAUTIONS and NOTES are used throughout this manual to emphasize important and critical instructions. For the purpose of this manual, WARNINGS, CAUTIONS and NOTES are defined as follows:

WARNING An operating procedure, practice, etc., which, if not correctly followed, could result in personal injury, or loss of life.

CAUTION An operating procedure, practice, etc., which, if not strictly observed, could result in damage to, or destruction of, equipment.

NOTE An operating procedure, condition, etc., which is essential to highlight.

CHANGE

NO. 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington D.C., *2 August 1990*

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FOR

**40-TON CRANE
CRAWLER MOUNTED**

**HARNISCHFEGER CORPORATION
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TM 5-3810-303-24, 13 August 1984, is changed as follows:

1. Remove old pages and insert new pages as indicated below.

2. New or changed material is indicated by a vertical bar in the margin of the page and by a vertical bar adjacent to the illustration identification number.

Remove pages	Insert pages
Warning Pages “3” and “4”	Warning Pages “3” and “4”
Warning Pages “7” through “13”	Warning Pages “7” through “14”
Title Page	Title Page
Section II, Table of Contents	Section II, Table of Contents
Section II, pages 2-5 and 2-6	Section II, pages 2-5 and 2-6
Section II, pages 2-13 and 2-14	Section II, pages 2-13 through 2-14.2
Section V, pages 5C-1 and 5C-2	Section V, pages 5C-1 and 5C-2
Section XII, pages 3 and 4	Section XII, pages 3 and 4
Section VII, pages 45 and 46	Section VII, pages 45 and 46
Section VII, pages 67 and 68	Section VII, pages 67 and 68

3. File this change sheet in front of the publication for reference purposes.

By Order of the Secretary of the Army:

CARL E. VUONO
General, United States Army
Chief of Staff

Official:

THOMAS F. SIKORA
Brigadier General, United States Army
The Adjutant General

Distribution:

To be distributed in accordance with DA form 12-25-E, Blocks 554,555, Unit, Direct Support and General Support maintenance requirements for TM 5-3810-303-24.

CAUTION

The signal horn will also sound if the Fairlead limit switch is activated. The limit switch is activated when the boom contacts the switch on the top of the Fairlead.

WARNING

Do not use this switch to override the boom hoist limit switch to allow the boom to be raised beyond the normal operating limits. This is an extremely dangerous operating procedure, since the boom could be raised to the point where the boom will topple over the back of the machine.

WARNING

Under no circumstances should a circuit breaker be prevented from tripping by any means. Overloaded electrical circuits can cause extensive damage to the machine and/or injury to personnel.

CAUTION

Do not attempt to propel the machine with the engine speed under 1000 rpm. Propelling at engine speeds below 1000 rpm could damage the propel pumps due to a lack of oil pressure.

CAUTION

Do not place the hydraulic oil diverting valve switch in the "lower" position until the hoses are attached to the fittings on the hydraulic cylinders.

WARNING

Removal of the propel motors and brakes leaves the machine in a free-wheel condition with no on-board means for braking. External braking must be provided.

WARNING

Personnel should use care to keep from spilling fuel, coolant, or other liquids upon themselves. Exposed parts of the body should not come into contact with metal during cold weather, as serious and painful injury may result.

CAUTION

Initial factory fill of MPG is of the soap base 12-Hydroxy Lithium Stearate type. Other soap base greases are not always compatible with initial fill lubricant, and Barium base grease is definitely not compatible. Various other soap base greases may be used if experience by the purchaser has shown these greases to be acceptable for the application. The grease systems must be thoroughly purged and the affected parts removed and cleaned before switching from a grease having one type of base to a grease having a different soap base.

CAUTION

If the machine is equipped with a fairlead, swing it out of the way to fully lower the boom. See FAIRLEAD and LAGGING Manual.

WARNING

Never allow a loaded boom to compress the backstop springs. If this minimum clearance is not maintained, tension within the boom hoist lines may collapse the boom over the backstops.

CAUTION

The maximum amount of rope that can be stored on each main load drum, when the machine is equipped as a liftcrane, is 710 feet.

WARNING

Keep hands and clothing clear of rotating drum.

WARNING

The live end of the rope must be in a straight line through the socket.

WARNING

Make sure the live end of the rope is not kinked at the point where it leaves the socket.

CAUTION

When the machine is operational, the gantry should be lowered for TRAVELING UNDER AN OBSTRUCTION ONLY. If the boom length is over 80 feet, the gantry must not be lowered. When moving the machine with the gantry in the “travel position”, the boom point must not be raised higher than 12 feet. Do not attempt to lift a load with the gantry in the lowered position.

CAUTION

When positioning the counterweight be certain each is resting evenly and firmly on its shear ledges.

WARNING

Do not stand under the boom or inside the boom structure when removing pins. The boom could fall if improperly supported and could cause serious injury.

WARNING

Consult the load rating chart regarding the boom lengths which require intermediate suspension.

CAUTION

The load hoist lines must have adequate slack when lowering the crane attachment to prevent any possibility of these lines becoming taut. These lines will tend to tighten as the attachment is lowered, and if adequate slack is not allowed, the attachment cannot be lowered completely. Damage to the attachment may also result.

WARNING

The anti-rotation bar must be in place prior to lifing the machine. See Figure 4-10. The anti-rotation bar must remain in place during transportation.

CAUTION

Never operate the engine with the oil level below the low mark or above the full mark.

WARNING

The final criterion for correct adjustment and operation is safe load handling.

CAUTION

Lower the boom to the ground before performing any maintenance work on the pawls.

CAUTION

Reapply the foot brake before moving the drum brake switch to the "OFF" position, and lower the load under the control of the foot brake.

WARNING

The final criterion for correct adjustment is will the brake hold the load? The brake must hold for safe load handling.

CAUTION

Never fill a hot engine with cold coolant. This could damage the radiator and/or engine.

WARNING

The oil in the reservoir is HOT. Therefore, take precautions when removing the reservoir drain plug to prevent oil burns.

CAUTION

Always be sure the adjustment collar lock pin is engaged in one of the 24 holes in the hub plate or the clutch will lose adjustment.

CAUTION

Do not allow temperature to exceed 225°F (107°C).

CAUTION

Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances which can "sweat" out during operation and cause the clutch to slip.

WARNING

Careful planning and supervision offer better protection than any known device. Insulated boom cages, proximity warning devices, and insulating links have limitations and can fail without warning. Insulated boom cages and links only protect part of the crane and can break down electrically when contaminated with dust and water. Operation of proximity warning devices can be affected by different arrangements of power lines, the movement of trucks, materials, and the crane itself, and other influences. Relaying on any of these devices could be dangerous because operators may think they are providing protection when in fact they are not.

CAUTION

Before engine start-up, check all wiring, fuel, water, and mechanical connections. Be prepared to shut down the engine if there should be some malfunction.

CAUTION

Bearing must never be spun when drying with compressed air.

CAUTION

A new tap can cut oversize.

CAUTION

Index tangs on pump hub (24) with the slots in charging pump drive GEAR.

CAUTION

Be sure the oil pump turns freely after is bolted to the converter housing.

CAUTION

Always be sure the adjustment collar lock pin is engaged in one of the 24 holes in the hub plate or the clutch will come out of adjustment.

CAUTION

Slowly lower the shaft so that O-ring (15) and seal (19) are not damaged.

CAUTION

Make sure that the swing clutch shoes do not drag. Dragging shoes will cause the upper to swing with the swing control lever in neutral.

CAUTION

The following procedures must be done very carefully to arrive at the right settings. If not correct, serious damage could result to the machine when operated.

CAUTION

To prevent overheating do not leave the pull-in winding energized more than 15 seconds. The current draw will decrease as the winding temperature increases.

CAUTION

Do not strike the diode, as the shock may damage it and the other diodes. Use only those diodes listed in the parts list for this unit. Never use substitutes.

CAUTION

The ohmmeter polarity must be determined by connecting its leads to voltmeter leads. The voltmeter will read up scale when the negative leads are connected together and the positive leads are connected together. The polarity of the voltmeter leads can be determined by connecting the leads to the identified terminals of a battery.

CAUTION

Change ohmmeter to X10 or middle scale.

CAUTION

Turn ohmmeter back to low or X1 scale.

WARNING

Do not use high voltage such as 110 volt test lamps, to check diodes.

WARNING

Do not use high voltage such as 110 volt test lamps, to check diodes.

CAUTION

Do not lift an engine by the webs in the air inlet openings of the cylinder block.

CAUTION

Do not use a methoxy propanol base antifreeze as it is detrimental to the water seals.

CAUTION

Main bearing cap bolts are especially designed for this purpose and must not be replace by ordinary bolts.

CAUTION

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.

CAUTION

If reconditioned valves are used, install them in the same relative location from which they were removed.

CAUTION

The shorter rocker cover bolt, which threads into the throttle delay bracket, can crack the bracket if overtightened. Also, the rocker cover bolt is especially designed for this purpose and must not be replaced with an ordinary bolts.

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.

CAUTION

Extreme caution should be used when removing a flywheel by either leaving one or two bolts in the flywheel, or installing two suitable guide pins to support the flywheel until a lifting tool or some other suitable safe lifting device is attached to the flywheel.

WARNING

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.

CAUTION

Clean the rust preventative 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".

CAUTION

When the intermediate bearings are locked into position with the lock screw, the bearing must have slight movement in the block bore.

CAUTION

Do not buff excessively. Do not use a steel wire buffing wheel or the spray tip holes may be distorted.

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.

CAUTION

The finished surface of the operating fork must be placed against the outer side of the thrust bearing.

CAUTION

To avoid breaking the oil seal rings, do not spread them more than necessary to place them over the end of the carrier.

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.

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.

CAUTION

Do not force the piston rings into place.

CAUTION

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.

WARNING

Do not hold the compressor wheel for any reason, while the engine is running. This could result in personal injury.

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. Keep away from open flames. Do not use a wire brush or steel blade scraper to clean parts.

CAUTION

Always check the clearance between the crankshaft gear and the oil pump idler gear with the engine in the upright or running position.

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.

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.

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

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.

CAUTION

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.

CAUTION

If a wrench is used on the crankshaft bolt at the front of the engine, so not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

WARNING

Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

WARNING

Starting fluid used in capsules is highly inflammable, toxic and possesses anesthetic properties.

CAUTION

If the slip joint is removed from the propeller shaft it must be assembled to the propeller shaft in the original position. The matchmarked arrows on the shaft and sleeve must be visible before disassembly. If the arrow marks are not visible, mark both members before disassembling them.

CAUTION

Do not adjust the chain too tight as this will cause excessive wear to the chain and sprocket.

CAUTION

Hydraulic oil must not come in contact with any brake or clutch lining during bleeding operations. If this does occur, replacement of the linings will be necessary.

CAUTION

No force must be used when installing the bushing assemblies into the body. If the bushing assemblies jam in the bore, remove and examine them for nicks or scratches. This type of damage can be removed with a fine grit hand stone.

CAUTION

The pressuring setting of 3000 psi must not be changed. Any attempt to change the setting will void any and all guarantees, expressed or implied.

CAUTION

The following steps must be performed carefully or damage to the system components can result. In no case should a pressure adjusting screw be turned rapidly, always make adjustments slowly.

CAUTION

When precharging the accumulator, use water pumped, oil pumped or dry nitrogen only.

CAUTION

Before breaking an electrical circuit, be sure the power is OFF. To do this, disconnect the battery ground cable.

CAUTION

Before breaking any circuit, be sure ail pawl locks are engaged and block or lower any load whose movement could generate pressure.

CAUTION

Do not stone edges of the sealing lands on the valve spool. Rather, use a 500 grit abrasive paper to remove any burrs found on the spool. Use the paper very lightly on the outer diameter of the spool only.

CAUTION

DO NOT scratch or mar finished surfaces when removing cup (03) and O-ring (04).

WARNING

Extreme caution must be exercised when removing the slewing ring, as it is necessary to completely remove the upper from the carbody. Every precaution must be taken to prevent the upper from falling or shifting while lifting the upper and when the upper is off the carbody.

CAUTION

Attempt to disassembly or repair the slewing ring will void any warranty, expressed or implied.

CAUTION

Reapply the drum brake pedal before moving the drum brake switch to the OFF position.

CAUTION

The following procedure must be done very carefully to arrive at the right settings. If not correct, serious damage could result to the machine when operated.

CAUTION

The next stop in this procedure involves removing pin (57) from the pawls. When removing pin (57) the drum brake operating mechanism should be supported so it will not fall.

CAUTION

The relief valves are factory set and should not be tampered with except to replace the entire cartridge.

CAUTION

Charge pressure must not be less than 160 psi for satisfactory operation,

CAUTION

If the system should become contaminated, DO NOT use a flushing solution to clean the system. The entire system must be disassembled and cleaned.

WARNING

Do not start the engine unless the pumps are in neutral (0 swash plate angle). Take safety precautions to prevent machine movement in case a pump is actuated during initial start-up.

CAUTION

The relief valves are factory set and should not be disassembled further.

CAUTION

Protect the exposed cavities into the pump from foreign material.

CAUTION

Make certain the pressure setting of the motor charge relief valve is below the pressure setting of the pump charge relief valve to assure that the cooling circuit will function properly.

CAUTION

It is not necessary to remove the pump to perform repairs on the charge pump, controller, relief valve, or check valves. However, it is extremely important that the disassembled pump be protected from airborne dust. Contamination introduced directly into the pump, have the greatest potential for causing damage. If this protection cannot be provided, it is suggested that the pumps be removed from the machine and repaired in a clean environment.

CAUTION

Repairs beyond the kits explained below will void the warranty on the pumps.

CAUTION

Do not lose any of the shim inside the plug.

CAUTION

The hydraulic amplifier assembly is a precision built component and must be handled with care. Avoid any contact of objects with the feedback wire protruding from the base of the assembly. Do not let metal particles or objects come in contact with the magnets.

CAUTION

Most solvents react with O-ring compounds. Remove all O-rings from parts before cleaning.

CAUTION

Failure to insert the bushing locating pin to a sufficient depth in the valve body will prevent proper install of the hydraulic amplifier assembly. This will result in external leakage and probable damage to the hydraulic amplifier assembly.

CAUTION

Apply force only around the edge of the inlet orifice assembly, or the filter may become damaged and result in controller malfunction.

CAUTION

Bring the pump on stroke with extreme caution since no reliefs other than pressure override valves are in the system.

CAUTION

Be careful not to damage O-rings or back-up rings during piston installation .

WARNING

The weight of the block and sling must equal 1500 lbs to prevent backward tipping with one side frame removed and one side frame installed. Proceed slowly and exercise caution throughout this procedure.

CAUTION

Do not let the hook block EXCEED A RADIUS OF 15 FEET, OR A TIPPING CONDITION COULD RESULT.

CAUTION

Do not let the hook block EXCEED A RADIUS OF 12 FEET, OR A TIPPING CONDITION COULD RESULT.

WARNING

Travel over flat, level, solid surfaces when moving the crane with the leads (and hammer) in the raised position, never exceed 2 or 3 mph. Before moving the crane, secure the leads to the crane (with catwalk) or use tag lines to keep the leads from swinging. In high winds (15 or 20 mph) do not raise the leads or move the crane.

WARNING

Do not move the crane under overhead obstacles (i.e., trees, power lines, bridges, etc.) with the leads In the raised position.

WARNING

Raise the outriggers (if equipped) to 2 to 3 in. off the ground when moving the crane with the leads In the raised position.

WARNING

Always position the hammer, head, and leads on the ground (before assembly) to within 25 feet of where the pile is to be driven.

WARNING

Front and rear ground guides will be used when moving the crane. One person will hold each tag line to prevent the leads from swinging.

WARNING

Personnel not directly involved with moving the crane or driving the pile will remaln at least 50 feet from the equipment.

WARNING

Always use the load chart to determine the boom angle, length and radius of the boom.

WARNING

Raise the outriggers (if equipped) 2 to 3 in. off the ground before driving a pile. Reset the outriggers on the ground before raising the leads.

WARNING

Set the swing lock brake before attaching the boom to the leads.

WARNING

Tire pressure (if applicable) must be 85 psi on P&H cranes. Tire pressure must be 100 psi (front) and 75 psi (rear) on Grove cranes.

Technical Manual
No. 5-3810-303-24

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 13 August 1984

ORGANIZATIONAL, DIRECT SUPPORT AND GENERAL SUPPORT MAINTENANCE MANUAL (INCLUDING SUPPLEMENTAL OPERATING, MAINTENANCE AND REPAIR PARTS INSTRUCTIONS)

FOR

40-TON CRANE CRAWLER MOUNTED

HARNISCHFEGER CORPORATION MODEL 5060

NSN 3810-01-145-8288

REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS

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 to you.

This technical manual is an authentication of the manufacturer's commercial literature and does not conform with the format and content specified in AR 25-30, The Army Integrated Publishing and Printing Program. This technical manual does, however, contain available information that is essential to the operation and maintenance of the equipment.

SAFE OPERATING PRACTICES FOR MOBILE CRANE AND EXCAVATOR USERS

INTRODUCTION

NOTE: This material replaces Catalogs 211 and 221.

Harnischfeger cranes and excavators are carefully designed, tested, and manufactured. When used properly by qualified operators, they will give safe, reliable service. Harnischfeger has offices world-wide to answer any questions about its products or their safe use.

Because cranes have the ability to lift heavy loads to great heights, they also have a potential for accidents if safe operating practices are not followed. This booklet will help you prevent accidents which could result in injury, death, or property damage.

General safe practices for working on machinery must be followed as well as the safe operating practices recommended here.

OPERATOR'S RESPONSIBILITY

Safety must always be the operator's most important concern. He must refuse to operate when he knows it is unsafe and consult his supervisor when safety is in doubt.

He must read and understand the Operator's Manual and see that the machine is in proper order before operating.

He must understand how to read the rating plate and know that his machine can safely lift each load before attempting to lift it.

He must be alert, physically fit, and free from the influences of alcohol, drugs, or medications that might affect his eyesight, hearing, or reactions.

He must see that people, equipment, and material are kept out of the work area. The area around the machine should be properly barricaded (see Operating Precautions #4 and 5).

When an operator's vision is blocked or when operating in hazardous areas such as near power lines or around people, a signalman must be used. Because the operator is not in the best position to judge distances and can not see all parts of the jobsite, a signalman may also be necessary at other times. Operators must understand standard crane signals and take signals only from designated signalmen.

SIGNALMAN'S RESPONSIBILITY

The primary duty of a signalman is to assist the operator in safe and efficient operation. Operators depend on designated signalmen to assist them in making movements without endangering people or property.

Signalmen must have a clear understanding of the work to be done so that they can safely coordinate each job with operators and other crew members.

Signalmen must place themselves where they can be clearly seen and where they can safely observe the entire operation.

Standard crane signals must be used unless other methods of signaling such as two way radios or flags have been agreed upon.

RESPONSIBILITIES OF ALL CREW MEMBERS

Any unsafe condition or practice must be corrected or reported to the job supervisor.

Everyone who works around cranes and excavators, including riggers and oilers, must obey all warning signs and watch out for his own safety and the safety of others. Crew members setting up machines or handling loads are expected to know proper machine erection and rigging procedures.

Watch for hazards during operations and alert the operator and signalmen of dangers such as power lines, the unexpected presence of people, other equipment or unstable ground conditions.

MANAGEMENT RESPONSIBILITY

See that operators are trained, competent, physically fit and, if required, licensed. Good vision is required, as are good judgment, coordination and mental ability. Any person who lacks any of these qualities must not be allowed to operate a crane or excavator.

Signalmen must have good vision and sound judgment, know standard crane signals and be able to give signals clearly. They must have enough experience to be able to recognize hazards and signal the operator to avoid them.

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Riggers must be trained to determine weights and distances and to select and properly use lifting tackle. Rigging is a complex subject far beyond the scope of this booklet. It is management's responsibility to see that riggers are properly trained.

Crew members must be given specific safety responsibilities and instructed to report any unsafe conditions to their supervisors.

PLANNING THE JOB

Most accidents can be avoided by careful job planning. The person in charge must have a clear understanding of the work to be done, consider all dangers at the jobsite, develop a plan to do the job safely, and then explain the plan to all concerned. Factors such as these should be considered:

- What crew members are needed and what responsibilities will they be given?
- What is the weight of the load to be lifted, the lift radius, boom angle, and the rated capacity of the crane?
- How will the signalmen communicate with the operator?
- What equipment is required to do the job safely? Is a crane or excavator the best equipment for the job?
- How can the equipment be safely transported to the jobsite?
- Are there gas lines, power lines or structures which must be moved or avoided?
- Is the surface strong enough to support the machine and load?
- How will loads be rigged?
- What special safety precautions will be taken if a crane must travel with a suspended load or if more than one crane is needed to lift a load? (See Operating Precautions #26, 27 and 28).
- Are unusual weather conditions such as winds or extreme cold expected?
- What steps will be taken to keep unnecessary people and equipment safely away from the work area?
- How can cranes be positioned to use the shortest boom and radius possible?

OPERATOR'S SAFETY CHECK

The operator must make a safety check before starting to work each day to see that the machine is in proper order. Some things to check are:

- Check the machine log book to see that periodic maintenance and inspections have been performed and all necessary repairs made.
- Check the operation of boom hoist kickout, boom angle indicator, backup alarms, and other safety devices.
- Carefully inspect load bearing parts such as wire rope, (load lines, boom hoist cable, suspension lines), boom, outriggers, and hooks.
- Be sure no unauthorized field modifications have been made. Such as added counterweights and booms that have been improperly repaired.
- Check for air and hydraulic oil leaks.
- After starting the engine, check all gauges for proper readings.
- Test all controls for proper operation.
- Check brakes and clutches. Test load brakes by lifting a load a few inches off the ground and holding it.

OPERATING PRECAUTIONS

1. Mistakes in calculating lifting capacity can cause accidents.

Several factors must be considered, including:

A. Load radius (the distance between the center of the crane rotation to the center of the load). Note that the radius will increase when the load is lifted.

B. Weight of the load, hook, and rigging.

C. Boom length, jib, parts of line, and operating area (side, rear).

Use the next lower rated capacity when working at boom lengths or radii between the figures on the rating chart. It is dangerous to guess the capacity for boom lengths or radii between those listed on the rating plate.

Trying to lift a load without knowing whether it is within the rated capacity while expecting the crane to start to tip to warn of an overload is very dangerous. Cranes may suddenly tip over or collapse if the load is too heavy.

Always stay within rated capacity. The operator must reduce the load under adverse field conditions until, in his judgment, the machine can safely handle the lift.

(See Operating Precautions #3, 10, 12, 16, 19, 27 and 28.)

2. Cranes and excavators may tip over or collapse if the operating surface cannot support their weight. Timber mats. steel plates or concrete rafts may be needed under outrigger pads or crawlers to distribute the load under the crane so that the bearing strength of the ground is not exceeded.

Determine the load bearing capacity of the ground or other surface on which machines will be operating. Be sure cranes and excavators are adequately supported. Avoid soft or unstable ground, sand, areas with high water tables, and partially frozen ground. When machines are working near trenches the trenches should be shored or sloped to prevent cave-ins or slides.

3. The rated capacity of a crane is determined with the crane leveled within 1% of grade (1 foot drop or rise in 100 foot distance). Out of level more than 1% will drastically reduce the lifting capacity.

Be sure cranes are level. All tires must be off the ground for "On Outrigger" ratings.

4. People can be crushed by the scissors-like action of the upper rotating on the lower.

Stay away from rotating cranes and excavators. Erect barricades to keep people away. Take the time to determine that these areas are clear before swinging.

5. People can be crushed by the rear (counterweight) of the machine if there is not enough room for it to swing.

Position machines so that people cannot be trapped between the counterweight and other obstructions.

6. Many people have been injured when riding crane hooks or loads or while being lifted in manbaskets. They have no control over how they are handled and no protection from impacts or falls. Small mistakes can be fatal.

Do not lift people with cranes. Use ladders, scaffolds, elevating work platforms or other equipment designed to lift people, but do not use cranes.

7. Power lines have killed or seriously injured people working around cranes and excavators. These accidents can be avoided by following a few simple rules.

Always determine whether there are power lines in the area before starting any job. OSHA regulations require at least ten (10) feet of clearance from lines carrying 50,000 volts or less. Greater clearances are required for lines with higher voltages. Some states require greater clearances than OSHA. Safety requires that you stay as far as possible from power lines and never violate minimum clearances.

Always take these precautions if power lines are present.

A. Notify the Power Company before beginning work.

B. You and the Power Company must take specific precautions. These may include locating cranes and materials away from power lines, de-energizing and grounding lines, rerouting lines, removing or barricading lines, and insulating lines with rubber sleeves.

C. Use a signalman to maintain a safe distance between any part of the machine or load and power lines. The operator is not in the best position to judge distances.

D. Warn people to stay away from the machine and load at all times. If the load must be guided into place, ask the Power Company about special precautions such as insulated poles or hot sticks.

E. Slow down. Give yourself time to react to problems and to double check the distance between power lines and any part of the machine or load.

WARNING

Careful planning and supervision offer better protection than any known device. Insulated boom cages, proximity warning devices, and insulating links have limitations and can fail without warning. Insulated boom cages and links only protect part of the crane and can break down electrically when contaminated with dust and water. Operation of proximity warning devices can be affected by different arrangements of power lines, the movement of trucks, materials, and the crane itself, and other influences. Relying on any of these devices could be dangerous because operators may think they are providing protection when in fact they are not.

8. The load line can break if the hook block contacts the end of the boom. This is called "two blocking". Two blocking can be caused by hoisting the hook into the and of the boom, lowering the boom or extending telescopic booms without paying out load line. Two blocking can pull jibs and lattice crane booms over backwards.

Always keep space between the hook block and boom point. Lower the hook when extending telescopic booms to avoid two blocking.

9. People can be injured if the hook, boom, load or outriggers are moved before everyone is clear.

Make sure everyone is in a safe place before moving the hook, boom, load or outriggers. Do not move loads over people. Do not allow the load to bump or catch on anything.

10. Rapid swings or sudden starts and stops can cause the hook and attached load to swing out of control.

Always start and stop movements smoothly and swing at speeds that will keep the load under control.

11. Dirty windows, darkness, bright sunlight, fog, rain. and other conditions can make it difficult for the operator to see.

Keep windows clean. Do not operate if you cannot see clearly enough to operate safely.

12. Even light winds can blow loads out of control, collapse booms, or tip machines. Winds aloft can be much stronger than at ground level.

Do not lift loads if winds create a hazard. Lower the boom if necessary. See the rating plate for possible restrictions.

13. Carelessness in getting on and off equipment can result in serious injuries.

Always wait until the machine has stopped. Do not jump on or off. Always use both hands and make sure you have good footing.

14. Slippery floors and steps, tools, trash, or other loose items can cause falls.

Keep the machine clean and dry.

15. Damaged crane booms may collapse. Lattice type booms will be weakened by damaged chords, bent or missing lacings, or cracked welds. Telescopic booms will be weakened by distorted bottom or side plates. In either case, the loss of strength is difficult to estimate.

Inspect the crane boom daily for damage. Do not use damaged booms.

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NOTE

Due to the high strength steels used in booms, special repair procedures are required. Repair procedures for lattice booms are described in Harnischfeger Catalog 238. Consult Harnischfeger for further information.

16. Crane booms can buckle if side loaded (pulled sideways). Typical causes of side loading are rapid starts and stops while swinging, dragging a load sideways, winds, or lifting when the crane is not level.

Take care to avoid side loading.

17. If the load strikes the boom or the boom hits a building or other object, the boom may collapse.

Never let the load or any other object strike the boom.

18. Boom suspension lines will stretch when the load is lifted and contract when the load is released. At high boom angles this may be enough to pull the boom backward over the crane.

When releasing loads be sure the boom never tightens against the backstops. Release loads slowly.

19. The load will swing out of control if it is not directly beneath the boom point when lifted. This can side load the boom and may cause the crane to tip or collapse.

Always place the boom point directly above the load when lifting.

20. Trying to lift a load which is stuck, frozen or attached to something else may result in tipping. boom collapse or other damage.

Be sure that loads are free before lifting.

21. If there is not enough wire rope on the drum the rope can be pulled off.

Keep at least two full wraps of wire rope on drums when operating.

22. Foot pedal brake locks are furnished on some cranes to allow the operator to rest his lags when suspending the load for short periods of time.

Keep your feet on the pedals while foot pedal brake locks are in use. Brakes may cool allowing the load to fall.

23. Trying to repair or adjust equipment with a suspended hook or load or with the boom raised could release machinery and let it move unexpectedly.

Always lower the load to the ground and the boom onto proper cribbing before doing maintenance or repair work.

24. Pressure in hydraulic systems can be retained for long periods of time. If not properly released before maintenance people attempt to work on the hydraulic systems this pressure can let machinery move or cause hot oil and hose ends to shoot out at high speed.

Release system pressure before attempting to make adjustments or repairs.

25. Pin-connected booms and jibs may fall if not properly supported when removing pins.

Make sure both ends of each boom and jib section are supported and the boom suspension lines completely slacked off before removing pins. Never stand on, inside, or under booms or jibs during assembly or disassembly.

26. As with all heavy equipment, care must be taken when cranes or excavators are driven (traveled) whether on or off the jobsite.

Watch for people, power lines, low or narrow clearances, bridge or road load limits, and steep hills or uneven terrain. Use a signalman in close quarters. Know the height, width, and weight of your machine. Retract and lock outriggers, place the boom in the cradle, and set swing brake or lock before travelling.

27. Load ratings for cranes are based on the machine being stationary and level. Traveling a crane with a suspended load or with the boom erected involves special hazards, including the possibility of side loading or tipping over.

Because of the many variables involved in pick and carry operations, the user must evaluate conditions and take precautions such as these:

- Follow the travel precautions listed in rule 26.
- Check the rating plate for limitations.
- Position the boom in line with the direction of travel.
- Reduce the maximum load while traveling to reflect operating conditions. The safe load will vary depending on speed, crane, terrain, and other conditions.
- Travel slowly and avoid sudden stops and starts.
- Avoid backing away from the load. This could increase the radius and cause the machine to tip over.
- Use tag lines to keep loads under control.
- Keep the load close to the ground.
- Use the shortest boom possible.

28. Using two or more cranes to lift a load involves many hazards not normally encountered in single crane lifts.

Multi-crane lifts must be carefully engineered, keeping the following points in mind.

- Since the load is not freely suspended, careful engineering studies must be made to ensure that the load carried by each machine is less than its rated capacity.
- Make sure slings are arranged to divide the load as planned.
- Review the lifting plan with operators, signalmen and other crew members before beginning the lift.
- Carefully coordinate crane movements through every stage of the lift.
- Avoid boom side loading (see #16).

29. Leaving a machine unattended can be very dangerous.

Before leaving his seat, the operator must take the following steps to prevent his machine from moving:

Lower the load or bucket to the ground. Lower the boom when necessary.

- Set the swing brake or lock.
- Set all drum pawls.
- Set parking brakes.
- Set propel brakes or locks on crawler machines.
- Disengage the engine clutch or shut off the engine.

30. All wire rope must be inspected daily to determine whether it should be replaced. See the inspection form in the Operator's Manual and contact wire rope manufacturers and their distributors for more information.

Wire rope should be replaced when any of the following conditions exist:

- In running ropes, six broken wires in one lay or three broken wires in one strand in one lay.
- Wear of one-third the original diameter of the outside individual wires.
- Evidence of heat damage from any cause.
- Reductions from nominal diameter of more than -

  1/32 inch for diameters 3/8 to 1/2 inch.
  3/64 inch for diameters 9/16 to 3/4 inch.
  1/16 inch for diameters 7/8 to 1-1/8 inches.
  3/32 inch for diameters 1-1/4 to 1-1/2 inches.
- In standing ropes, more than two broken wires in one lay in sections between end connections or more than one broken wire at an end connection.
- Evidence of kinking, bird caging, crushing, cuts, abrasions, sharp bends or any other damage that results in distortion of the rope structure.
- Rust or corrosion.

WARNING

Do not use your hands to guide wire rope onto drums

31. Improper wire rope connections may fail under load.

Wire rope end connections must be installed properly and inspected daily.

- Wedge sockets should be installed so that the loaded side of the rope is in a straight line with the edge of the socket and not bent by the wedge. Prevent the rope end from slipping out of the wedge socket by attaching a short piece of rope to the rope end with two U-bolt clamps.
- U-bolt clamps (clips) should be installed so that the U-bolt is on the unloaded side and the saddle is on the loaded side.

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SECTION I

INTRODUCTION

SCOPE

This manual provides maintenance personnel with information and instructions for servicing and repairing this machine. In order to become familiar with the various parts of the machine, it is urged that maintenance personnel study the instructions and illustrations in this manual and use it as a reference when performing repair or maintenance operations.

An Operator's Manual is provided with each machine to provide the essential information regarding day-to-day maintenance, adjustment, and lubrication of the machine.

NOTE

Sections I, II and III of the Operator's Manual have been duplicated as the first three sections of this manual to provide maintenance personnel with the tabulated data, controls, and operation, and lubrication information that may be necessary in the performance of repair or maintenance operations.

GENERAL INFORMATION

The information, specifications and illustrations in this publication are based on the information for U.S. built machines in effect at the time this manual was printed. Continuing improvement and advancement of product design may cause changes to your machine which may not be included in this publication. Each publication is reviewed and revised, as required, to update and include these changes in later editions.

Whenever a question arises regarding your machine, or this publication, please consult your Harnischfeger representative for the latest available information.

Part numbers are used occasionally in this manual to identify various parts and assemblies. The part numbers shown must not be used when ordering repair parts. Always obtain part numbers from the Repair Parts Manual for your machine serial number.

SAFETY

The Safe Operating Practices in the beginning of this manual are reproduced in a separate publication, Catalog 240, which is furnished with each machine. It is most important that operators and maintenance personnel read and be familiar with the information in Catalog 240 and this manual before operating or servicing this machine, both for personal protection and for the safety of other workmen and bystanders.

Additional copies of Catalog 240 are available, in reasonable quantities, to owners of Harnischfeger excavators and cranes at no cost. Submit such requests to the Harnischfeger Technical Publications Department.

SERIAL NUMBER LOCATION

Figure 1-1 illustrates the machine serial number which is located on the front right side of the revolving frame. Always indicate the machine serial number in all correspondence to properly identify the machine, and to ensure that the correct parts are obtained, when ordered.

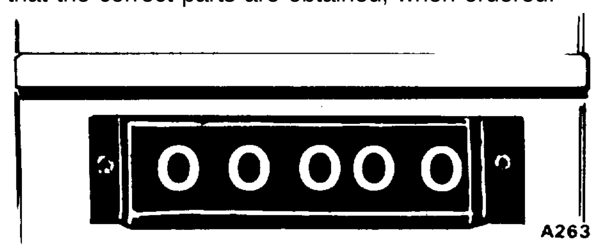

Figure 1-1. Machine Serial Number

WARRANTY

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.

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.

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 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. Further, if the Government, prior to placing vehicles in service, elects to place quantities of such newly delivered vehicles in Government depot storage, the contractor agrees that the time period of the warranty will not begin to run for such stored vehicles until each vehicle is withdrawn from Government storage or until six months from date of acceptance, whichever occurs first. The Government prior to placing each new vehicle in storage and again at time of its withdrawal, shall notify the contractor thereof and identify each vehicle at its time in and out of storage. Vehicles designated as Production Samples shall be treated as vehicles placed in storage for warranty purposes.

If a Safety Recall defect occurs during vehicle warranty period, the contractor agrees to extend the term of the warranty by a period of time equal to the time period required to make necessary safety defect corrections. Additionally, to the extent the contractor or his supplier(s) provide to commercial customers a greater warranty for the supplies furnished herein, 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 such greater warranty shall govern.

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. On all Government Owned Vehicles and Foreign Military Sales (FMS) Vehicles destined for shipment outside CONUS, the contractor's Iiability regarding warranty is limited to furnishing replacement parts F.O.B. CONUS port of debarkation for those parts which prove to be defective in material or workmanship. The contractor shall designate a resident point of contact/agent in both West Germany and Korea to coordinate resolution of all warranty claims reported within those locations. The contractor's POC/agent will be responsive to claims filed, assisting in the resolution of all valid warranty claims reported, for the life of the contract and 15 months thereafter.

In addition, the Government shall have the option (a) to return the vehicles 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 vehicles 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 vehicle 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 located within the 50 states, when the Government elects to correct them itself, the cost of labor involved in the correction of defects shall be borne by the contractor and shall be computed at the contractor's then prevailing hourly rate for such services in that geographical area, based upon the number of labor hours appearing in the contractor's flat rate time schedule manual, or the Government's actual cost, whichever is less. With respect to defective supplies located outside the 50 states, when the Government elects to correct them itself, the cost of labor involved shall be borne by the contractor at the then prevailing hourly rate in the geographical area for such services based upon the number of labor hours appearing in the contractor's flat rate time schedule manual of the Government's actual cost, whichever is less. Additionally. the contractor shall be responsible for reasonable costs of disassembly/reassembly of items necessarily removed in connection with repair or replacement on vehicles wherever located

If the Government elects to have warranty repair or replacement performed by the contractor, the Government shall deliver the vehicle to contractor's local facility or dealershlp for warranty corrective repair or replacement. Receipt for such vehicle by the contractor's local facility or dealership wiIl be deemed proper notification by the Government of any breach of the warranty provided by this provision. If the Government elects to effect warranty repairs or replacement itself, the contractor shall be notified in writing of any breach in the warranty within 30 days after discovery of the defect. Within 10 days after receipt of such notice, the contractor shall submit to the Contracting Officer a written recommendation as to the corrective action required to remedy the breach. 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 paragraph d, above, and the contractor shall, notwithstanding any disagreement regarding the existence of a breach of warranty, comply with any Contracting Officer directions related to such correction or replacement. After the notice of breach, 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 d 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 c, 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.

Any supplies or parts thereof corrected or furnished in replacement pursuant to this clause shall also be subject to all provisions of this clause to the same extent as supplies initially delivered

The Contractor shall prepare and furnish to the Government, data and reports applicable to any correction required under this clause (including revision and updating of all affected data called for under this contract) at no increase in the contract price.

The Contractor shall furnish with his proposal a listing of distributors, dealers, franchise outlets where warranty claims may be exercised.

The Contractor wiIl take all actions necessary to assure that all current flat rate time schedule manuals concerning vehicles under contract are on file with the TACOM Maintenance Directorate (DRSTA-M), of if not on file, within 60 days after contract award and furnish same to said Maintenance Directorate.

A synopsis or simplified summary of the warranty coverage and its implementation will be impaired 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 firewall.

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.

DESCRIPTION

The engine serves as the power source for the upper work functions and the lower propel drive system. Power is transmitted through the clutch and torque converter into the worm shaft (see Figure 1-2). The worm shaft drives the boom hoist shaft which is coupled to the swing shafts and main drum shafts by a pair of chains. Consequently, the boom hoist shaft, main shaft and swing shaft turn at all times when the engine clutch is engaged. However, the drumshafts do not turn the drums or the swing gear until the proper clutch is engaged by the operator.

The engine drives a hydraulic control pump which provides hydraulic power to the control valves in the operator's cab. When the operator engages the controls in the operator's cab, the control valves direct fluid to their respective clutch, brake and pawl. Also the control pump supplies hydraulic oil to the crawler extension/retraction valves mounted on the carbody. These valves direct oil to the side frame extension cylinders.

This crane is a friction and hydraulic machine. All upper work functions are performed by friction clutches and brakes. Hydraulic cylinders are used to apply the clutches and planetary brakes. The drum, swing and boom hoist brakes are released by hydraulic cylinders working against the brakes' spring actuators.

A pump drive, mounted at the rear of the upper, is driven directly by the engine. Two variable displacement pumps are mounted on and driven by the pump drive.

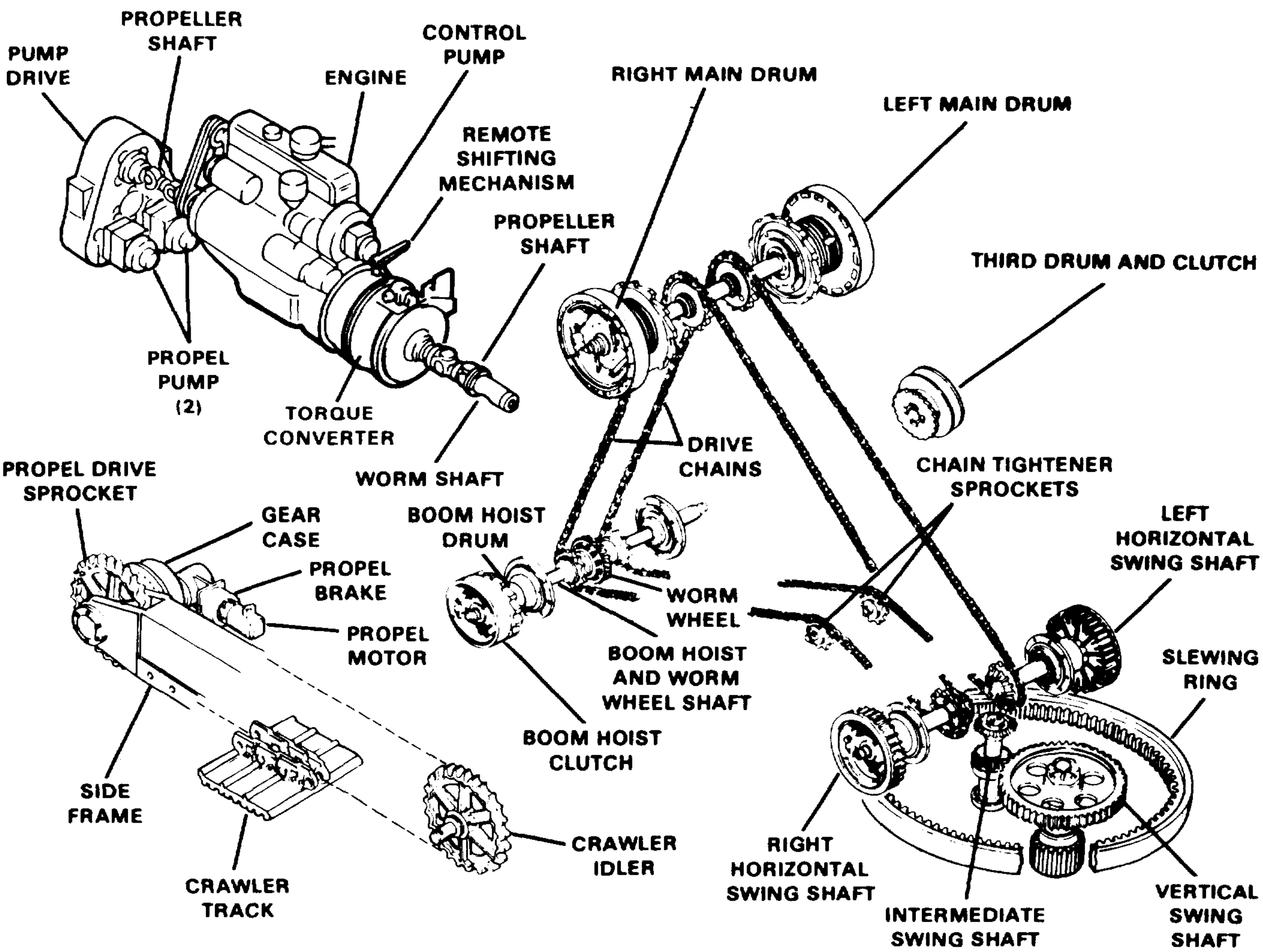

Figure 1-2. Mechanical Train Schematic

The two variable displacement pumps provide power to the crawler motors. Both crawler motors drive their respective sprocket to propel the machine. Crawler speed and direction (forward, reverse, left or right) are accomplished through the propel controller in the operator's cab.

TERMINOLOGY

Certain terms are frequently used in this manual. For better understanding, several are defined below and illustrated in Figure 1-3.

LOWER: The portion of the machine on which the upper is mounted.

CARBODY: The traveling base upon which the upper and side frames are mounted.

SIDE FRAME: A frame attached to the carbody which supports the crawler track and crawler motors.

UPPER: The upper is defined as the revolving portion of the crane. It is sometimes referred to as the superstructure.

REVOLVING FRAME: The revolving frame is the deck of the upper on which all upper machinery is mounted.

LOWER MACHINE FRONT: This is the end of the lower opposite the propel motors.

UPPER MACHINE FRONT: The front of the upper is the end having the boom.

LOWER MACHINE REAR: This is the end of the lower which has the propel motors mounted.

UPPER MACHINE REAR: The rear of the upper is the counterweight end.

RIGHT SIDE: The right side of the machine is to the operator's right when he is seated at his controls and is facing forward.

LEFT SIDE: The left side of the machine is to the operator's left when he is seated at his controls and is facing forward.

ATTACHMENT: An alternate designation for front end equipment. In the case of the lift crane, it includes the gantry, boom, backstops, and jib.

HOIST: The process of lifting the load.

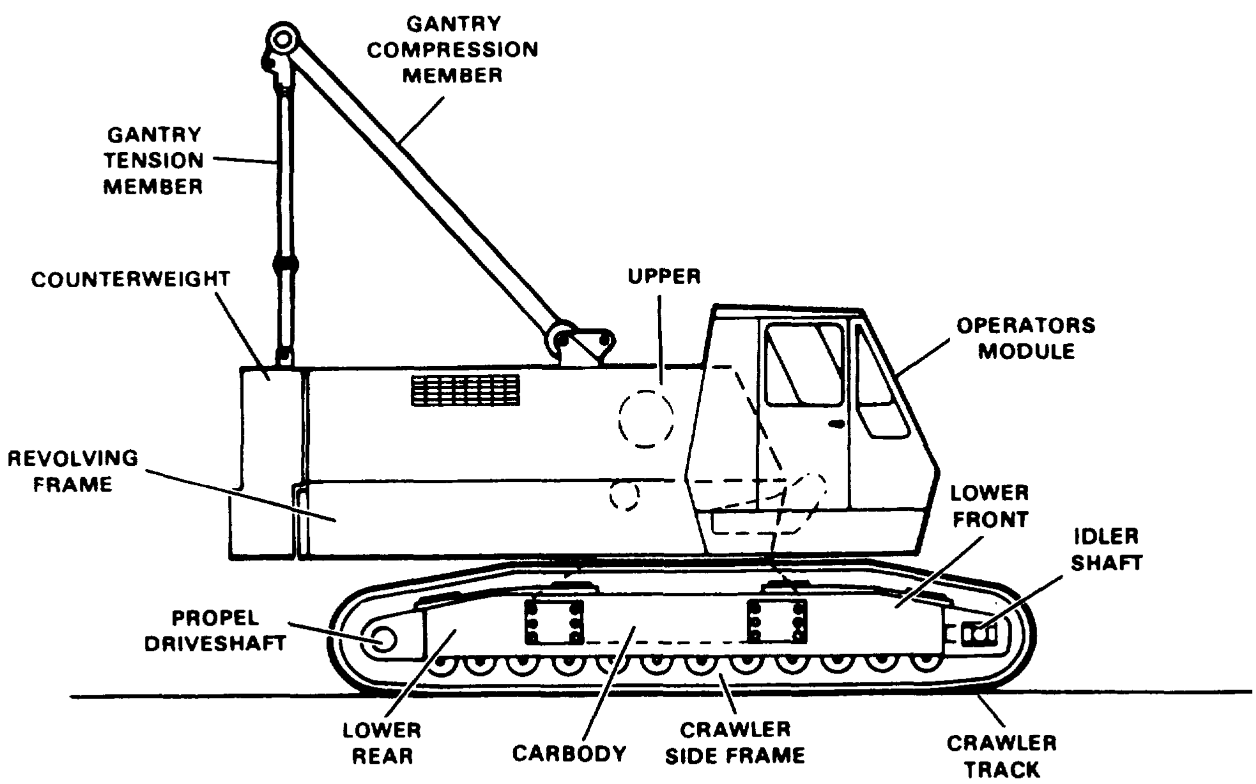

Figure 1-3. Crane Terminology

SWING: Swing is defined as the function of rotating the upper of the machine.

BOOM HOIST: The process of raising and lowering the boom.

PROPEL: The process of moving the machine forward, reverse, left or right.

TABULATED DATA

TORQUE VALUES: Unless otherwise specified, torque all common bolts and screws on this machine to the values shown in Table 1-1. The torques provided are to be used with dry threads. The use of thread lubricant or plated threads will substantially lower the torque values required.

LIQUID CAPACITIES: Table 1-2 provides a listing of the liquid capacities for machine components. The capacities are also given in the lubrication charts provided in Section III.

METRIC CONVERSIONS: Use Table 1-3 to convert the English units in this manual to metric units.

GENERAL DIMENSIONS: Figure 1-4 gives the dimensions commonly required for machine shipping and erection.

Table 1-1. Recommended Torque Values in Foot-Pounds (Dry Threads)*

Screw, Stud or Bolt Diameter (in) Coarse Threads UNC	Grade 5	Grade 8
1/4-20	6	9
5/16-18	12-14	17-19
3/8-16	22-24	31-34
7/16-14	36-39	50-55
1/2-13	54-59	76-84
9/16-12	77-85	110-120
5/8-11	107-118	153-166
3/4-10	190-210	270-292
7/8-9	280-310	437-475
1-8	425-460	650-710
1-1/8-7	570-620	930-1000
1-1/4-7	810-870	1310-1410
1-3/8-6	1060-1140	1730-1850
1-1/2-6	1410-1510	2290-2460
Fine Threads UNF	**Grade 5**	**Grade 8**
1/4-28	7	10-11
5/16-24	14-16	20-22
3/8-24	25-28	35-39
7/16-20	39-43	55-61
1/2-20	63-69	86-94
9/16-18	87-95	123-134
5/8-18	126-138	171-187
3/4-16	213-233	300-328
7/8-14	312-338	480-520
1-12	466-504	715-770
1-1/8-12	640-695	1040-1120
1-1/4-12	900-960	1460-1560
1-3/8-12	1210-1300	1970-2100
1-1/2-12	1585-1700	2570-2750

* Torque values are based on using plated hardware. If lubricants are used. torque will vary.

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Table 1-2. Liquid Capacity Chart

IDENTIFICATION	U.S.	METRIC
Cooling System	5.75 Gal.	21.8 Liters
Detroit Diesel 4-71T		
Crankcase with Filter	20 Qts.	18.9 Liters
Fuel Tank	76.5 Gal.	289.6 Liters
Battery	500 Oz.	14.8 Liters
Propel Pump Transmission	2.3 Gal.	8.7 Liters
Gear and Chain Case	7.0 Gal.	26.5 Liters
Torque Converter Reservoir	17.0 Gal.	64.3 Liters
Hydraulic Reservoir (Propel) (Control)	22.0 Gal.	83.3 Liters
Propel Gear Case	2.4 Gal.	9.1 Liters
Throttle Reservoir	12 Oz.	0.355 Liters

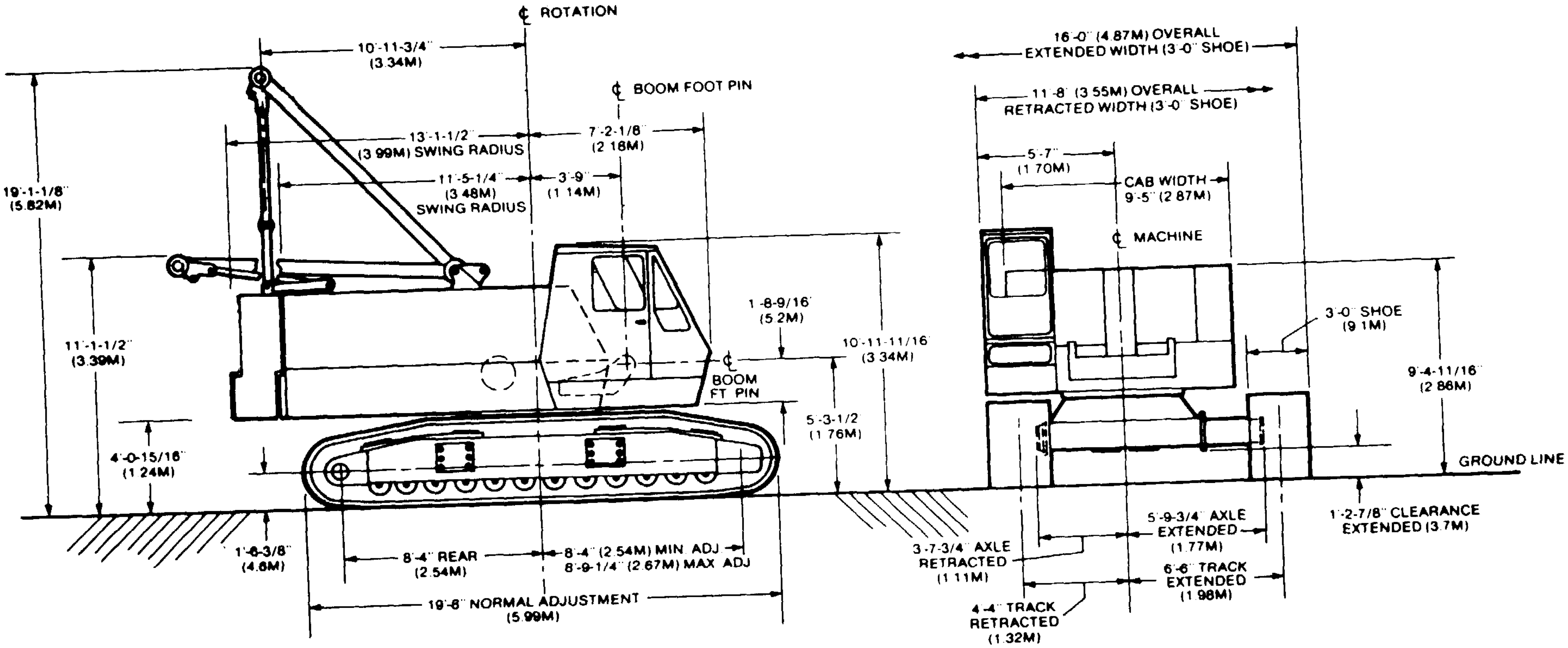


Figure 1-4. General Dimensions (2105J170)

Table 1-1. English to Metric Conversions

Multiply	by	to get equivalent number of:
LENGTH		
Inch	25.4	millimetres (mm)
Foot	0.3048	metres (m)
Yard	0.9144	metres
Mile (Statute)	1.609	kilometres (km)
AREA		
$Inch^2$	645.2	$millimetres^2$ (mm^2)
	6.45	$centimetres^2$ (cm^2)
$Foot^2$	0.0929	$metres^2$ (m^2)
$Yard^2$	0.8361	$metres^2$
VOLUME		
$Inch^3$	16 387.	mm^3
	16.387	cm^3
	0.0164	litres (l)
Quart	0.9464	litres
Gallon	3.7854	litres
$Yard^3$	0.7646	$metres^3$ (m^3)
MASS		
Pound	0.4536	kilograms (kg)
Ton (Short)	907.18	kilograms
Ton (Short)	0.907	tonne (t)
FORCE		
Kilogram	9.807	newtons (N)
Ounce	0.278	newtons
Pound	4.448	newtons

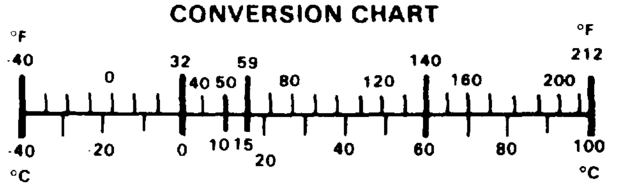
Multiply	by	to get equivalent number of:
TORQUE		
in-lbs	0.11298	newton-metres (N.m)
ft-lbs	1.3558	newton-metres
ft-lbs	0.1383	kg-m
POWER		
Horsepower	0.746	kilowatts (kW)
PRESSURE OR STRESS		
Inches of mercury	3.377	kilopascals (kPa)
Inches of water	0.2491	kilopascals
Pounds/sq. in. (psi)	6.895	kilopascals
Pounds/sq. in. (psi)	0.069	bars
ENERGY OR WORK		
BTU	1 055.	joules (J)
Foot-pound	1.3558	joules
Kilowatt-hour	3.6×10^6 or 3600000	joules (J = one W.s)
VELOCITY		
Miles/hour	1.6093	kilometres/hr (km/h)

TEMPERATURE

$$°F = \frac{9}{5}\,°C + 32$$

$$°C = \frac{5}{9}\,(°F - 32)$$

CONVERSION CHART



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STORAGE

Storage of the main machine, engine and torque converter is covered in a separate section of this Operator's Manual. See Section VI.

TOOLS AND TEST EQUIPMENT

Used For	Tool Number
Boom Hoist Assembly Tool - See Subsection 8C, Page 8C-4	218T1470

List of Items Furnished

Used For	Tool Number
Shear Pin Puller	921T1
Chain Tightener	100N1042
Chain Link	20Z592D2
2-3/4" Socket	21Z115D33
2" Socket	21Z115D21
Padlock	21Z1
Grease Gun	21Z101D2
Tubular Wrench Handle	221T8
Grease Fitting	44Z1D5
Grease Fitting	44Z1D6
Grease Fitting	44Z1D10
Grease Fitting	44Z1D14
Grease Gun Hose	44Z21
Grease Gun Adapter	44Z386
Bleeder Hose	44Z683
1-5/8 - 1" Socket	21Z115D14
Boom Hoist Clutch Spacer (Spare)	18T6700D16
Counterweight Sling	9230P2

ENGINE SPECIFICATIONS

	1800 rpm	2100 rpm	2300 rpm
Lubrication System			
Lubricating Oil Pressure (psi):			
Normal	43-65	45-65	45-65
Min. for Safe Operation	28	30	30
† Lubrlcattng Oil Temperature (degrees F.):			
Normal	200-235	200-235	200-235
Air System			
Air Box Pressure (inches mercury) - Min. at Full Load:			
At Zero Exhaust Back Pressure	21.0	30.0	37.0
At Max. Full-Load Exhaust Back Pressure (clean ports)	19.5	27.7	34.7
Air Inlet Restriction (inches water) - Max.:			
Full-Load Speed:			
Dirty Air Cleaner (dry)	14.5	20.0	20.0
Clean Air Cleaner (dry)	8.7	12.0	12.0
No-Load Speed:			
Dirty Air Cleaner (dry)	8.7	12.0	12.0
Clean Air Cleaner (dry)	5.2	7.2	7.2
Crankcase Pressure (inches water) - Max.	0.5	0.9	1.2
Exhaust Back Pressure (inches mercury) - Max.:			
Full Load	2.0	3.0	3.0
Fuel System			
Fuel Pressure at Inlet Manifold (psi) - Normal	50-70	50-70	50-70
Fuel Spill (gpm) - Min. at No Load (.080" orifice)	0.9	0.9	0.9
Pump Suction at 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

†The lubricating oil temperature range is based on the temperature 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.
*Indicates area over radius.

ENGINE SPECIFICATIONS (Cont.)

	1800 rpm	2100 rpm	2300 rpm

Compression

Compression Pressure (psi at sea level):

Average - New Engine at 600 rpm	475
Minimum at 600 rpm	425
Type	2 cycle
Number of Cylinders	4
Bore (inches)	4.25
Bore (mm)	108
Stroke (inches)	5
Stroke (mm)	127
Compression Ratio (nominal)	17 to 1
Total Displacement (cu. in.)	284
Total Displacement (litres)	4.66
Firing Order	1-3-4-2
Number of Main Bearings	5

TABLE 1-2. DRUM PERFORMANCE DATA

DRUM PERFORMANCE DATA W/DDA 4-71T & ALLISON TORQUE CONVERTER

CRANE DRUMS

		Right and Left Drum						
		1st Layer		4th Layer		7th Layer		
Line Pull		Line Speed		Line Speed		Line Speed		
lbs	kg	ft/min	m/min	ft/min	m/min	ft/min	m/min	
		361.0	110.1	436.2	133.0	497.2	151.6	Hoisting
5,000	2,270	259.1	79.0	317.7	96.9	376.3	114.8	Lowering
		314.1	95.8	357.6	109.1	398.0	121.4	Hoisting
10,000	4,540	259.1	79.0	317.7	96.9	376.3	114.8	Lowering
		269.1	82.1	281.1	85.7	277.3	84.6	Hoisting
15,000	6,810	259.1	79.0	317.7	96.9	376.3	114.8	Lowering
		209.9	64.0	201.1	61.3	183.6	56.0	Hoisting
20,000	9,080	259.1	79.0	317.7	96.9	376.3	114.8	Lowering

TABLE 1-2. DRUM PERFORMANCE DATA (Cont.)

BOOM HOIST DRUMS

Line Pull		1st Layer Line Speed		4th Layer Line Speed		7th Layer Line Speed		
lbs	kg	ft/min	m/min	ft/min	m/min	ft/min	m/min	
3,000	1,360	530.4	161.7	670.2	204.3	796.6	242.8	Hoisting
		253.4	77.2	325.2	99.1	397.0	121.0	Lowering
6,000	2,720	477.3	145.5	566.1	172.5	644.5	196.4	Hoisting
		253.4	77.2	325.2	99.1	397.0	121.0	Lowering
9,000	4,080	418.4	127.5	473.2	144.2	476.0	145.1	Hoisting
		253.4	77.2	325.2	99.1	397.0	121.0	Lowering
12,000	5,440	357.0	108.8	353.0	107.6	327.0	99.7	Hoisting
		253.4	77.2	325.2	99.1	397.0	121.0	Lowering

CLAMSHELL/DRAGLINE DRUMS

		Clamshell 1st Layer		Dragline 1st Layer			
		Right & Left Drum		Right Drum		Left Drum	
Line Pull		Line Speed		Line Speed		Line Speed	
lbs	kg	ft/min	m/min	ft/min	m/min	ft/min	m/min
5,000	2,270	361.0	110.1	361.0	110.1	336.0	102.4
10,000	4,540	314.1	95.8	314.1	95.8	297.3	90.6
15,000	6,810	269.1	82.1	269.1	82.1	258.0	78.6
20,000	9,080	209.9	64.0	209.0	64.0	210.8	64.3

NOTES:

1. Line speeds based on engine at full load governed rpm.
2. Max. permissible working line pull for crane drum 15,000 lbs. (6,804 kg).
3. Max. permissible working line pull for boom hoist drum - 7,600 lbs. (3,447 kg).

SECTION II

CONTROLS AND OPERATION

SECTION II

CONTROLS AND OPERATION

CONTROL IDENTIFICATION

The instruments and controls in the operator's module are shown in Figure 2-1. The numbers in the figure correspond to the numbers in the following list, which identifies the controls and describes their function.

Before attempting to operate this machine, the operator should carefully study all of the information in this section and in Catalog 240. The operator should become thoroughly familiar with the location and purpose of each control on the machine.

1. ENGINE SPEED CONTROLS. The engine speed controls are mounted on the swing lever and on the floor. Turn the handle clockwise (looking from above) or depress the pedal to increase engine speed. Turn the handle counterclockwise or release the pedal to decrease engine speed.

2. SWING CONTROL LEVER. Push this lever forward, away from the operator, to swing the upper toward the boom. Pull toward the operator to swing the upper away from the boom.

3. SWING BRAKE CONTROL SWITCH. Move this switch to the right (ON) to set the swing brake. Push this switch to the left (OFF) to release the swing brake.

4. RIGHT DRUM BRAKE PEDAL. Depress this pedal lo apply the right drum brake. Allow the pedal to return to the free position to release the right drum brake.

5. LEFT DRUM BRAKE PEDAL. Depress this pedal to apply the left drum brake. Allow the pedal to return to the free position to release the left drum brake.

6. LEFT DRUM CONTROL LEVER. Pull this lever back, toward the operator, to raise the load on the drum. Push this lever forward to lower the load.

7. LEFT DRUM TURN INDICATOR. The left drum turn indicator is located on the left drum control lever. The operator can feel the indicator move as he operates the left drum lever. The faster the left drum rotates the faster the motion of the indicator, the slower the rotation of the left drum the slower the motion of the indicator.

8. RIGHT DRUM CONTROL LEVER. Pull this lever back, toward the operator, to raise the load on the right drum. Push this lever forward to power lower the load.

9. RIGHT DRUM TURN INDICATOR. The right drum turn indicator is located on the right drum control lever. Its operation is identical to the left drum turn indicator (item 7).

10. SIGNAL HORN BUTTON. Depress this button to sound the signal horn.

CAUTION

The signal horn will also sound if the Fairlead limit switch is activated. The limit switch is activated when the boom contacts the switch on the top of the Fairlead.

11. BOOM HOIST CONTROL LEVER. Pull this lever back to raise the boom. Push the lever forward to lower the boom. The boom hoist brake will set when the lever is returned to the neutral position.

12. PROPEL CONTROL LEVER. The propel control lever provides the means to control the forward and backward motions as well as the steering functions of the crane. Forward or backward movement of the lever controls the speed in the respective direction. Movement to the right or left and slightly forward or backward controls the steering functions.

13. PROPEL LOCK SWITCH. Move this switch away from the operator (ON) to set the propel brakes and lock the propel system. Move the switch toward the operator (OFF) to release the propel brakes. These brakes are holding brakes and not intended to be used in stopping the propel motion.

14. OPERATOR'S SEAT WITH SEAT BELT. The operator's seat has several comfort adjustments which include fore and aft seat tilt, fore and aft seat position, back angle adjustment, arm rest adjustment and head rest adjustment. Always use seat belt when operating machine.

15. THIRD DRUM CONTROL LEVER. Pull this lever back, toward the operator, to raise the load on the third drum. Push this lever forward to release the third drum brake and lower the load. Neutral position applies the third drum brake.

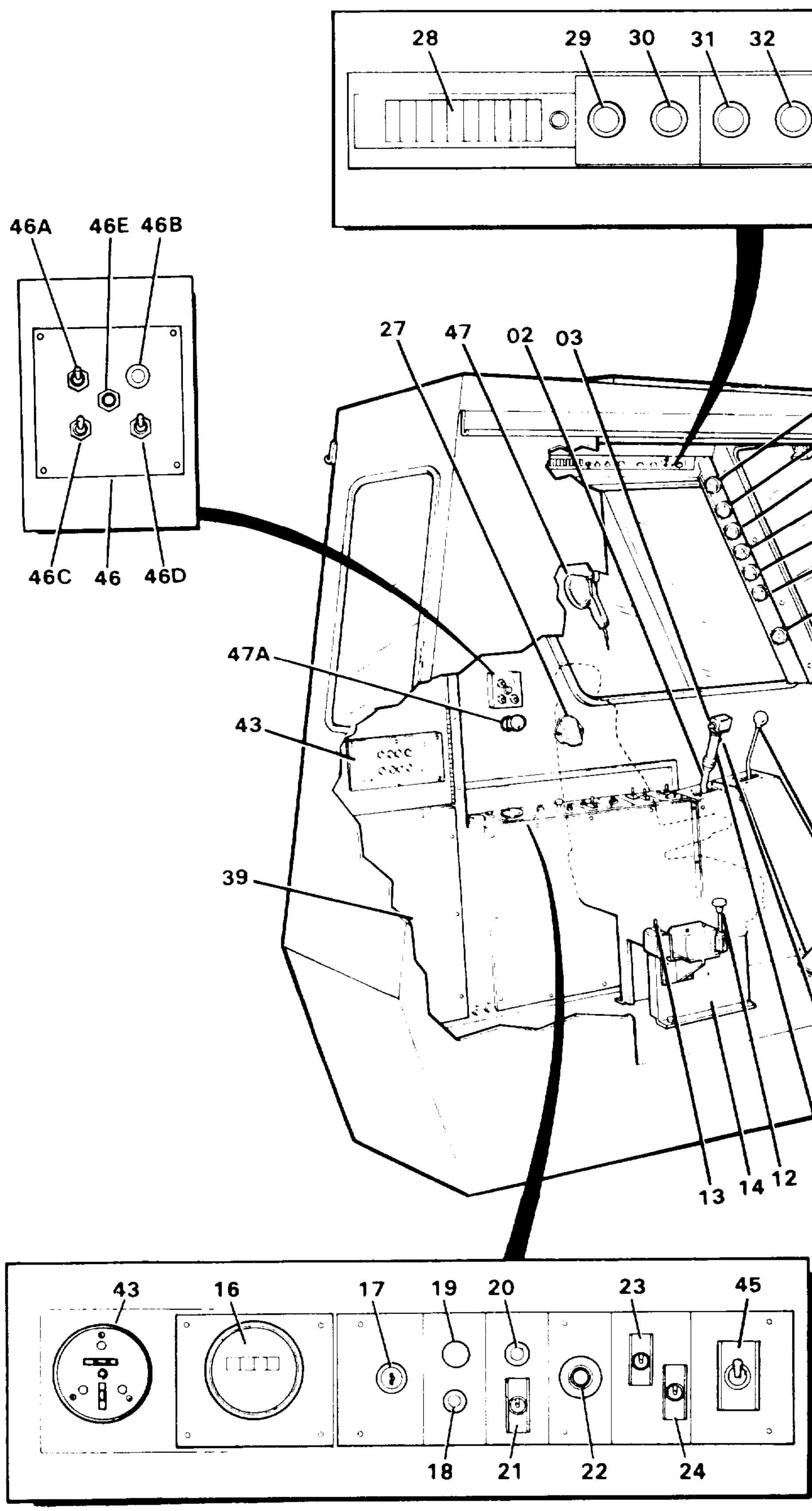


Figure 2-1. Operator's Controls

LEGEND FOR FIGURE 2-1

01. ENGINE SPEED CONTROL
02. SWING CONTROL LEVER
03. SWING BRAKE CONTROL SWITCH
04. RIGHT DRUM BRAKE PEDAL
05. LEFT DRUM BRAKE PEDAL
06. LEFT DRUM CONTROL LEVER
07. LEFT DRUM TURN INDICATOR
08. RIGHT DRUM CONTROL LEVER
09. RIGHT DRUM TURN INDICATOR
10. SIGNAL HORN BUTTON
11. BOOM HOIST CONTROL LEVER
12. PROPEL CONTROL LEVER
13. PROPEL LOCK SWITCH
14. OPERATOR'S SEAT WITH SEAT BELT
15. THIRD DRUM CONTROL LEVER
16. HOURMETER/TACHOMETER
17. IGNITION AND START SWITCH
18. STARTING AID BUTTON
19. PANEL LIGHT SWITCH
20. CLUTCH ENGAGE LIGHT
21. ENGINE CLUTCH SWITCH
22. BOOM HOIST RELEASE SWITCH
23. LEFT DRUM PAWL SWITCH
24. RIGHT DRUM PAWL SWITCH
25. LEFT DRUM BRAKE SWITCH
26. RIGHT DRUM BRAKE SWITCH
27. PANEL LIGHT
28. DOME LIGHT
29. TOP WIPER SWITCH
30. WINDSHIELD WIPER SWITCH
31. HEATER CONTROL
32. DEFROSTER FAN SWITCH
33. LOAD WEIGHING SYSTEM (SEE FIGURE 2-2)
34. ENGINE FAULT WARNING LIGHT
35. ENGINE OIL PRESSURE GAUGE
36. ENGINE WATER TEMPERATURE GAUGE
37. ENGINE VOLTMETER
38. FUEL GAUGE
39. TORQUE CONVERTER TEMPERATURE GAUGE
40. TORQUE CONVERTER CHARGE PRESSURE GAUGE
41. HYDRAULIC SYSTEM PRESSURE GAUGE
42. DIPPER TRIP CONTROL
43. ELECTRICAL SYSTEM CIRCUIT BREAKERS
44. LEVEL
45. SWING LOCK SWITCH
46. FLOODLIGHT CONTROLS
47. TROUBLE LIGHT

---

16. HOURMETER/TACHOMETER. The hourmeter indicates the total number of hours the engine has been run. The tachometer indicates engine speed (rpm).

17. IGNITION AND START SWITCH. Rotate the key clockwise to energize the machine's electrical system. Turn the key against the spring resistance to engage the engine starter. Turn the key counterclockwise to de-energize the electrical components and shut down the engine. The key must be returned to the OFF position before attempting a restart.

18. STARTING AID BUTTON. The engine starting aid is used to assist in cold weather starting. Depress this button to provide a shot of ether for cold weather starting,

19. PANEL LIGHT SWITCH. Rotate this switch clockwise to illuminate the panel light. Control the brightness of the light by rotating the switch clockwise or counterclockwise as desired.

20. CLUTCH ENGAGE LIGHT. This green light will be lit when the engine clutch is engaged.

21. ENGINE CLUTCH SWITCH. Move this switch toward the operator to engage the engine clutch. Push this switch away from the operator to disengage the engine clutch.

NOTE

The engine clutch switch must be in the disengaged position in order to start the engine.

22. BOOM HOIST RELEASE SWITCH. This switch is used to override the boom hoist limit switch, if the boom is lifted beyond the normal operating limits. Depress and hold this switch, to override the boom hoist limit switch. *and lower the boom.* While this switch is depressed the signal horn will sound.

WARNING

Do not use this switch to override the boom **hoist limit switch to allow the boom to be raised beyond the normal operating limits. This is an extremely dangerous operating procedure, since the boom could be raised to the point where the boom will topple over the back of the machine.**

23. LEFT DRUM PAWL SWITCH. Move this switch toward the operator (ON) to engage the safety stop pawl into the drum teeth of the left drum. Push the left drum control lever forward momentarily to lock the pawl into the drum teeth. To release the pawl move the switch to the OFF position then pull the left drum control lever toward the operator until the drum turns, which allows the pawl to disengage from the drum teeth.

24. RIGHT DRUM PAWL SWITCH. Move this switch toward the operator (ON) to engage the safety stop pawl into the drum teeth of the right drum. Push the right drum control lever forward momentarily to lock the pawl into the drum teeth. To release the pawl, move the switch to the OFF position then pull the right drum control lever toward the operator until the drum turns, which allows the pawl to disengage from the drum teeth.

25. LEFT DRUM BRAKE SWITCH. Move this switch up (ON) to lock the spring set left drum brake in the applied position. Pull the switch down (OFF) to release the brake.

26. RIGHT DRUM BRAKE SWITCH. Move this switch up (ON) to lock the spring set right drum brake in the applied position. Pull the switch down (OFF) to release the brake.

27. PANEL LIGHT. This light illuminates the side control panel. The light is controlled by switch (19).

28. DOME LIGHT. This light is used to illuminate the operator's module. A switch located on the light is used to turn the light on and off.

29. TOP WIPER SWITCH Turn this switch clockwise, to the detent, to operate the top window wiper at slow speed. Turn the switch past the detent to operate the wiper at high speed.

30. WINDSHIELD WIPER SWITCH. Turn this switch clockwise, to the detent, to operate the windshield wiper at slow speed. Turn the switch past the detent to operate the wiper at high speed

31. HEATER CONTROL. Place this switch in the center position to operate the fan at low speed. Place the switch in the extreme right positron to operate the fan at high speed.

There is also a heater shutoff valve located on the engine. Turn the valve clockwise when heat is not required. Turn the valve counterclockwise when heat is desired.

32. DEFROSTER FAN SWITCH Turn this switch clockwise to energize the defroster fan. Control the speed of the fan by turning the switch clockwise or counterclockwise as desired.

33. LOAD WEIGHING SYSTEM. The load weighing system continuously monitors load moment and boom angle. The computer calculates and displays the load moment and the boom angle. If preset load limits are approached or exceeded, the computer visually and audibly alerts the operator. The items below are furnished with the load system.

A. CENTRAL UNIT. The central unit monitors the variable boom and load operating conditions. These signals are processed by the central unit and transmitted to the meters. The control unit contains some controls necessary to calibrate and test the computer system.

B. LOAD MOMENT METER. This meter indicates total load moment. It also contains program selector switches, warning lights and horn and test buttons.

C. ANGLE METER. This meter indicates boom angle.

WARNING

This unit is an operating aid and cannot be used as a substitute for the rating plate. To maintain system accuracy the unit must be properly tested each day and before each major lift. The unit should be inspected on a weekly basis for pinched or cracked cables. Also check that all connectors are tight.

34. ENGINE FAULT WARNING LIGHT AND BUZZER. This warning device will be activated when the engine water temperature rises above normal or oil pressure drops below normal.

NOTE

After start-up the warning device will remain activated until the engine oil pressure rises to the normal pressure. If oil pressure does not reach normal within 15 seconds after start-up, shut down the engine immediately and correct the cause of the low oil pressure.

35. ENGINE OIL PRESSURE GAUGE. This gauge indicates engine oil pressure. The gauge should read between 45 and 70 psi during normal operation. There should be approximately 10 psi at low idle.

36. ENGINE WATER TEMPERATURE GAUGE. This gauge shows the temperature of the engine coolant. The gauge should read between 185-200°F during normal operation.

37. ENGINE VOLTMETER. The voltmeter measures the voltage produced by the alternator and indicates the condition of the battery. See Figure 2-3 for an explanation of the voltmeter readings.

38. FUEL GAUGE. This gauge shows the amount of fuel remaining in the fuel tank.

39. TORQUE CONVERTER OIL TEMPERATURE GAUGE. During operation of the machine, the torque converter oil temperature should range between 200-210°F. If the temperature does not remain within this range, locate and correct the difficulty. The temperature must never exceed 250°F.

40. TORQUE CONVERTER CHARGE PRESSURE GAUGE. During operation of the machine, this gauge should indicate a pressure of approximately 30 psi. Wide variations from this pressure indicate a problem in the torque converter. The machine should be shut down and the problem corrected immediately. At idle the chrage pressure should be approximately 15 psi.

41. HYDRAULIC SYSTEM PRESSURE GAUGE. This gauge indicates the pressure in the upper hydraulic system. The normal pressure in this system is 1500 psi with a working range of 1400-1710 psi.

42. DIPPER TRIP CONTROL. Use this button to control the dipper door on the shovel. Press the button to open the door. Release the button to allow the door to close.

43. ELECTRICAL SYSTEM CIRCUIT BREAKERS. The function of the circuit breakers is to protect the various upper electrical circuits.

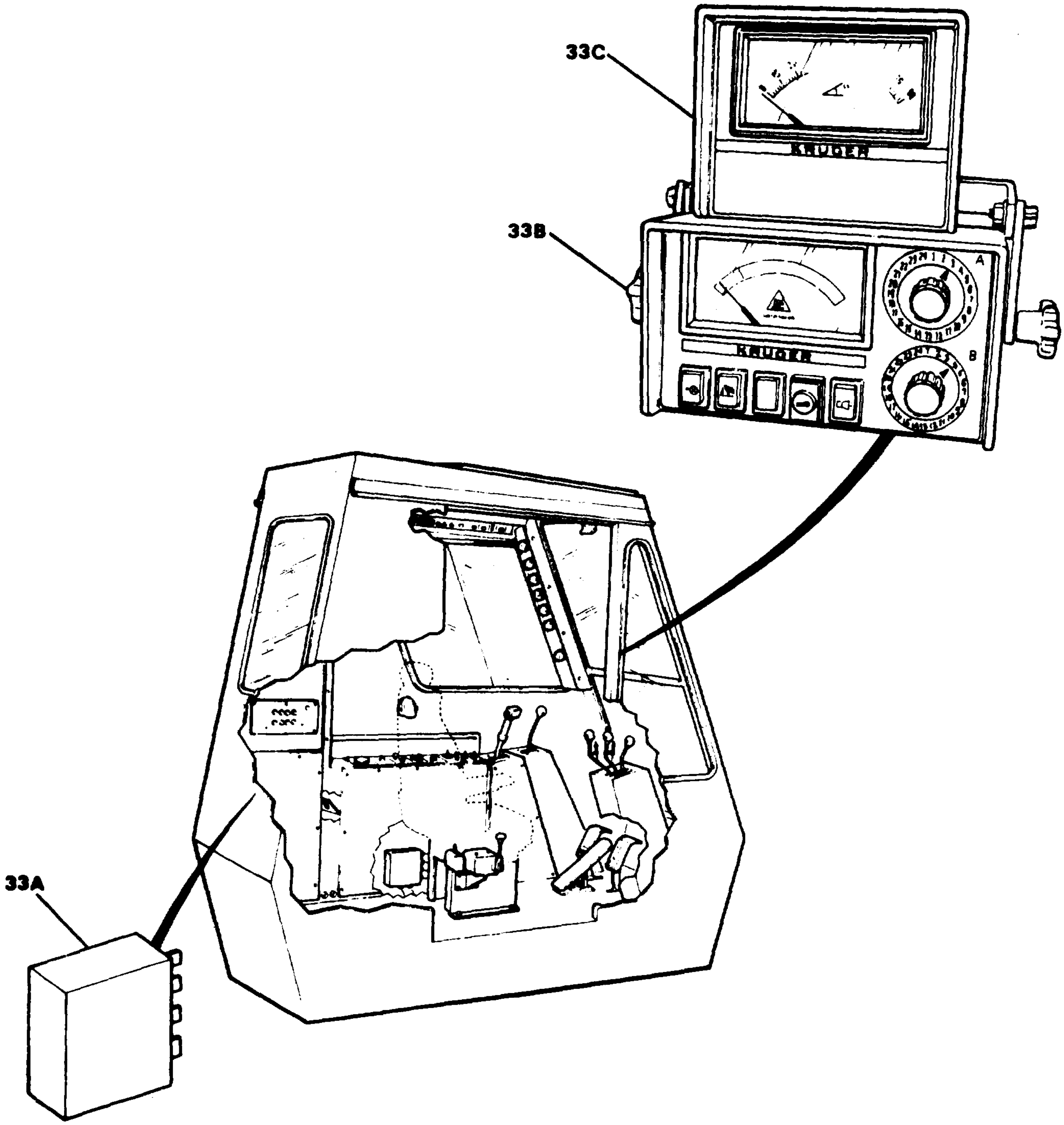
WARNING

Under no circumstances should a circuit breaker be prevented from tripping by any means. Overloaded electrical circuits can cause extensive damage to the machine and/or injury to personnel.

An electrical overload will cause a breaker to trip. Reset the circuit breaker and continue operation. The circuit breaker contains a trip-free feature which allows its contacts to open even it the breaker is manually hold in the reset position against an overload. If the circuit breaker should trip shortly after it is reset. check the circuit protected by the circuit breaker for the cause of the overload.

44. LEVEL. Check the level of the machine with this gauge.

45. SWING LOCK SWITCH. Move switch toward operator to engage the 360° swing lock. Move switch away from operator to disengage swing lock.



TA5015640

Figure 2-2. Load Weighing System

Engine not running or running at slow idle.	Engine running fast enough to make generator* produce.

1

Dead or disconnected battery. Disconnected or badly connected meter.

1

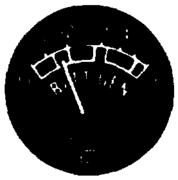
Disconnected meter. Engine could not run with dead or disconnected battery unless circuit was completed around battery.

2

Very low battery charge. Engine might not start.

3

Low battery charge. Constant reading in this area would indicate need for check on generator and voltage regulator.



2 3

When meter pointer stays below 13.3 or 26.6 with the engine running fast enough to operate generator, it shows that generator is not operating or voltage regulator is out of adjustment, or that current being drawn from battery by lights, heater fan, or other load, exceeds generator output.

4

Well-charged battery. This indicates a good battery and also that generator and voltage regulator are operating properly.

5

The pointer might remain in this position temporarily when the engine has been stopped after considerable use, due to a "surface charge" in the battery. To get a correct reading, turn on headlights for a few minutes.

4 5

When engine is started, pointer may stay in this area temporarily but should gradually rise above 13.3 or 26.6 as generator reaches normal output.

---

6 7

Under normal conditions, a 12V battery is fully charged at 12.8V; a 24V battery at 25.6. A slightly higher reading may occur under the conditions outlined in No. 5 but, generally speaking, any reading above 12.8 or 25.6 when the engine is stopped is not a true reading.

*NOTE: The word "generator" refers to both generator and alternator since both require the same instrumentation.

While a 12V gauge is shown, the principle of the voltmeter is the same for a 24V electrical system. The only differences are the values on the gauge face.

6

This is the area in which the pointer should be when generator, voltage regulator and battery are all in good condition and working properly.

7

When the pointer goes above 15.2 or 30.4, the voltage regulator is set too high or is jammed and continued operation of the engine will burn out the battery.

P-100

Figure 2-3 Voltmeter Operation

46. FLOODLIGHT CONTROLS. This panel and switch are used to control the floodlight on the machine. The toggle switches are identified as follows:

A. UPPER LEFT. This switch controls the floodlight on the left side of the upper.

B. UPPER RIGHT. This switch controls the floodlight on the right side of the upper.

C. LOWER LIGHTS. This switch controls the lower floodlights.

D. MACHINE HOUSE. This switch controls the machine house floodlights.

E. CIRCUIT BREAKER.

47. TROUBLE LIGHT. A trouble light is provided in the main cab. Lamp socket (47A) is provided to plug in the trouble lamp and hook (47B) is used to store the coiled up trouble lamp. A trouble light is also located in the right rear corner of the main machinery deck.

48. PLANETARY LOCKOUTS. Use these plates as shown in Figure 2-4 to prevent the left and right drum controls (Items 06 and 08) from being moved forward. This locks out the planetary lowering of the drums and is used when the machine is performing duty cycle work such as a dragline. Set the plates on the drum lever console as shown and secure with machine screws and washers.

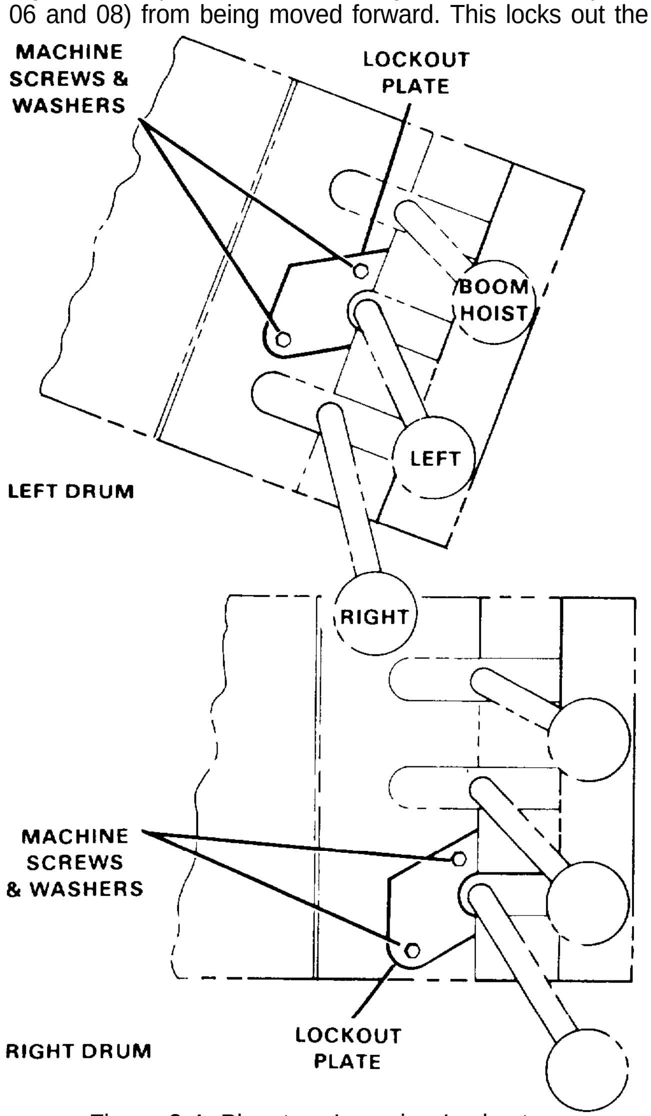


Figure 2-4. Planetary Lowering Lockouts

49. DIVERTER SWITCH (NOT SHOWN). This switch is located under the revolving frame and accessible through a hinged panel at the front left side of the revolving frame. See the topic, Extending and Retracting the Crawlers, later in this section for the operation of this switch.

50. ANTI-ROTATION BAR (See Figure 2-5). This anti-rotation bar should be used when the machine is transported from one site to another. The revolving frame can be locked in either the forward or rearward position.

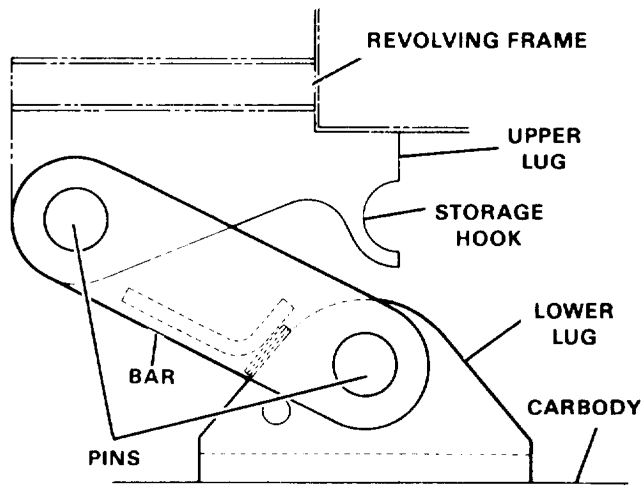


Figure 2-5. Anti-Rotation Bar (2100J1046)

51. CRAWLER EXTENSION AND RETRACTION CONTROLS (See Figure 2-6). These controls are mounted on the revolving frame and are used to extend and retract the crawler tracks. See the topic, Extending and Retracting the Crawlers, later in this section for the operation of these controls.

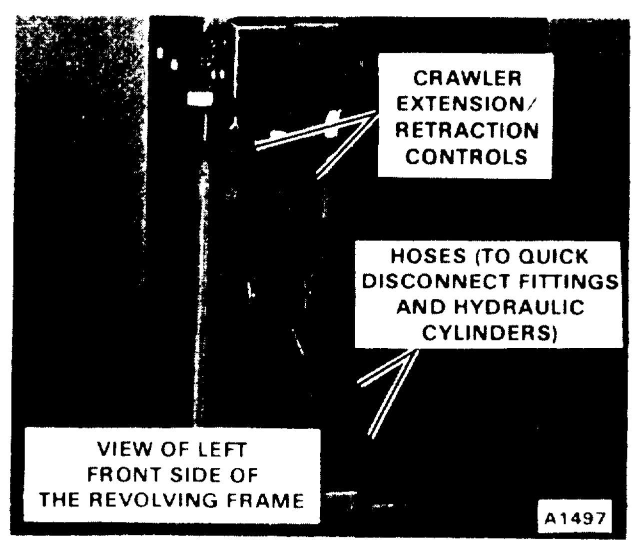


Figure 2-6. Crawler Extension and Retraction Controls

52. DRUM COVER. A drum cover is provided (see Figure 2-7) to protect the drums and rope. If the drum cover is to be used with the hoist rope in place, adjust boom angle to align the hoist ropes with the slots in the cover. Close the remainder of the slot using the built-in VELCRO® closure. The cover is to be used for MACHINE STORAGE ONLY. Roll up and tie back the cover as shown before operating the machine or when the machine is being lifted by the forward lifting lugs.

MACHINE OPERATION

GENERAL

The following operating suggestions are offered as a reminder rather than as an attempt to instruct, since the Harnischfeger Corporation is well aware of the fact that a machine of this size is not entrusted to anyone except a fully qualified operator.

1. Always consult the rating plate for the maximum load which may be lifted with the various combinations of boom length, boom angle, crawlers extended or retracted, and other variable factors which may be involved with lifting the load.

2. When swinging the load, it should be near the machine and as close to the ground as possible.

3. Always pay out wire rope from the drums when the boom is being lowered to prevent "two blocking" the hook block.

4. If the operator must leave the machine he should lower all loads to the ground. The swing brake should be applied to prevent the upper from turning. Also disengage the engine clutch and apply the propel brake. Do not leave the machinery turning over.

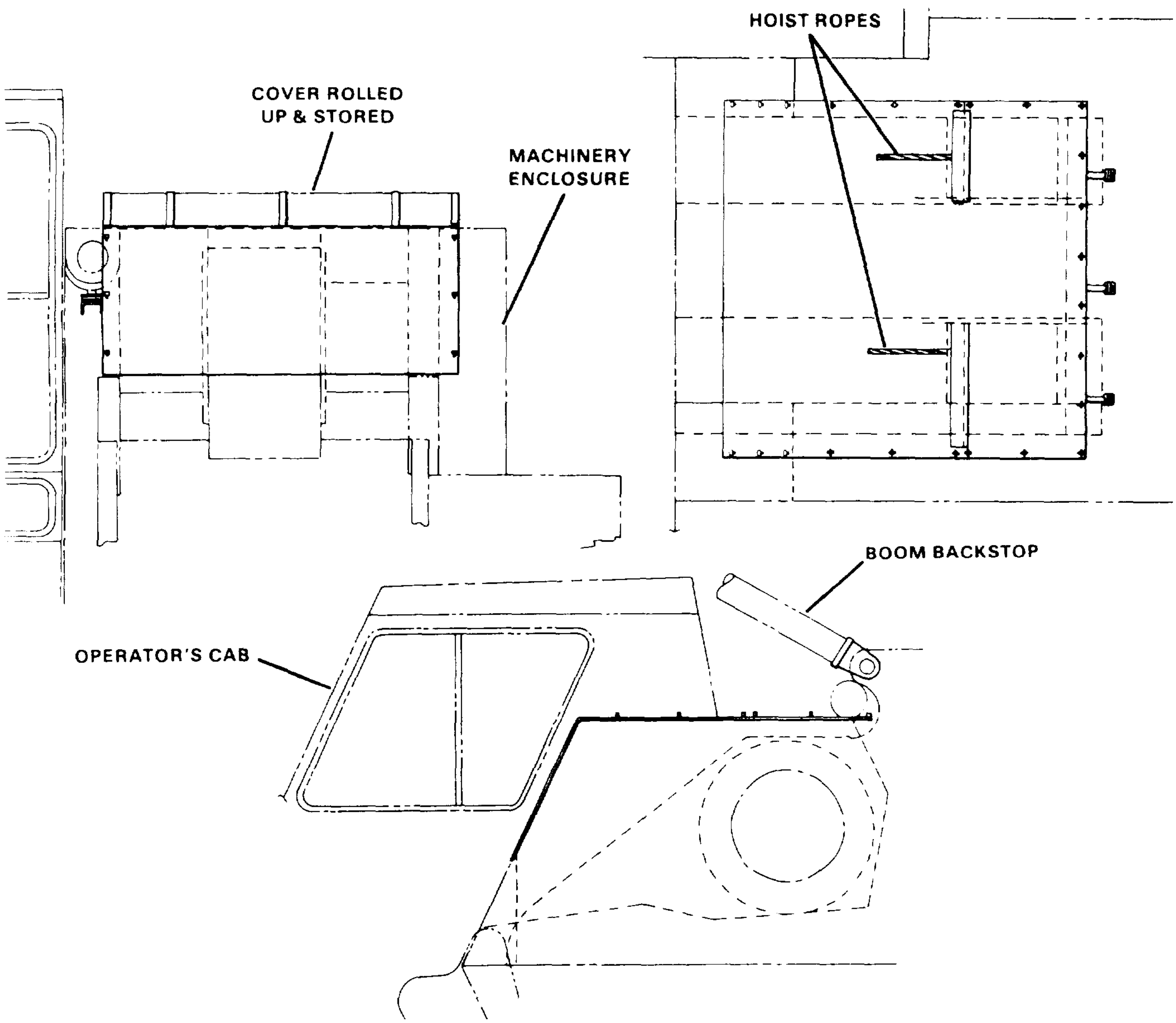


Figure 2-7. Drum Cover

PREOPERATION INSPECTION

Before actually operating the machine each day, perform the "A" Maintenance Checks outlined in Section V.

STARTING THE ENGINE

To start the engine, proceed as follows (see Figure 2-1):

1 Move the engine clutch switch (item 21) to the disengaged position.

2. Check to be sure that the left and right drum brake switches (items 25 and 26) are in the "on" position.

3. Make certain that the boom hoist swing, and left and right drum levers are in the neutral position. The swing and propel brakes must be applied.

4. Turn the ignition switch to the "start" position until the engine starts. If the engine does not start within 30 seconds, turn the key to the "off" position and wait two minutes before attempting to start the engine again. The starter will engage only when the starting sequence begins with the key in the "off" position.

NOTE

The use of a cold weather starting aid may be required in extremely cold weather. Press the starting aid button (item 18), wait two seconds and engage the starter. Repeat the procedure for temperatures below 0°F.

5. Check all gauges, immediately after the engine starts, to be sure they are reading properly. If the readings are improper, stop the engine immediately and determine the cause of the improper gauge reading before continuing operation.

6. Allow the engine to run at 800 to 1000 rpm for 4 or 5 minutes before working the machine.

PROPELLING THE MACHINE

Propel direction and steering are controlled by the propel control lever (see Figure 2-8). Propel speed and torque are affected by the engine rpm and by the proportional movement of the propel control lever. Propel the machine as follows:

CAUTION

Do not attempt to propel the machine with the engine speed under 1000 rpm. Propelling at engine speeds below 1000 rpm could damage the propel pumps due to a lack of oil pressure.

1. Increase the engine speed to the maximum governed rpm's.

2. Release the propel brakes by moving the propel lock switch to the "off" position.

3. Move the propel controller in the desired direction of travel. Propel direction as related to control lever movement is illustrated in Figure 2-8.

4. When the machine has been moved to its new location allow the propel control lever to return to neutral and place the propel brake switch in the "on" position.

EXTENDING AND RETRACTING THE CRAWLERS

A bank of valves, located at the left front side of the upper, controls the extension and retraction of the crawler tracks. Flow to this valve bank is controlled by the combination valve located at the hydraulic reservoir. This valve is controlled by a switch mounted adjacent to the valve bank in the left front side of the upper as shown in Figure 2-6.

Connected to the valve banks are two hoses that are stored on the underside of the upper platform. These hoses have quick disconnect adapters that fasten to the hydraulic cylinders The adapters are reversed so the extension hose can only be connected to the extension port. The same is true for the retraction hose.

To extend or retract the crawlers, proceed as follows:

1. Equip the rear of the machine with one counterweight (see Section IV). Equip the front of the machine in one of the following ways:

A. The boom base section in the horizontal position.

B. The basic boom (base plus tip) in the horizontal position and blocked securely.

2. Locate the machine on firm, level ground and swing the upper so the boom is over the crawler to be extended. Lower the boom to the horizontal and block it securely.

3. Connect the hydraulic cylinders to the side frame brackets of the crawler to be extended. Fasten with the pins provided. Connect the hoses to the hydraulic cylinders.

CAUTION

Do not place the hydraulic oil diverting valve switch in the "lower" position until the hoses are attached to the fittings on the hydraulic cylinders.

4. Position the diverting valve switch to "lower", thereby diverting hydraulic fluid to the crawler extend/retract system.

5. Remove the keeper plate capscrews with the axle locking bolts attached from the side to be extended that secure each axle to the carbody (see Figure 2-9).

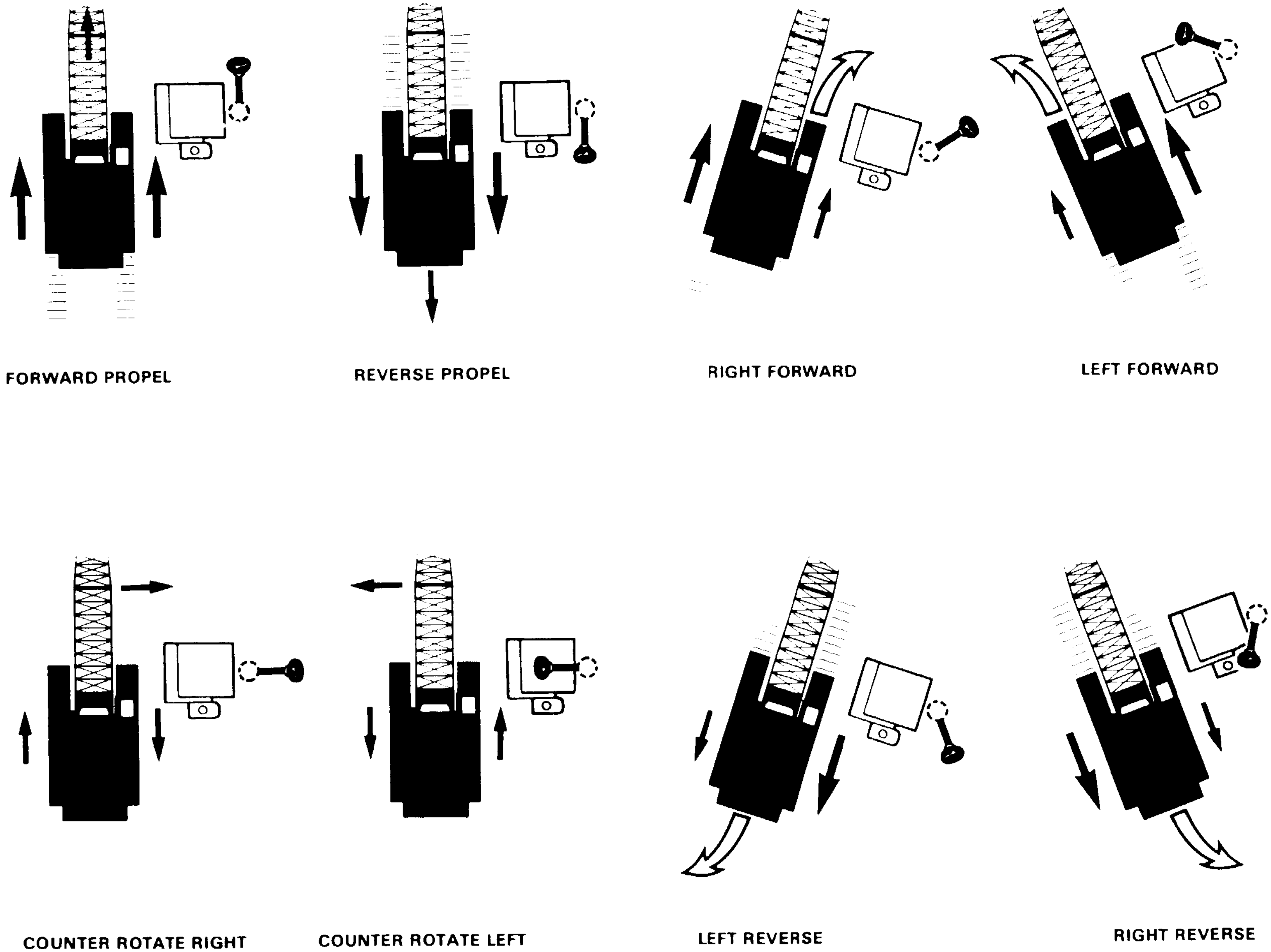


Figure 2-8. Propelling the Machine

NOTE

The bolt capscrew holds the axle locking bolt to the keeper plate. The keeper plate capscrew holds the keener plate to the carbody. Keep in mind to *always remove the inboard capscrews* which are the capscrews that hold the keeper plate to the carbody.

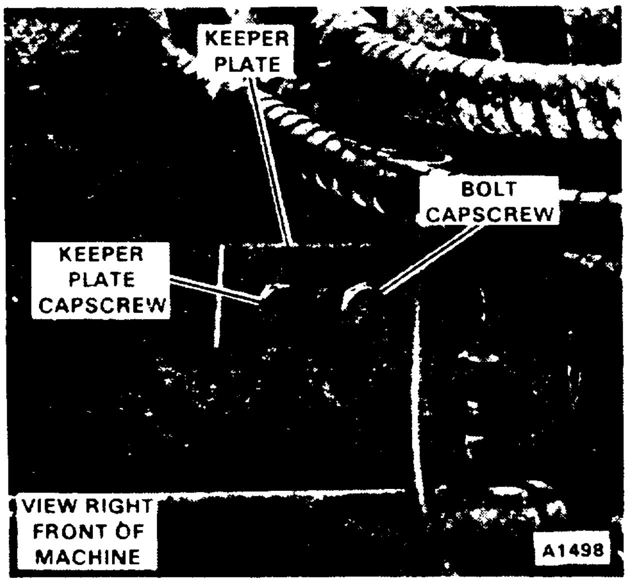


Figure 2-9. Axle Locking Bolts and Keepers

6. Extend the hydraulic cylinders to the end of their stroke by moving thecontrol levers simultaneously. The right hand lever controls the cylinder by the operator's side. The left hand lever controls the cylinder on the opposite side of the machine. It may be necessary to operate the control levers separately in case the axles tend to bind.

7. Install the axle locking pins to secure the axles in the extended position. Fasten the keeper plate in place with the capscrews provided.

8. Unpin the hydraulic cylinder at the crawler side frame and retract the cylinder. Swing the cylinder 180 degrees and pin it to the opposite crawler side frame bracket,

9. Move the diverter valve switch to the "upper" position. Disconnect the hoses from the hydraulic cylinders and temporarily store them under the upper platform.

10. Have all personnel stand clear of the machine and swing the upper 180 degrees. Repeat steps 2 through 8 for the other crawler.

11. The procedure for retracting the crawlers is the same as that given for extending; only now, the valves are operated simultaneously to retract the crawler side frames.

12. After the completion of either procedure, place the diverting valve switch in the "upper" position and store the hoses under the platform on the left side of the machine.

LIFTCRANE OPERATING CYCLE

The liftcrane operating cycle consists of five steps setting the boom angle (boom hoist operation), lifting the load (hoisting operation), swinging the load, spotting the load, and lowering the load (see Figure 2-10).

The functions of the drums during liftcrane operation are tabulated below. The numbers in the column "controls" correspond to the items in Figure 2-1.

Drum	Function	Controls
Right	Main Load Line	4, 8, 24, 26
Left	Jib Load Line	5, 6, 23, 25
Boom Hoist	Boom Hoist Line	11

STOPPING THE ENGINE

To stop the engine, proceed as follows:

1. Make certain that the drum and swing controls are in the neutral position, and the swing and propel brakes are applied. Engage the drum pawls and set the drum brakes.

2. If possible, allow the engine to run at half speed or less for several minutes before stopping the engine. This will allow the engine to cool down.

3. Place the ignition switch in the OFF position to stop the engine.

MACHINE TOWING

If, because of power loss, it should become necessary to tow this machine, the propel motors and brakes must be removed from the propel gear cases. See Section IX of the Shop Manual.

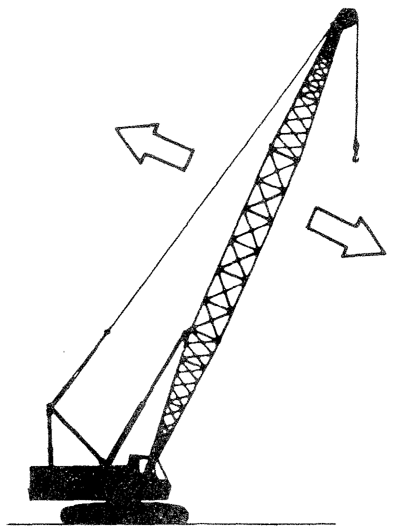
WARNING

Removal of the propel motors and brakes leaves the machine in a free-wheel condition with no on-board means for braking. External braking must be provided.

HAND SIGNALS

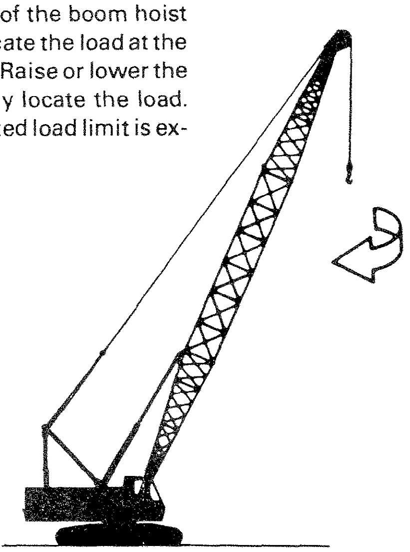
It is frequently necessary during crane operation for the operator to depend on a signalman for instructions. When moving the machine into a position where there is very limited clearance, or when handling loads that are out of sight of the operator, the use of a signalman is essential. The hand signals illustrated in Figure 2-11 are those generally accepted throughout the industry. Both the operator and the signalman should be thoroughly familiar with the

SETTING THE BOOM ANGLE. Position the boom at the proper angle for the load and working conditions. Refer to the rating plate for proper boom angle. Pull the boom hoist lever back to raise the boom. Push the boom hoist lever forward to lower the boom. Be sure to pay out line from the left and right drums, as required, to prevent the hook block(s) from coming in contact with the boom point.



SWINGING. Move the swing brake switch to the left (OFF) to release the swing brake. Push the swing lever forward to swing the upper to the left (toward the boom). Pull the swing lever back to swing to the right (away from the boom). To stop or reverse the swing motion, slowly move the swing lever in the opposite direction (plugging the swing motion). If you wish to hold the upper from turning, move the swing brake switch to the right (ON) position.

Spotting the load requires accurate control of the boom hoist and swing movements. It takes practice to locate the load at the exact spot without hunting or overshooting. Raise or lower the boom hoist lever as necessary to accurately locate the load. Never extend the boom out so far that the rated load limit is exceeded. See the rating plate.



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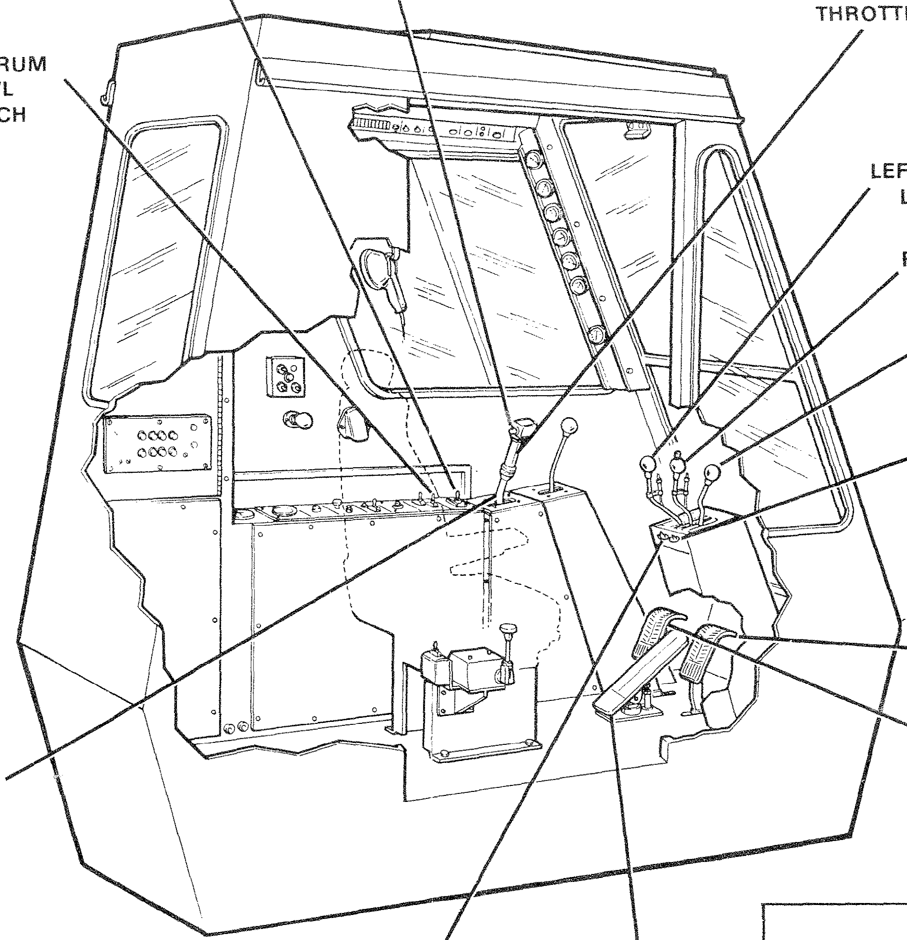
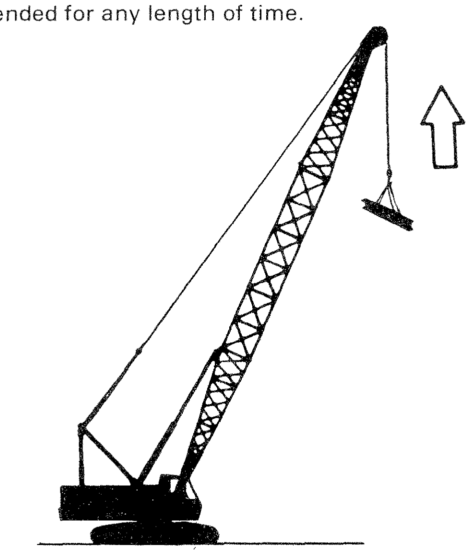
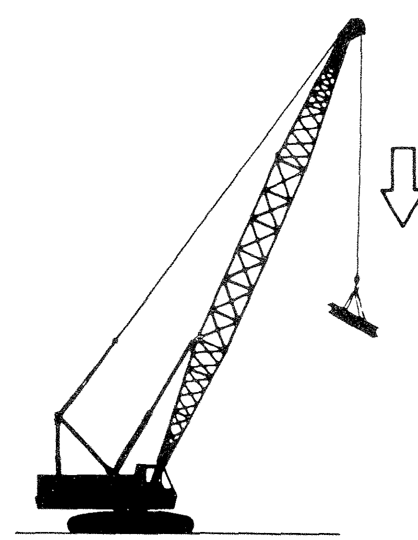


LIFTING THE LOAD (HOISTING). The operation of lifting the load consists of lowering the hook block, hooking on the load and then lifting the load.

Depress the brake pedal. Pull the drum brake switch down (OFF). Engage the planetary lowering by pushing the drum lever forward and release the brake pedal. This will power down the hook block. Control the lowering speed with the engine throttle, or depress the brake pedal, pull the drum lever back to neutral, and then slowly release the brake pedal. Attach the load to the hook block, then pull the drum lever back to raise the load. Pull the drum pawl switch towards the operator (ON) and move the drum brake switch up (ON) if the load is to be suspended for any length of time.



LOWERING THE LOAD. Depress the brake pedal. Pull the drum brake switch down (OFF). Select the proper transmission range to suit the load being lowered. Engage the planetary lowering by pushing the drum lever forward and releasing the drum brake pedal. This will power down the load.



NOTE

Control the lowering speed with the engine throttle, or depress the brake pedal, pull the drum lever back to neutral and then slowly release the brake pedal.

Figure 2-10. Liftcrane Operating Cycle

ALWAYS STAND IN CLEAR VIEW OF CRANE OPERATOR. BE SURE TO STAY A SAFE DISTANCE FROM HOOK BLOCK OR BOOM.

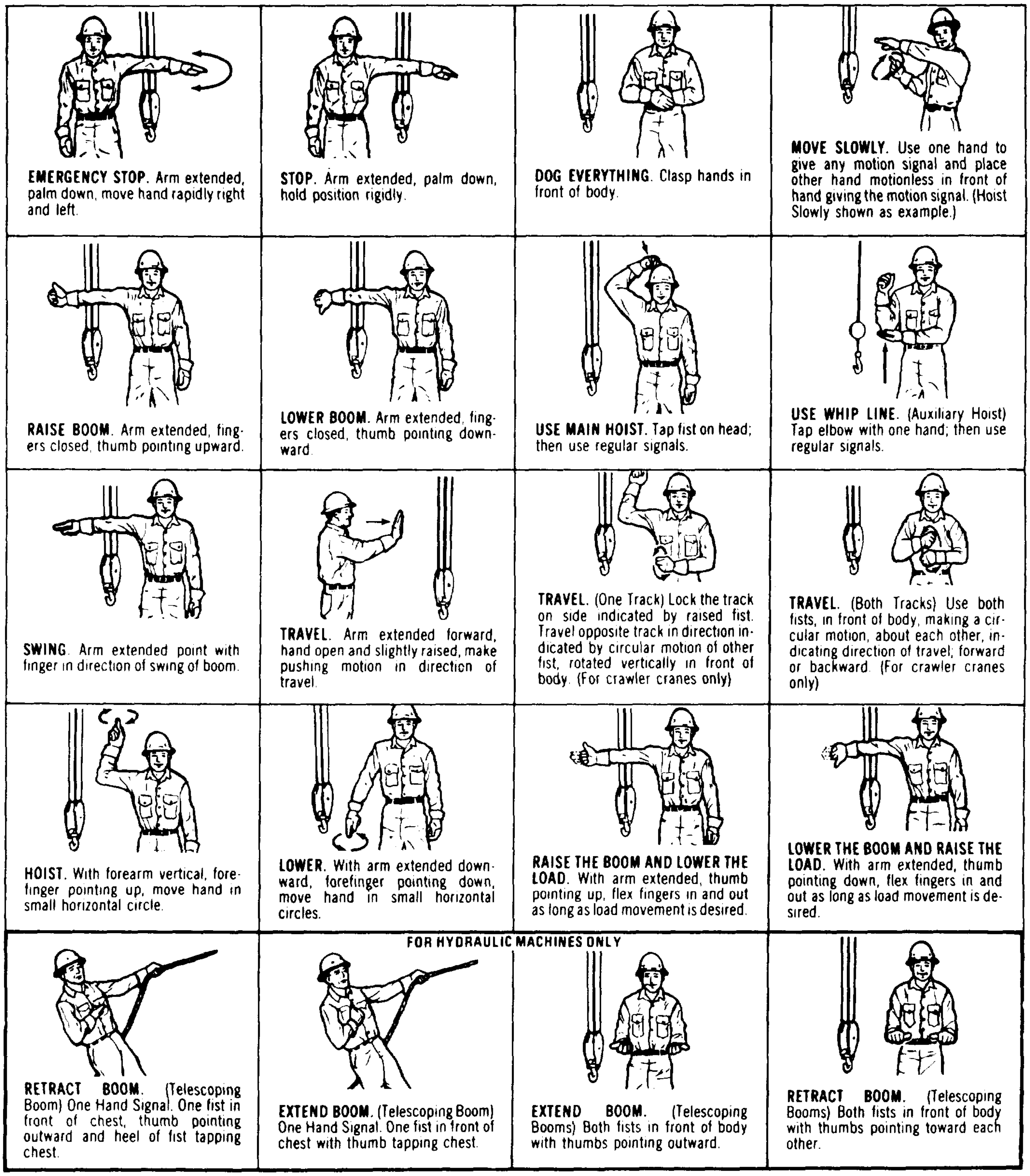


Figure 2-11. Hand Signals for Crane Operation

standard hand signals illustrated to ensure cooperation and teamwork.

ATTACHING THE LEADS USING A LATTICE BOOM

NOTE

- Tire pressure for P&H crane should only be 85 psi.
- Tire pressure for Grove crane should only be 100 psi (front) and 75 psi (rear).

1. Position the crane at the top of the leads, one boom length away (see figure 2-11.1). Lower the boom to approximately 3 ft. from the top of the leads.

NOTE

Connect the left lead, plate first (the left plate boom pin is solid).

2. Move the crane into position, connect the leads to the boom with the lead plates (see figure 2-11.1). Remove the catwalk.

3. Run the main and auxiliary winch cable to the bottom of the leads. Lay the hook blocks on the back of the leads (see figure 2-11.1). Attach the tag lines (rope) approximately 2 ft. from the bottom of the leads (see figure 2-11.1).

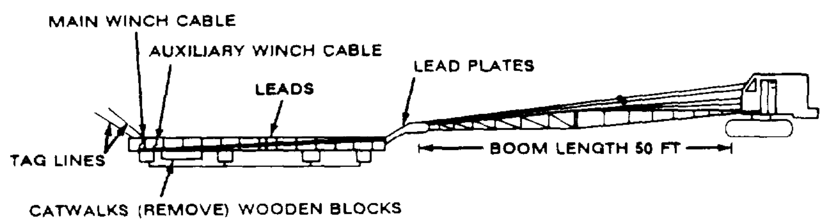


Figure 2-11.1. Connect Leads

WARNING

In high winds (15 or 20 mph) do not move the crane with the leads raised. Move the crane at speeds of 2 to 3 mph when the leads are raised. Use front and rear ground guides when moving the crane. Move on a flat, solid surface. Raise the outriggers (if equipped) before moving the crane.

4. Keeping the boom cables tight at all times, slowly raise the boom and move the crane toward the lead section, raising the leads until they are vertical to the ground (see figure 2-11.2). One person will hold each tag line while raising the leads.

5. Hold the tag lines and raise the leads 2 to 3 in. Raise the outriggers. Move the crane to the hammer, set the leads on the ground (lower outriggers), disconnect the tag lines and reconnect the tag lines to the hammer. Remove the lead angle guides from the hammer.

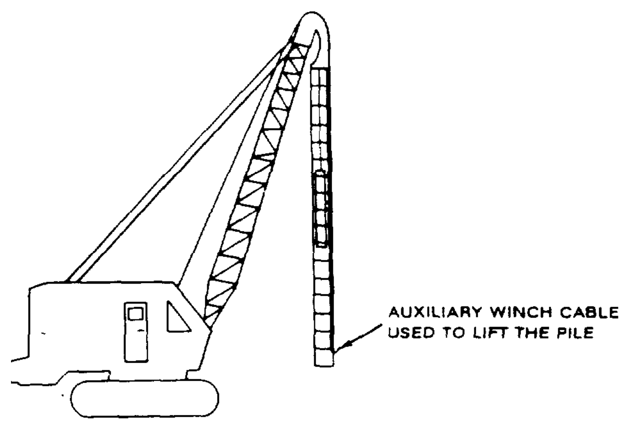


Figure 2-11.2. Raising Leads

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CAUTION

Dragging the hammer may cause damage.

6. Connect the main winch cable to the hammer lifting eye. Remove the intake and exhaust port covers from the hammer. Holding the tag lines securely, slowly raise the hammer and position inside the leads (see figure 2-11.3).

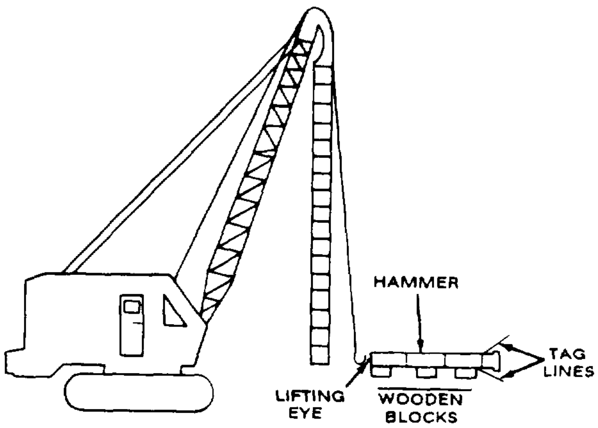

Figure 2-11.3. Raising Hammer

7. Attach the lead angle guides (12 bolts) to the leads/hammer and secure the bolts.

8. Raise the hammer and leads 2 to 3 in. off the ground. Raise the outriggers and move the crane to within 2 ft. of the driving head. Lower the outriggers.

9. Inspect the cushions for damage, replacing those that are damaged.

10. Raise the hammer just high enough to clear the head.

11. Raise the leads, then raise the outriggers (2 to 3 in.). Move the crane with the leads around the hammer and head.

CAUTION

Dropping the hammer may cause damage to the head.

12. Slowly lower the hammer onto the driving head. Attach the head to the hammer using the cables on the head. Secure cable clamps.

Move crane at 1 to 2 mph.

13. Raising the leads and the outriggers, move the crane (1 to 2 mph) to the site where the pile is to be driven. Lower leads and the outriggers, level the crane. If applicable, attach the transmitter to the operator's cab outside the door (4 bolts) and secure bolts. Attach hoses to the hammer and transmitter.

14. Attach the auxiliary winch cable to the pile, raise the hammer just high enough to set the pile under the hammer.

CAUTION

Dropping the hammer may cause damage.

15. Raise the pile, positioning it directly under the hammer. Slowly lower the hammer onto the pile.

16. Raise the outriggers 2 to 3 inches off the ground. Consult the hammer's TM or manufacturer's manual to start/stop the hammer.

17. Reverse steps 13 to 1 to remove the head and the hammer. and to lower/remove the leads.

OPERATION UNDER UNUSUAL CONDITIONS

GENERAL. Unusual conditions refer to environment: specifically, extreme cold, extreme heat, dust or sandy conditions, areas with high humidity or salt air, and high altitudes. Separate paragraphs are devoted to each of these conditions.

OPERATION IN EXTREME COLD. Operation in extreme cold presents special problems due to the increased brittleness of metallic and rubber parts, the danger of freezing and the increased difficulty of keeping parts lubricated adequately.

WARNING

Personnel should use care to keep from spilling fuel, coolant, or other liquids upon themselves. Exposed parts of the body should not come into contact with metal during cold weather, as serious and painful injury may result.

1. Refer to Section III for lubricant recommendations for cold weather operation. Change the lubricant if necessary.

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2. Drain and flush the cooling system, to insure proper circulation of coolant throughout the radiator core. Clean the radiator cooling fins, particularly the air passages through the core. Check the condition of the radiator hoses, clamps, thermostat, and radiator core.

When freeze protection is required, an ethylene glycol base permanent antifreeze should be used. An inhibitor system is included in this type of antifreeze and no additional inhibitors are required in initial fill, if a minimum antifreeze concentration of 30% by volume is used. Solution of less than 30% concentration does not provide sufficient corrosion protection and additional inhibitors may have to be added. Concentrations over 67% adversely affect freeze protection as shown in Figure 2-12.

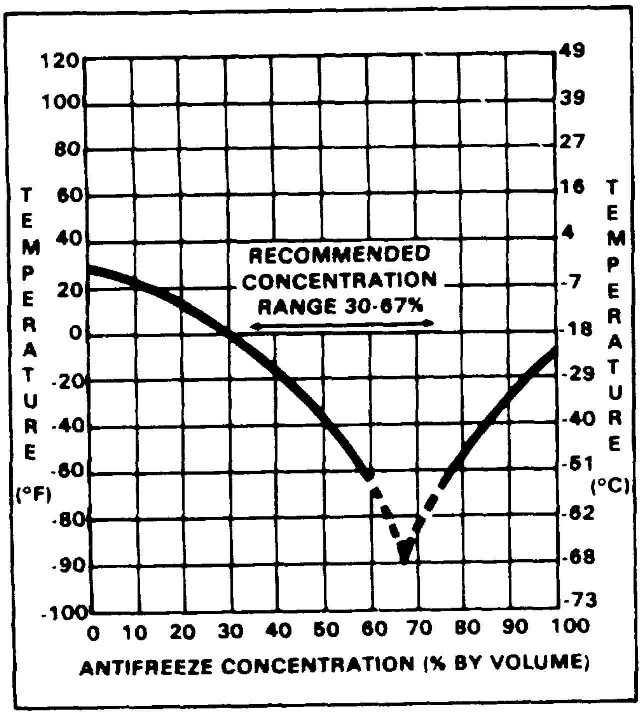

Figure 2-12. Antifreeze Concentration and Temperature

Inhibitor depletion will occur in ethylene glycol base antifreeze through normal service. The inhibitor should be replenished at approximately 500 hour intervals with a non-chromate inhibitor system.

NOTE

A high quality corrosion inhibitor can be added to the cooling system, if desired. Do not, however, use a chromate base inhibitor with an ethylene glycol antifreeze. That combination can produce chromium hydroxide, commonly known as "green slime".

3. Keep the battery fully charged at all times, The electrolyte in a discharged battery will freeze at a higher temperature than that in a fully charged battery.

NOTE

If it is necessary to add water to the battery, do so only immediately before or during operation, or with an external charger connected to the battery. Charging the battery, by any means, mixes the water and electrolyte, and thereby prevents the water from freezing.

Keep the battery terminal connections clean and free from snow and ice which could short circuit the terminals. Clean the cable connectors and battery posts thoroughly, using a soda and water solution to remove corrosion.

In extremely cold weather, it is advisable to remove the battery and store it in a heated area if the machine is to be idle overnight or for any extended period.

4. Keep the fuel tank as full as possible at all times to minimize condensation. If water is detected in the fuel supply, drain the tank and refill it with clean fuel.

5. Start the engine in accordance with the engine manufacturer's recommendations for cold weather starting, and run it at approximately 1200 RPM until the engine has warmed up.

NOTE

Cover part of the radiator, to aid warmup and to maintain engine running temperature. During warmup only, the entire radiator may be covered.

The correct grade of oil for the prevailing ambient temperature should be used in the crankcase to prevent hard cranking. The diesel fuel should have a pour point of l0°F less than the lowest expected temperature. In case of emergency, white kerosene may be added to the fuel to bring the pour point down to the required temperature in order to prevent clogging of filters and small passages by wax crystals. The addition of kerosene is NOT recommended for general use.

6. Disengage the propel brake and move the propel controller to move hydraulic oil through the pumps, thereby insuring proper lubrication of pump and motor components.

7. Before shutting down the machine drive the machine onto wooden planks or mats to prevent the machine from being frozen to the ground.

OPERATION IN EXTREME HEAT. Operation inextreme heat presents special problems due to the difficulty in keeping the engine and hydraulic oil from overheating.

1. Refer to Section III for lubricant recommendations for hot weather operation. Change the lubricant if necessary.

2. Make certain that the engine crankcase oil is at the proper level. An inadequate supply of crankcase oil will prevent proper dissipation of heat from the engine.

3. Drain and flush the cooling system, to insure proper circulation of coolant throughout the radiator core. Clean the radiator cooling fins, particularly the air passages through the core, of insects, leaves, dirt, and other foreign material that will restrict air flow.

4. Inspect the cooling system for leaks. Replace worn or damaged hoses. Tighten the hose clamps.

5. Keep the water pump fan belt adjusted properly.

6. If the engine becomes overheated from lack of coolant, let the engine run at a fast idle and add coolant slowly.

7. If the engine overheats after refilling the cooling system, shut down the engine and allow it to cool. Drain the cooling system by opening the drain cocks on the radiator and the engine block, and flush out the system. Refill the cooling system with coolant; *do not use salt or mineral water solutions in the cooling system.*

8. Keep as much air as possible circulating around the battery. Check the electrolyte level frequently; add distilled water as necessary to keep the electrolyte level 3/8 inch above the plates.

9. Keep the air intake and exhaust openings clear. Keep the engine clean, and allow air to circulate freely around the engine.

10. Avoid racing the engine; and avoid operation at full throttle when part throttle will handle the load.

11. Avoid lugging the engine; keep the engine speed high enough to maintain fan speed.

12. Avoid idling the engine unnecessarily; shut the engine down during a lull in the operation.

OPERATION IN DUSTY AND SANDY AREAS. Operation in dusty or sandy areas presents special problems due to the abrasive action of dust which shortens the life of parts. Make every effort to keep dust and sand out of the moving parts of the crane machinery and engine.

1. All lubricants and lubricating equipment must be kept clean. Service breathers and air cleaners frequently to remove accumulated sand and dust. Lubricate more frequently to keep a supply of clean lubricant in the moving parts. Clean all lubrication fittings thoroughly before attaching the grease gun.

2. Keep the hydraulic oil reservoir filler caps tight to prevent sand and dust from entering the hydraulic system. Service the hydraulic oil filters frequently to keep the system free from sand and dust.

3. Inspect the clutch and brake linings frequently. After operation in dust or sand, blow loose grit out of linings. Failure to keep the linings clean will result in worn bands, scored drums, and unsatisfactory operation.

4. Keep unused cables in boxes. Clean and lubricate operating cables frequently.

5. Keep the fuel tank filler cap tight to prevent sand or dust from entering the fuel tank. Service fuel filters frequently to keep them free from sand and dust.

6. Use wood blocking or mats under the crawlers when operating in sand.

OPERATION IN HUMID OR SALT WATER AREAS. Moisture and salt will cause deterioration of paint, cables, wiring, and all exposed metallic parts. Keep parts dry and well lubricated in high humiditv or salt water conditions.

1. Completely remove rust and corrosion at the first appearance on any part of the machine. Wash off salt water and dry parts thoroughly; paint the exposed surfaces immediately. Place a film of lubricant or grease on all polished or machined metal surfaces and other surfaces which cannot be painted.

2. Keep parts lubricated thoroughly to repel water from polished metal surfaces and to prevent the entry of water into bearings. Keep lifting cables lubricated.

OPERATION AT HIGH ALTITUDES. Operation at high altitudes presents special problems due to lower atmospheric pressure and wide temperature ranges. At altitudes above 5000 feet it may be necessary to change the engine fuel injectors. Make certain that the air cleaners are clean and free from obstructions. Check the engine frequently for overheating.

LOAD WEIGHING SYSTEM

IDENTIFICATION

CENTRAL UNIT The central unit consists of the standard elements (main printed circuit board, fuse, sockets, etc. and the vertical programmed P.C. boards. It also contains the following items (Figure 2-13):

A. By-Pass Key. Located at the bottom of the box it deactivates the shut-off system. Meters, lights and horn on the control panels are Indicating even with a deactivated shut-off system.

WARNING

It is recommended that the system by-pass key switch be used with care. Unwarranted use of it to override the shut-off system can result in loss of life, destruction of property and irreparable damage to the crane. The key switch can be used in overriding the system in case of extreme emergency. The operator using the key in extreme emergency should use sound judgement.

B. Fuse. A 2 amp fuse is located in central unit. It is used to protect the load weighing system from electrical overload.

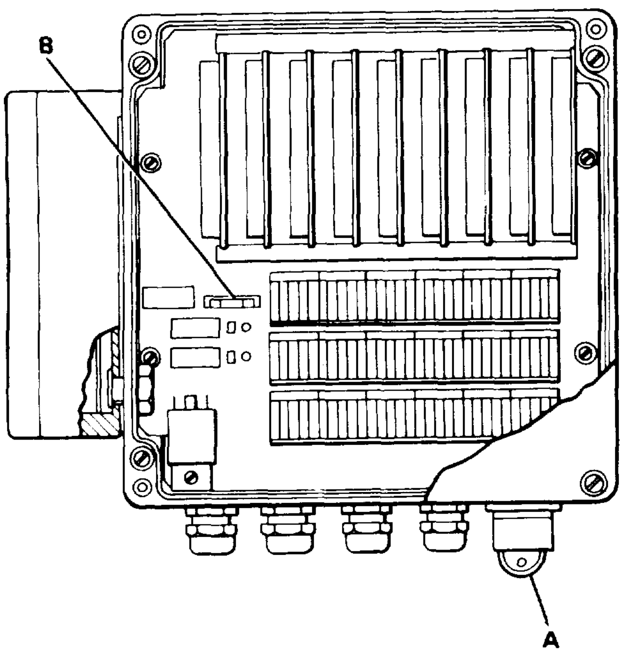

Figure 2-13. Central Unit

ANGLE METER. This meter indicates boom angle from 0° to 90° (see Figure 2-14):

CONTROL PANEL. This unit contains the following items (see Figure 2-14):

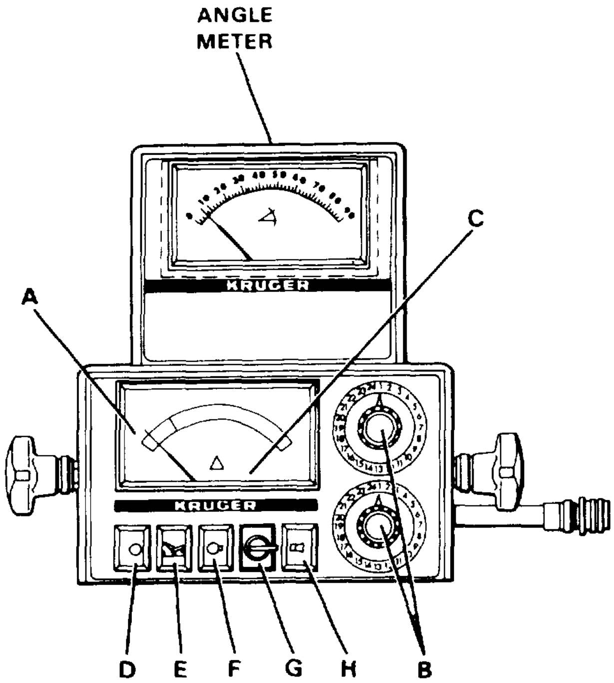

Figure 2-14. Angle Meter and Control Panel

A. The Analog Meter. This meter indicates total load moment. The meter scale is divided into three color coded segments — GREEN, YELLOW and RED — representing APPROVED, CAUTION and PROHIBITED, respectively. When the needle of the load moment meter is in the red zone of the scale, the boom lowering and hoisting controls are out of function by means of the shut-off system.

B. Program Selector Switches. Program selector switch A is on tab, switch B is on the bottom.

C. Electronic Beeper.

D. Shut-Off Light/Reset Button

E. Load Moment Warning Light/Pre-Warning Light.

F. Test Button/Pilot Light.

G. Key Switch.

H. Horn On/Off Button.

OPERATION

NOTE

The system by-pass key switch must be used to override the shut-off system when positioning the jib (without load on the block) lower than rated angle for rigging.

WARNING

Remove the by-pass key from the switch, located on the central unit, right after rigging as unwarranted use of it to override the shut-off system can result in loss of life, destruction of property and irrepairable damage to the crane. The operator is the only person responsible for safe operation of the crane.

Set up the load weighing system as follows:

1. Turn the program selector switches to the configuration for main boom/jib and crawler position. See Table 2-1.

2. Turn ignition ON.

— The green pilot light is ON (F, Figure 2-14).

— The red shut-off light is ON (D, Figure 2-14).

— The load moment needle moves into the green area of the seals.

— The load moment and angle meter are illuminated.

NOTE

The shut-off light will come on when the by-pass key switch is in either position.

3. Press and hold the green test button (F, Figure 2-14).

— The load moment needle will move to the left hand side of the seal.

— The yellow pre-warning light will come on.

4. Release the test button

— The load moment needle will go back to the original position.

— The yellow pre-warning light will go off.

— The red shut-off light is on.

TABLE 2-1. PROGRAM SELECTOR SWITCHES

NOTE

Program selector switch "A" is the top dial on the control panel. Switch "B" is the bottom dial.

Dial A Position	Configuration
1	Main boom w/crawlers extended
2	N/A
3	Main boom w/crawlers retracted
4	Jib w/crawlers extended
5	Jib w/crawlers retracted

TABLE 1-2. DRUM PERFORMANCE DATA (Continued)

Dial B Position	Boom Configuration
1	Main Boom 50'
2	Main Boom 60'
3	Main Boom 70'
4	Main Boom 80'
5	Main Boom 90'
8	Main Boom 100'
7	Main Boom 110'
8	Main Boom 120'
9	Main Boom 130'
10	Main Boom 140'
11	Main Boom 150'
12	Main Boom 160'

EXAMPLES

With dial "A" in position 4 and dial "B" in position 3 you monitor:

Jib w/crawlers extended, main boom 70'.

With dial "A" in position 3 and dial "B" in position 4 you monitor:

Main boom 80' with crawlers retracted.

5. Press the red on button (D, Figure 2-14) (shut-off light/reset button). The red shut-off light (on button) will go off when the button is released.

6. The system is now ready for operation.

WARNING

Repeat the above procedure at least once a day to test the circuit AND BEFORE EACH MAJOR LIFT.

LIGHT FLASH ON THE CONTROL PANEL AND THEIR CAUSE

1. Shut-off light comes ON (D, Figure 2-14): Maximum allowable lifting capacity is being reached. Needle of the load meter is in the red. Lower the load or raise the boom and reset after corrected.

2. Pre-warning light comes ON (E, Figure 2-14): Approximately 90% of total load moment is reached. CAUTION.

NOTE

If a light flash occurs without reason or cannot be corrected, consult the manufacturer.

SECTION III

LUBRICATION

SEE SOMARPI

SECTION IV

UPPER POWER TRAIN

SUBSECTION 4A

ENGINES

GENERAL

The information contained in this section is limited to troubleshooting, removal, and installation of the engine.

TROUBLESHOOTING

A trouble shooting chart and procedures at the end of this subsection lists some of the difficulties which may be experienced with the engine and associated systems.

ENGINE (51U70)

REMOVAL. If it is determined that the engine must be removed from the machine, proceed as follows:

1. Lower the boom to the ground and pin the upper spreader to the boom base. Lower the high gantry to the travel position and unreeve the boom hoist lines. Remove the high gantry.

2. Disconnect and remove the exhaust system from the exhaust manifold.

3. Remove all sheet metal over the engine and torque converter.

4. Disconnect the battery ground cable.

5. Drain the engine oil and coolant.

6. Disconnect and remove the radiator.

7. Disconnect and tag mechanical controls (engine throttle cable, clutch cable, etc.), fuel lines and all electrical wiring to the engine. Cap all fuel and hydraulic lines to prevent entry of contaminants. Disconnect all hydraulic lines from the torque converter.

8. Disconnect the propeller shafts from the torque converter and the pump drive.

9. Make a thorough visual inspection of the engine and engine compartment to be sure all necessary electrical, mechanical, fuel and hydraulic lines have been disconnected and are out of the way to allow removal of the engine.

10. Attach suitable lifting slings to the engine.

11. Remove the nuts, washers and capscrews from the engine mountings at the corners of the engine. Slowly lift the engine and torque converter out of the machine as a unit.

12. Inspect the mountings and replace them if necessary.

REPAIRS AND ADJUSTMENTS. Engine repairs and adjustments are covered in Section XI of this manual.

INSTALLATION. To install an engine in this machine, proceed as follows:

1. Make a thorough inspection of the engine compartment to be sure that all wiring, fuel, water, hydraulic lines and mechanical linkages are clear of the engine mountings and frame.

2. Lift the engine into the engine compartment using a suitable sling attached to the engine.

3. Tighten the engine mounting bolts, lockwashers and nuts.

4. Connect the propeller shafts to the torque converter and to the pump drive.

5. Connect all electrical wiring that was disconnected when the engine was removed.

6. Connect all fuel, and water lines and mechanical linkages that were disconnected when the engine was removed.

7. Reconnect hydraulic lines to the torque converter. Install the clutch control and adjust as described in Subsection 4B.

8. Replace and connect the radiator.

9. Replace all sheet metal.

10. Install the exhaust system on the exhaust manifold.

11. Fill the cooling system and crankcase with coolant and oil respectively. See Section I I I.

CAUTION

Before engine start-up, check all wiring, fuel, water, and mechanical connections. Be prepared to shut down the engine if there should be some malfunction.

12. Start and run the engine. Check for oil, water, fuel and hydraulic leaks.

TROUBLESHOOTING PROCEDURES

General

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered in the following paragraphs.

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:

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 (See Subsection 11I).

4. Start the engine. Then hold an injector follower down with a screwdriver to prevent operation of the injector (see Figure 4A-1 on page 4A-3). 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 (See Subsection 11I).

B. Check the compression pressure.

C. Install a new injector.

D. If the cylinder still misfires, remove the cam follower (See Subsection 11B) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 4A-1 on page 4A-3.

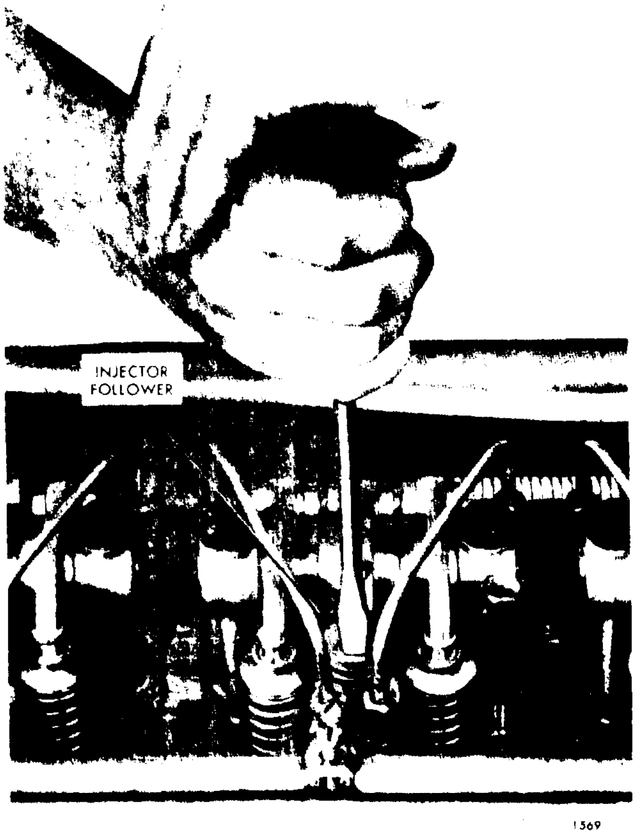

Figure 4A-1. Locating a Misfiring Cylinder

Check the compression pressure as follows:

1. Start the engine and run it at approximately one-half rate 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 guage from Diagnosis Kit J 9531-01 (see Figure 4A-2).

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.**

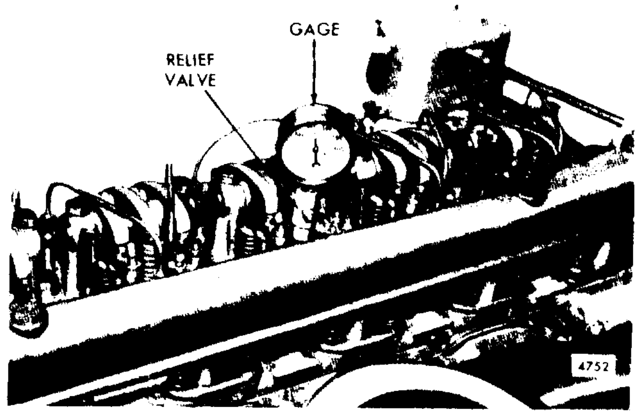

Figure 4A-2. Checking Compression Pressure

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude should not be less than the minimum shown in Table 4A-1. In addition, the variation in compression pressure between cylinders must not exceed 25 psi (172 kPa) at 600 RPM.

For example, if the compression pressure readings were as shown in Table 4A-1, it would be evident that No. 3 cylinder should be examined and the cause of the low compression pressure be determined and corrected.

The pressures in Table 4A-1 are for an engine operating at an altitude near sea level. All of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the No. 3 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 (see Figure 4A-3 on page 4A-4). A broken or stuck ring will not have a “spring-like” action.

MINIMUM PRESSURE	ALTITUDE	AIR DENSITY	CYL	GAUGE READING
400 psi (2758 kPa)	500 Ft (152 M)	0.0715	1	445 psi (3066 kPa)
370 psi (2551 kPa)	2500 Ft (762 M)	0.0663	2	440 psi (3032 kPa)
340 psi (2344 kPa)	5000 Ft (1524 M)	0.0613	3	405 psi (2791 kPa)
315 psi (2172 kPa)	7500 Ft (2286 M)	0.0567	4	435 psi (2997 kPa)
295 psi (2034 kPa)	10000 Ft (3048 M)	0.0525		

Table 4A-1. Compression Pressure Comparison

B. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

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 fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipe 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 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 and element with fuel oil as described 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 retightened securely before replacing the rocker cover.

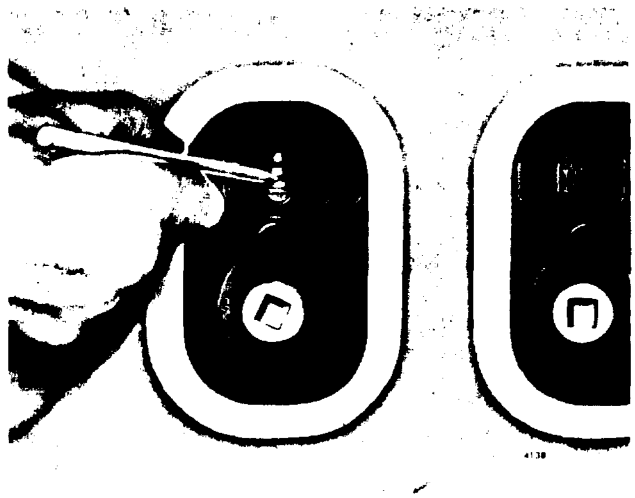

Figure 4A-3. Inspecting Piston Rings

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.

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 Subsection 11C under Troubleshooting.

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 turbocharger oil seals, defective blower, cylinder head or end plate gaskets, or excessive back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

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 Operations Conditions in Subsection 11A.

NOTE

The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.

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 formations or foreign matter in the exhaust system.

Check the exhaust back pressure, measured in inches of mercury, with a manometer. 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 pipe area for an accurate measurement.

Check the readings obtained at various speeds (at no load) with the Engine Operating Conditions in Subsection 11A.

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), 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.

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 Subsection 11A.

Air Inlet Restrictions

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 cleaner will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the compressor inlet. 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 Subsection 11A.

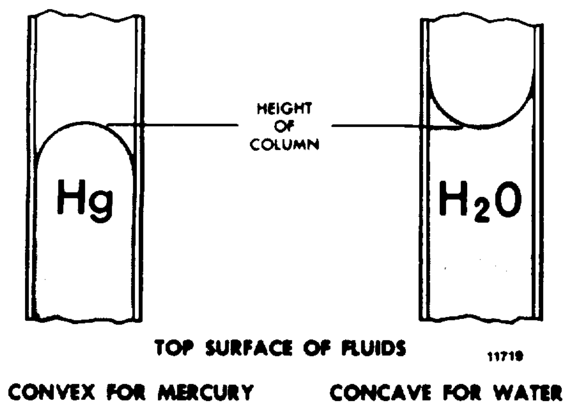

Figure 4A-4. Comparision of Column Height for Mercury and Water Manometers

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 shape. Water wets the surface and therefore has a concave shape. A mercury column is read by sighting horizontally between the top of the convex mercury surface (see Figure 4A-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 diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

To convert manometer readings into other units of measure, use the follow values:

PRESSURE CONVERSION CHART				
1"	Water	=	0.0735"	Mercury
1"	Water	=	0.0361	psi
1"	Mercury	=	13.6000"	Water
1"	Mercury	=	0.4910	psi
1	psi	=	27.7000"	Water
1	psi	=	2.0360"	Mercury
1	psi	=	6.8950	kPa
1	kPa	=	0.1450	psi

Troubleshooting Guide

	Cause	Low Power	Poor Performance, or Erratic Action	Rough Idle, Engine Vibrating	Excessive Engine Smoke - Black	Excessive Engine Smoke - White or Blue	Low Oil Pressure	Abnormal Coolant Temperature	Hard or No Starting	Recommended Remedy
GENERAL	Excessive oil in or Restriction of Air Cleaner.	X	X	X	X	X			X	Service or Replace Filter as Required.
	Faulty Injection Pump(s).	X	X	X	X	X			X	Have Pump Removed and Repaired.
	Contaminated or Poor Quality Fuel.	X	X	X	X				X	Drain, Clean Tanks and Filter and Refill per Engine Mfg. Specs.
	Cranking R.P.M. Too Low (Cold or Hot).								X	Check Battery and Starter. Replace if Necessary.
	Low Compression.	X	X	X	X	X			X	Overhaul Engine.
	Exhaust Blockage.	X	X	X				X		Remove Obstruction, Check for Bent or Crushed Pipes.
	Incorrect Calibration.	X	X	X	X				X	Have Engine Re-calibrated.
TIMING	Injection Pump-to-Engine Timing Incorrect.	X	X	X	X				X	Re-Time to Engine Manufacturer's Specifications.
	Injection Pump Drive (Train) Worn - Coupling Keyway.	X	X	X					X	Remove, Inspect and Replace Worn Parts.
	Injection Pump Internal Timing Incorrect.	X	X	X	X	X			X	Remove Injection Pump. Re-Time (Internally).
	Timing Advance Device Not Operating Properly.	X	X	X	X	X			X	Remove Injection Pump. Replace or Repair Advance Unit.
GOVERNOR	Throttle Linkage Mis-Adjusted.	X	X	X						Adjust to Engine Manufacturer's Specifications.
	Throttle Linkage Sticking, Binding or Worn.	X	X							Check for Binding, Worn or Loose Parts, Foreign Particles. Repair or Replace Parts and Adjust to Specifications.
	Improper Governor Operation.	X	X	X						Adjust or Repair to Permit Proper Governor Operation.
	Control Rack(s) or Governor Linkage Sticking or Binding.	X	X	X						Remove Injection Pump. Repair
	Worn or Loose Governor Linkage or Components or Weak or Broken Governor Torsion Spring.	X	X	X						Repair or Replace.

Troubleshooting Guide (cont'd)

	CAUSE	LOW POWER	POOR PERFORMANCE, OR ERRATIC ACTION	ROUGH IDLE, ENGINE VIBRATING	EXCESSIVE ENGINE SMOKE - BLACK	EXCESSIVE ENGINE SMOKE - WHITE OR BLUE	LOW OIL PRESSURE	ABNORMAL COOLANT TEMPERATURE	HARD OR NO STARTING	RECOMMENDED REMEDY
NOZZLES	Nozzle Defective - Leaking - Worn.	X	X	X	X				X	Remove, Repair or Replace, Reassemble, Test, Set Opening Pressure.
NOZZLES	Incorrect Nozzle Opening Pressure	X	X	X	X				X	Re-Set to Specifications.
NOZZLES	Nozzle Cap Nut Incorrectly Torqued.	X	X	X	X				X	Remove, Retighten Cap Nut Using Proper Nozzle Centering Sleeve, Replace Copper Gasket, Clean Engine Recess and Re-Install in Engine.
NOZZLES	Nozzle Incorrectly Installed or Torqued in Engine.	X	X	X	X				X	Remove, Replace Copper Gasket, Clean Recess, Reassemble to Engine (Tighten Evenly to Require Torque Value).
NOZZLES	Nozzle Valve Sticking.	X	X	X	X				X	Remove, Clean, Repair or Replace as Required.
NOZZLES	Nozzle Spray Holes Plugged or Partially Plugged.	X	X	X					X	Remove Nozzle. Clean Holes or Replace Nozzle as Required.
NOZZLES	Incorrect Nozzle in Engine.	X	X	X	X				X	Always Use The Correct Nozzle Recommended For The Engine. Do Not Mix Nozzles in The Same Engine Unless Permitted By Manufacturer.
OIL LEAKAGE	Oil Lines or Connections Leaking.						X			Repair or Replace.
OIL LEAKAGE	Lube Oil Diluted.					X	X	X		Check for Internal Oil or Water Leak. Drain and Replace Oil.
OIL LEAKAGE	Fuel Supply Pump Leaking					X	X			Replace.
OIL LEAKAGE	Faulty Gasket or Oil Seal.						X			Replace.
OIL LEAKAGE	Defective Oil Pressure Sending Unit.						X			Check Unit and Gauge. Replace if Necessary.
COOLING SYSTEM	Insufficient Coolant.		X					X		Add Necessary Coolant.
COOLING SYSTEM	Loose or Broken Fan Belt.							X		Check and Adjust or Replace.
COOLING SYSTEM	Faulty Thermostat.							X		Replace.
COOLING SYSTEM	Defective Water Pump.		X					X		Repair or Replace.
COOLING SYSTEM	Coolant Passages Clogged.		X					X		Drain and Flush Cooling System. Check Hoses.
COOLING SYSTEM	Defective Water Temperature Sending Unit.							X		Check Unit and Gauge. Replace if Necessary.

Troubleshooting Guide (cont'd)

	CAUSE	LOW POWER	POOR PERFORMANCE, OR ERRATIC ACTION	ROUGH IDLE, ENGINE VIBRATING	EXCESSIVE ENGINE SMOKE - BLACK	EXCESSIVE ENGINE SMOKE - WHITE OR BLUE	LOW OIL PRESSURE	ABNORMAL COOLANT TEMPERATURE	HARD OR NO STARTING	RECOMMENDED REMEDY
FUEL SUPPLY PRESSURE	Fuel Filters Clogged or Restricted.	X	X	X					X	Remove and Clean or Replace.
	External or Internal Fuel Leaks.	X	X						X	Inspect and Repair.
	Air Leaks In Fuel Suction System.	X	X	X					X	Inspect and Correct. Replace Parts where Required.
	Restriction in Fuel Suction Lines.	X	X	X						Clean and Repair or Replace Parts as Required.
	Little or No Fuel In Tank		X	X					X	Fill Tank With Proper Grade Fuel
	Supply Pump Worn or Damaged.	X	X	X					X	Remove Supply Pump, Replace or Repair.
	Supply Pump Relief Valve Worn or Stuck Open, or Spring Broken.	X	X	X					X	Remove Supply Pump. Replace or Repair.
	Overflow Valve Leaking or Stuck Open, or Spring Broken.	X	X	X					X	Clean and Repair or Replace.
	Supply Pump Check Valves Not Operating Properly or Damaged.								X	Remove Supply Pump. Repair.
	Air in Fuel System.	X	X	X					X	Prime System with Hand Priming Pump to Force Out Trapped Air.
	Fuel Return Line to Tank Restricted.		X	X						Clean and Flush. Replace if Necessary.
	Improper Grade Fuel for Temperature.	X	X	X	X				X	Drain Fuel. Fill With Correct Grade.
	Fuel Pump Inoperative.								X	Inspect and Correct. Replace Parts Where Required.
OIL SUPPLY	Improper Oil Viscosity					X	X	X	X	Drain and Replace Oil With Proper Viscosity for Conditions.
	Oil Cooler or Filter Clogged.						X			Remove, Clean or Replace.
	Clogged Pump Intake.						X			Remove and Clean, or Replace.
	Faulty Cooler or Pump Relief Valve.						X			Remove, Clean, Repair or Replace
	Oil Pump Damaged.						X			Remove and Replace.
	Low Crankcase Oil Level.						X	X		Check and Add Oil.

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SUBSECTION 4B

CLUTCHES

GENERAL

The information in this subsection is limited to the clutch actuator and adjustment. The clutch itself is covered with the torque converter (53Z659) in Subsection 4C.

CLUTCH CONTROL (2100J1152)

ADJUSTMENT. To adjust the clutch, proceed as follows (see Figure 4B-1 on page 4B-2):

1. With the clutch in neutral position and lever (01) in enaged position as shown, install actuator (05) and secure with pin (02), washers (04) and cotter pin (03). Adjust actuator (05) to 10.94” between mounting eyes by turning rod end (06) by hand.

2. Apply grease to the rod of plunger (07).

3. Check that the plunger groove of plunger (07) is engaged with reverse switch (08) at its deepest position.

4. Locate rod end (09) with its mating hole in adapter plate (10) by turning the threaded portion of the rod eye as needed. Secure with lockwasher (11) and nut (12).

CLUTCH ACTUATOR (88U24D1)

DESCRIPTION. The clutch is controlled by an electrically operated actuator. This actuator is simply a jack screw which is driven through a gear and clutch arrangement by a DC motor.

TROUBLESHOOTING. Table 4B-1 on page 4B-3 lists only one difficulty that may be experienced with the clutch actuator. The chart lists the probable causes and possible remedies to the problem.

REMOVAL. To remove the clutch actuator, proceed as follows:

1. Disconnect the electrical leads to the motor.

2. Remove the attaching hardware from both ends of the actuator.

3. Remove the actuating assembly to a clean work area.

DISASSEMBLY. To disassemble the clutch actuating assembly, proceed as follows (see Figure 4B-2 on page 4B-4):

1. Remove the four screws from the screw housing end and the other screw from the gear housing end.

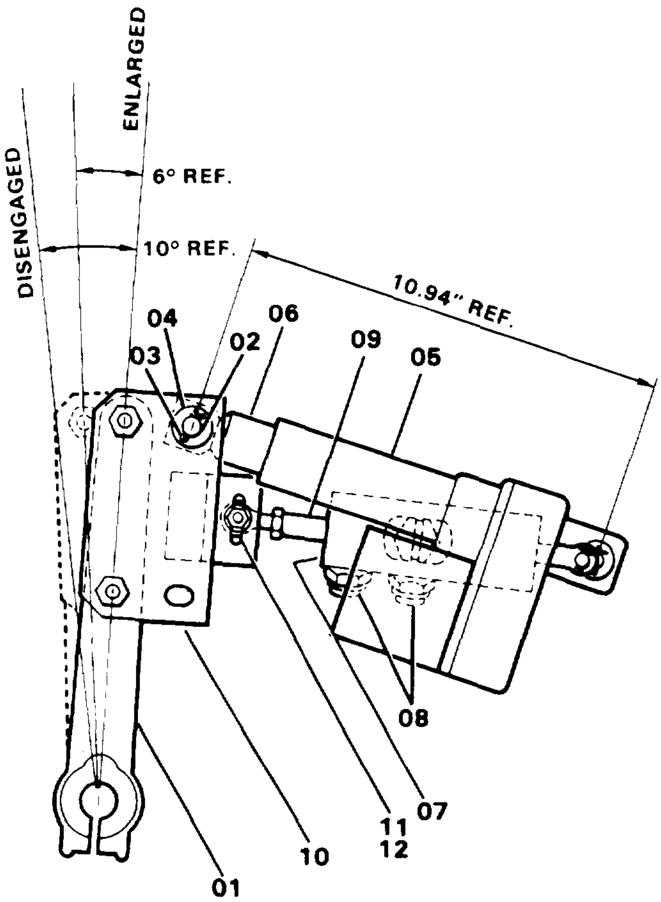
2. Remove the gear housing and the reduction gear.

3. Loosen the nuts and washers, then remove the motor.

4. Carefully check the location of the small groove end of the grooved pin and drive that end out of the screw clutch. Remove the screw clutch from the actuator screw. See the insert in Figure 4B-2 on page 4B-4.

INSPECTION AND TESTING. Inspect and test the actuator components as follows:

1. Inspect the reduction gear for chipped or broken teeth.



01. LEVER
02. PIN
03. COTTER PINS
04. WASHERS
05. ACTUATOR
06. ROD END
07. PLUNGER
08. REVERSE SWITCH
09. ROD END
10. ADAPTER PLATE
11. LOCKWASHER
12. NUT

Figure 4B-1. Clutch Adjustment

2. Check the condition of the gear teeth on the screw clutch. Check the Belleville springs and ratchet mechanism for signs of wear.

3. Test the motor for proper operation as follows:

A. Attach a ground lead from a 24 VDC power source.

B. Attach a power lead from the source to either the black lead or the orange lead on the motor (determines direction of rotation),

C. Introduce a load to the gear of the motor and observe current draw. Under maximum load, the motor should draw 7.5 amps. If current draw is more than this, replace the motor. Test the motor for both directions of rotation.

4. Replace all defective parts.

ASSEMBLY AND INSPECTION. Assembly and installation are simply the reverse of disassembly and removal. However, before installation, check the unit for proper operation.

After installation, see the topic "Adjustment" on page 4B-1 for the proper setting of the clutch actuator.

PROBLEM	PROBABLE CAUSE	POSSIBLE REMEDY
Clutch actuator inoperative	1. Motor burned out.	1. Replace the motor.
	2. Reduction gear teeth chipped or broken.	2. Replace the reduction gear.
	3. Screw clutch inoperative.	3. Replace the screw clutch

Table 4B-1. Clutch Actuator Troubleshooting

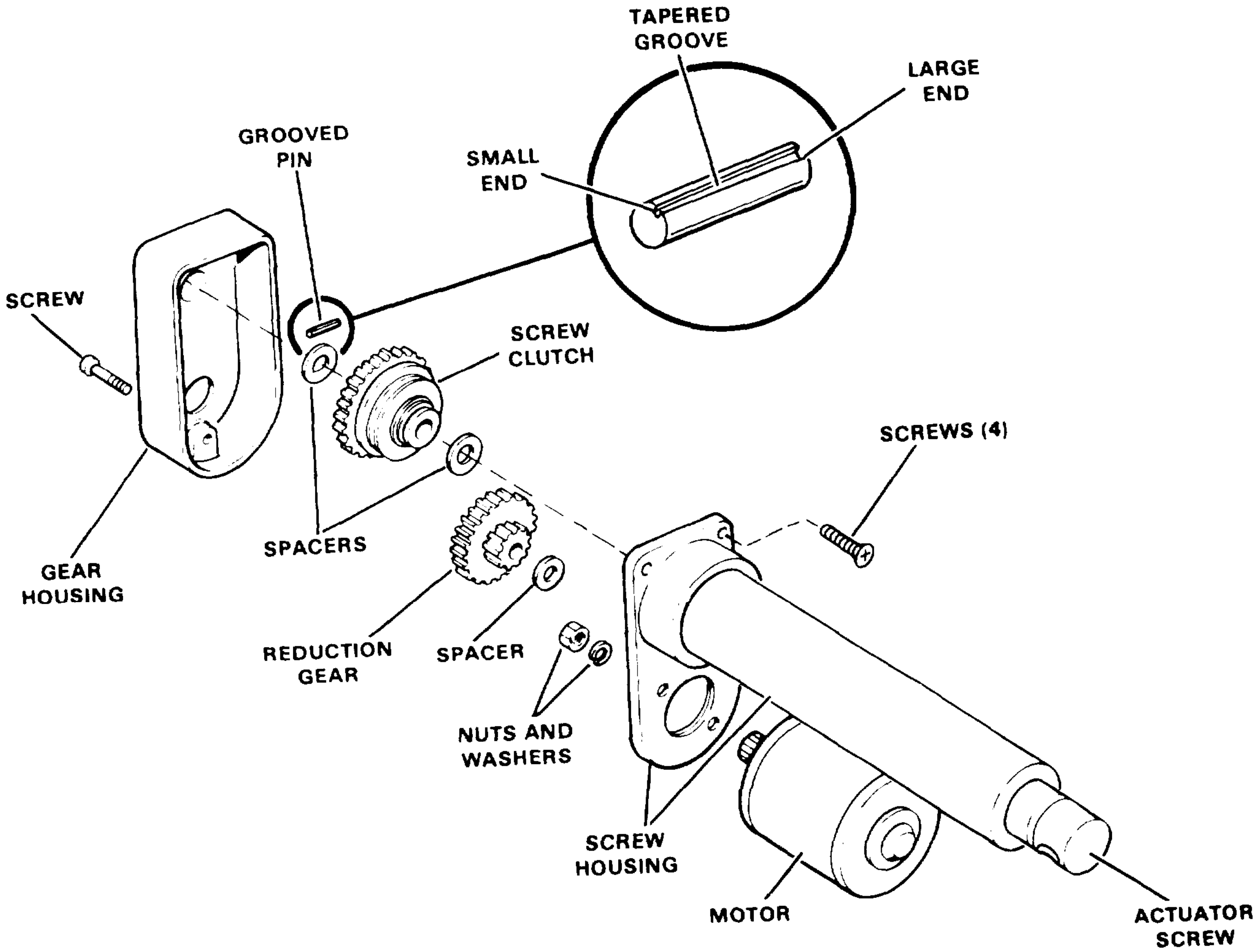


Figure 4B-2. Clutch Actuator (88U24D1)

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SUBSECTION 4C

TRANSMISSIONS

GENERAL

The information in this subsection covers the removal, repair and installation of the torque converter and pump drive.

PUMP DRIVE (53U84)

GENERAL. The pump drive used to drive the hydraulic pumps on this machine is simply a three station gear box. The pump drive is mounted at the rear of the upper and driven by a propeller shaft directly from the front of the engine.

The input flange drive meshes with the top pump drive gear and drives the other two pump drives through the intermediate gear. The two propel pumps are mounted directly on the pump drive flange adapters. The pump input shafts engage with the splined adapters inside the pump adapters.

REMOVAL. To remove the pump drive, proceed as follows (see Figure 4C-1 on page 4C-2).

1. Remove the drain plug from the pump drive and drain the lubricant into a container. Inspect the drain plug for metal chips, clean and install.

2. Remove the propel pumps from the pump drive as described in Subsection 9B.

3. Disconnect the universal joint from the pump input flange drive and remove breather (11), reducer (10), and elbow and tubing (12).

4. Support the pump drive with a suitable lifting device and remove the mounting capscrews and lockwashers. The pump drive weighs approximately 200 lbs. Lower the pump drive from under the upper.

5. Place the pump drive on a flat work surface with the output side down. Remove dipstick (06) and set aside for assembly.

DISASSEMBLY. To disassemble the pump drive, proceed as follows (see Figure 4C-1 on page 4C-2):

1. Remove the capscrews holding cover (02) to case (08). Pull the cover off and remove gear (05) and bearings (04).

2. Turn the case over with the pump drives facing up and remove capscrews (18) and nuts (22).

3. Remove input adapter housing (27) and flange drive (28).

4. Mark the position of pump adapters (17) with relation to the case and remove the pump adapters.

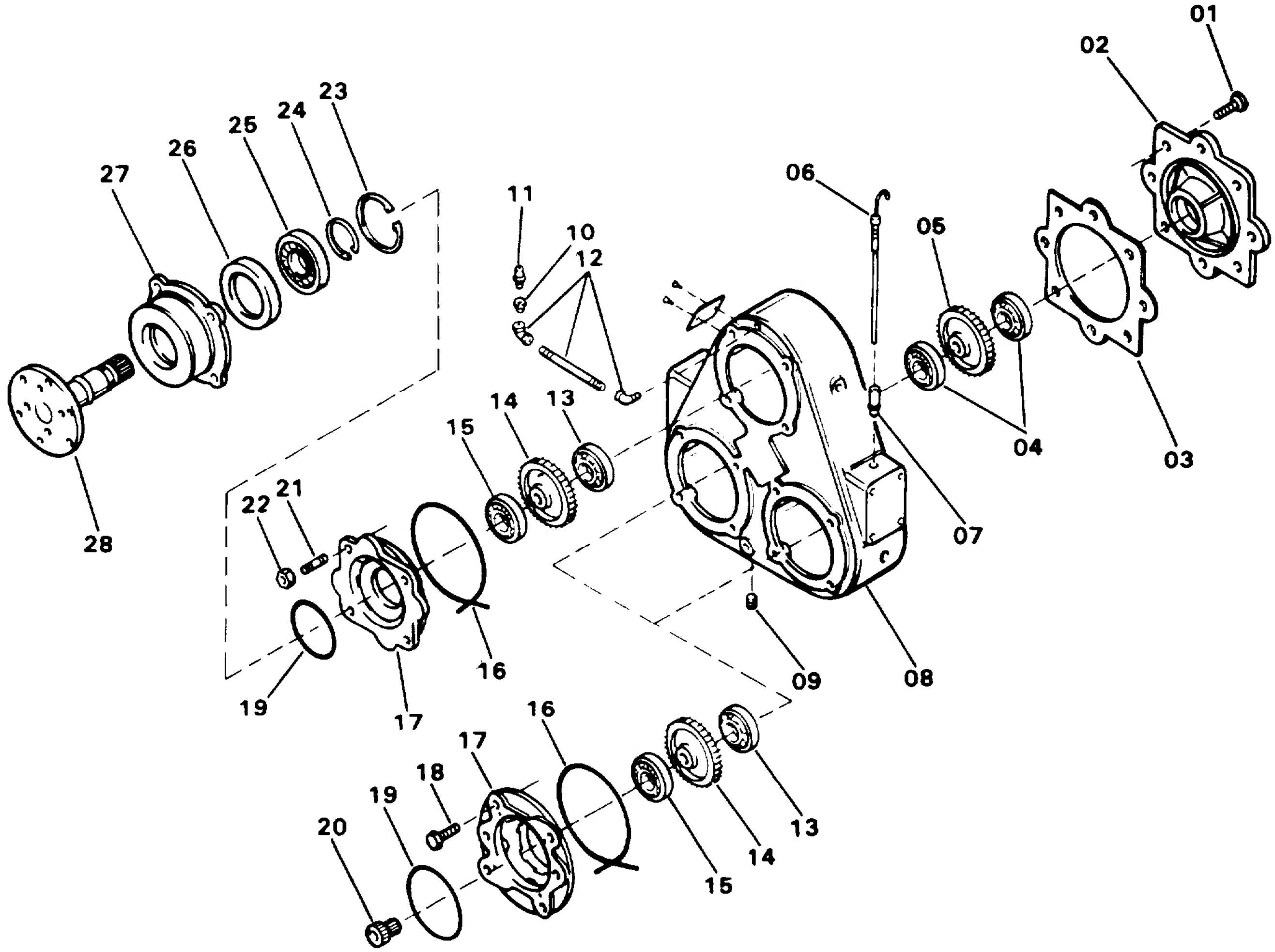
5. Remove output gears (14) with the bearings from the case.

5. Remove and discard plastic cords (16) and O-rings (19) from the pump adapters.

7. Pull the bearings from the gears. Bearings are press fitted to the gear hubs.

8. Disassemble the flange drive from the input adapter housing as follows:

A. Remove snap ring (24) that holds flange drive (28) in adapter housing (27) and snap ring (23) that retains bearing (25).



01. CAPSCREW	11. BREATHER	21. STUDS
02. COVER	12. ELBOWS AND TUBING	22. NUTS
03. GASKET	13. BEARING	23. SNAP RING
04. BEARINGS	14. OUTPUT GEARS	24. SNAP RING
05. INTERMEDIATE GEAR	15. BEARING	25. BEARING
06. DIPSTICK	16. PLASTIC CORD	26. SEAL
07. DIPSTICK TUBE	17. PUMP ADAPTERS	27. ADAPTER HOUSING
08. CASE	18. CAPSCREW	28. FLANGE DRIVE
09. MAGNETIC DRAIN PLUG	19. O-RING	
10. REDUCER	20. SLEEVE ADAPTERS	

Figure 4C-1. Pump Drive (53U84)

B. Remove flange drive (28) from the adapter housing.

C. Remove the bearing and seal (26) from the adapter housing.

CLEANING, INSPECTION AND REPAIR. Prior to assembly, all parts should be inspetted. The inspection procedure should be followed carefully to insure maximum wear life from the rebuilt unit. Any questionable parts should be replaced to avoid making additional repairs prior to the next scheduled overhaul. To inspect the parts, proceed as follows:

1. Clean all of the components with a suitable cleaning solvent and dry thoroughly with compressed air. Steam cleaned parts should be oiled immediately after drying.

CAUTION

Bearing must never be spun when drying with compressed air.

2. All gasket material must be removed from all surfaces of the pump drive components.

3. Check all bearing balls and races for pitted or spalled areas. Check bearing axial and radial clearances. Check the

fit of bearings in the mating bores and on shafts. Replace bearings which are damaged.

4. Check all gear teeth and shaft splines for cracks, broken teeth, and twisted teeth. Replace damaged parts.

5. Replace snap rings that are worn or bent.

6. Replace all O-rings, seals, gaskets, and plastic cords when the pump drive is assembled.

7. Inspect bores for wear, scratches, grooves and dirt. Remove scratches and burrs with crocus cloth.

8. Inspect mounting faces for nicks, burrs, scratches, and foreign matter.

9. Inspect threaded openings for damage. Chase damaged threads with the correct size tap.

10. Replace the case and/or adapter housing if cracked.

11. Inspect all machined surfaces for damage that could cause oil leakage or other malfunction of the part.

ASSEMBLY. To assemble the pump drive, proceed as follows (see Figure 4C-1 on page 4C-2):

NOTE

Lubricate all parts during assembly with the lubricant specified in Section I I I.

1. Press bearings (04, 13 and 15) onto the gear hubs.

2. Position gear (05) in the bore of the case.

3. Place a non-hardening sealant on both sides of gasket (03) and install cover (02) to case (08). Apply Loctite 262 to capscrews (01) and torque to 200 ft-lbs.

4. Turn the case over and install gears (14) in their proper places so that bail bearings (13) seat squarely in the case bore.

5. Insert O-rings (19) and plastic cord (16) into pump drive adapters (17).

NOTE

Using old plastic cord (16) as templates, cut new lengths of plastic cord to fit in the grooves in pump adapters (17). Knead the plastic cords into the appropriate grooves. Install the plastic cords so the cut ends will be nearest the top of case (08) when the adapters are installed.

6. Assemble studs (21) in the tapped holes in the case.

7. Align the matchmarks and assemble pump adapters (17) with capscrews (18) onto ball bearings (15). Take care not to cut plastic cords (16). Apply Loctite 262 to the capscrews and torque to 200 ft-lbs.

8. Assemble the flange drive to the input housing adapter as follows:

A. Install seal (26) and press bearing (25) into adapter housing (27).

B. Install snap ring (23) then insert the flange drive into the adapter housing.

C. Install snap ring (24) into the flange drive groove.

9. Insert O-ring (19) into the groove in the pump adapter.

10. Align the splines of the flange drive with the splines in the output gear and insert the adapter housing onto studs (21).

11. Apply Loctite 271 to the studs and torque the nuts to 150 ft-lbs.

INSTALLATION. To install the pump drive, proceed as follows:

1. Raise the pump drive into position between the mounting supports. The pump drive weighs approximately 200 lbs.

2. Install and tighten the mounting capscrews and the lockwashers.

3. Place the adapter plate between the universal joint and flange drive (28). Install and tighten the attaching hardware.

4. Check for installation of the sleeve adapters and install the propel pumps as described in Subsection 9B.

5. Install the elbows and tubing to the top of the pump drive. Set the tubing at an angle slightly above the horizontal.

6. Replace the dipstick and fill the case with the type and amount of lubricant as specified in Section III. Check the dipstick for proper level.

7. Install the adapter and the breather in the elbow at the end of the tubing.

TORQUE CONVERTER (53Z659)

General

DESCRIPTION. The torque converter combines all the desireable characteristics of a hydraulic torque multiplier and a fluid coupling to transmit engine power to the crane machinery. The torque converter automatically adjusts the output torque to the load demand, and permits the engine to operate at its most effective output.

The torque converter employs the rotating housing principle. It is a single stage, 2 phase type of converter with three elements: pump, turbine and stator. For detailed specifications see Table 4C-2 on page 4C-9.

The torque converter permits the engine to operate at its most effective output. It protects the engine from damaging shock loads and harmful engine lugging and stalling, thereby increasing the life of the engine and equipment, and their service availability. Because torque is multipled hydraulically and automatically, engine power is fitted to the load more efficiently. This eliminates gear shift guess and reduces operator fatigue.

Torque drive provides infinitely variable torque ratios with the design range.

HYDRAULIC SYSTEM. A separate tank serves as the oil reservoir for the converter. A breather is provided for expansion and contraction of the oil.

The flow of oil, shown in Figure 4C-2 on page 4C-5, in the system is from the oil reservoir through the oil pump to the converter and back to the oil reservoir. Incorporated in this circuit are: an oil filter, an oil cooler, pressure regulating valves and pressure and temperature gauges.

DESCRIPTION. The torque converter consists of three elements, pump, turbine and stator.

The torque converter is a rotating housing type of converter. The elements are enclosed in a housing which consists of the converter pump and the engine flywheel. Greater flexibility is obtained because the converter can function both as a torque multiplier and a fluid coupling.

The converter pump is the input member of the torque converter assembly and is connected directly to the engine. The vanes of the pump direct the oil against the vanes of the turbine.

The turbine is splined to the converter output shaft. The oil from the pump drives the turbine, therefore transmitting torque to the output shaft. The vanes of the turbine direct oil against the vanes of the stator.

The stator is designed to rotate in one direction and to lock up when acted upon (by oil from turbine) from the opposite direction. When the stator locks up, it provides the necessary reaction member for torque multiplication, or it can freewheel when torque multiplication demand decreases.

To accomplish this function, the stator is mounted on a cam and rollers on the converter ground sleeve. The cam and roller arrangement permits the stator to rotate in one direction only, namely, in the direction of the converter pump and turbine. A similar arrangement is the bicycle coaster brake which allows the pedals to rotate forward only.

The oil pump is mounted in the converter housing and is driven by the hub of the converter pump. The oil pump provides charging pressure and cooling flow for the converter through internal passages. When the engine runs, the pump operates.

The pressure regulating valves, located in the charging oil pump cover, control the oil pressure to the converter circuit (see Figure 4C-2 on page 4C-5).

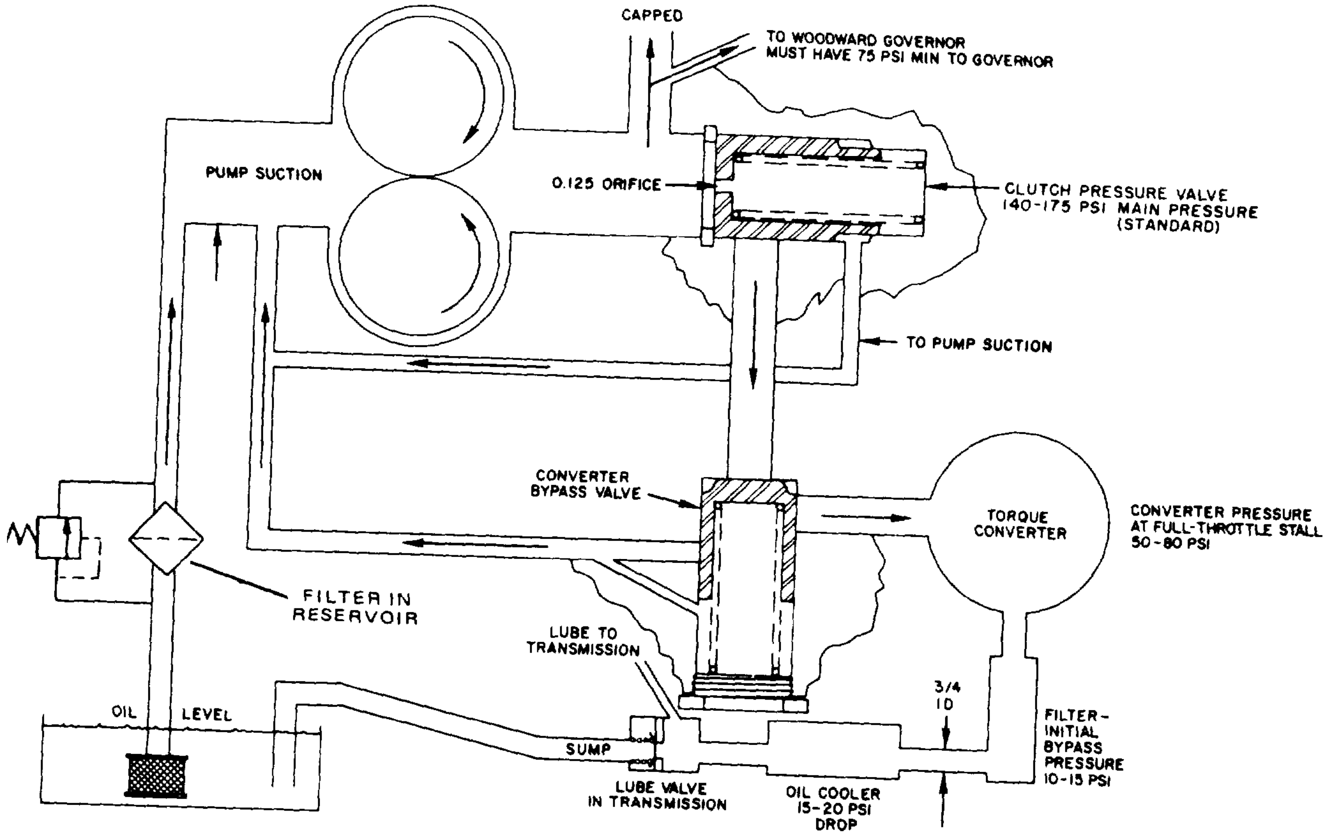


Figure 4C-2. Oil System - Schematic

The clutch pressure valve regulates oil pressure to the transmission clutches; when this pressure is satisfied, the valve opens and directs oil to the converter system.

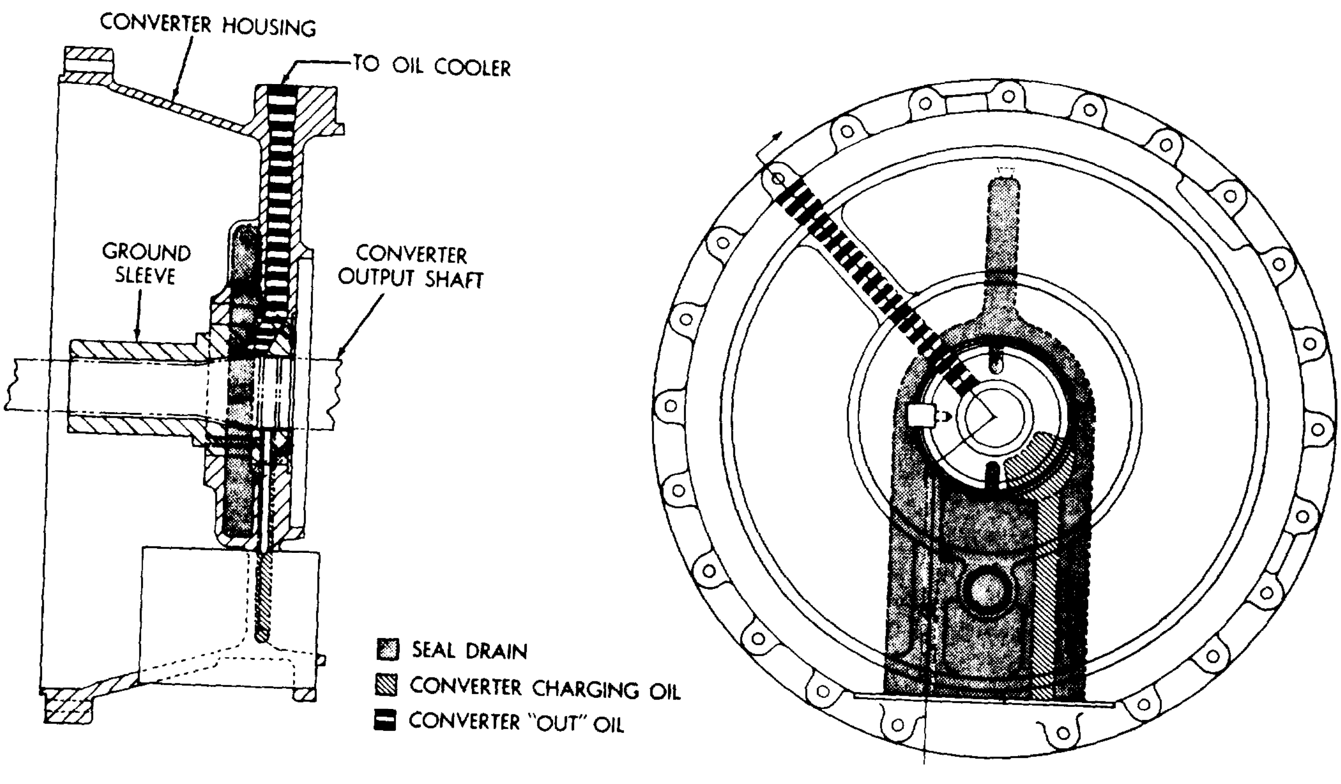


Figure 4C-3. Oil Flow Passage

This system charges the converter. When the desired pressure is reached in this system, the converter pressure regulator valve opens and allows excess oil to return to the inlet side of the pump. In coming oil from the oil pump flows through internal passageways in the converter housing and through the ground sleeve. It enters the converter elements between the converter pump and stator. The oil leaves the converter elements between the turbine and stator and flows inside the ground sleeve along the output shaft and out through a passageway in the converter housing to the oil reservoir by way of the oil filter and oil cooler.

OPERATION.. The torque converter functions in two distinct phases - multiplying torque hydraulically and operating as a fluid coupling. The load deter-mines the phases in which the converter operates.

Converter phase means that the stator is stationary [locked up). As a result, the greatest possible torque multiplication of input torque to output torque is taking place.

Since the stator is stationary (locked up), the oil leaving the turbine is directed back to the pump by the vanes of the stator in the same direction the pump is turning. This redirects oil flow then aids the pump and is the key to torque multiplication.

The torque converter goes into the fluid coupling phase as the turbine speed nears the speed of the pump. Since the turbine is connected directly to the output shaft, as the demand for torque multiplication decreases, the flow of oil wihtin the converter cahanges. This change of oil flow acts upon the opposite side of the stator, causing it to freewheel. As the turbine speed approaches pump speed, the input torque to output torque ratio is approaching 1 to 1.

If the turbine slows down and the demand for output torque increases, the converter automatically multiplies torque. The stator locks up, thus reverting to converter phase operation.

In this unit the clutch is over running (freewheeling) anytime the converter pump is driving the turbine.

When the engine RPM is reduced and the converter turbine attempts to rotate faster than the pump, the sprag-type clutch locks up. This connects the converter output shaft mechanically to the engine, utilizing full engine compression for lowering light loads. The clutch releases instantly when engine power is applied to the machinery.

Preventative Maintenance

CHECKING CONVERTER-IN OIL PRESSURE. The charging oil pump pressure (converter-in) should be 50 psi (345 kPa) and 80 psi (552 kPa) maximum at full throttle stall condition. The maximum permissible pressure at full throttle, no load, is 120 psi (827 kPa) It is most important that the values not exceed the limits given. This pressure can be checked at either of the two converter-in pressure check points (Figure 4C-4 on page 4C-7) on the charging oil pump. If the pressure is not normal, refer to Table 4C-1 on page 4C-8.

METAL CONTAMINATION OF OIL. If the oil in the hydraulic system becomes contaminated with metal particles, all the components of the hydraulic system - torque converter, oil lines, filters, reservoir, strainer, cooler, valves and oil pumps. must be thoroughly cleaned
usually means overhaul of the components. Metal particles in the oil (except for the minute particles normally trapped in the oil filter) are evidence of failure of some part, either in the converter or in the transmission.

CHECKING FOR LOCKED STATOR. If it should become necessary to check for a locked stator by observing temperature drop rate, increase converter-out temperature to 230°F (110°C) by stalling the converter output shaft at full throttle Release the converter output shaft and immediately check the rate of temperature drop with no load on the converter and maximum input RPM. Temperature should start to drop after 15 seconds.

A slow temperature drop rate indicates that the stator probably is locked. A rapid temperature drop rate indicates normal stator operation.

CHECKING ENGINE CONVERTER ALIGNMENT. If the engine has been overhauled, or if the converter pilot bear-

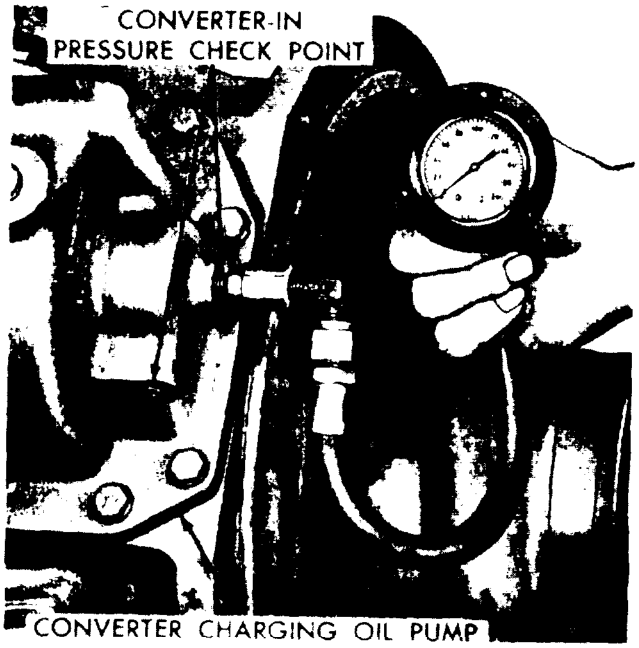


Figure 4C-4. Checking Converter-in Pressure

ing was defective at converter overhaul, check the converter installation as outlined below.

Check the runout of the engine crankshaft with the engine bell housing face. This should not exceed 0.013 of an inch (0.33 mm). If the runout does exceed 0.013 (0.33 mm). See Engine Repair, Section 11.

Check the runout of the engine flywheel housing pilot diameter with the engine crankshaft. This should not exceed 0.013 of an inch (0.33 mm). If the runout does exceed 0.013 (0.33 mm). See Engine Repair, Section 11 before continuing.

Check to see whether seal rin (see item 10, Figure 4C-39 on page 4C-341, is preventing the cover from adequately squeezing the bearing outer race. The seal chamfer must be large enough to prevent the seal from overlapping the chamfer and holding the cover away from the flywheel.

If misalignment between the engine and converter is found to be excessive, do not install the converter until it is corrected. Misalignment puts abnormal loads on the pilot bearing and could contribute to a premature bearing failure.

OIL SEAL DRAIN LINE. Excessively high converter operating temperature will sometimes result in oxidation of the oil, causing carbon deposits to occur in the hydraulic system. The seal drain line will become restricted sufficiently to cause a pressure buildup at the pump hub seal. Leakage or complete failure of the pump hub seal will result. Remove the seal drain line from the converter housing periodically and check for carbon buildup. If any carbon is evident, remove the deposit and reinstall the fitting and seal drain line. Watch the engine flywheel housing drain hole for indications of leakage at the pump hub seal. If the problem of carbon buildup persists, correct the conditions causing high operating temperatures.

Troubleshooting

The information in Table 4C-1 on page 4C-8 will help you locate the source of converter trouble. This table is organized to cover troubles that may occur first - due to improper maintenance. Remember that the converter is part of the power package, and, therefore, the whole package must be considered when running down the source of trouble.

Removal

If the torque converter is to be removed at the time the engine is removed, refer to the topic Engines, in Subsection 4A. The torque converter can be removed from the upper without removing the engine by following this procedure.

1. Remove the machine house sheet metal over the torque converter, as necessary.

2. Disconnect the clutch operating mechanism from the torque converter.

3. Disconnect the propeller shaft from the torque converter.

4. Drain the hydraulic reservoir. Mark and disconnect the hydraulic lines to the torque converter. Plug the lines to prevent the entry of dirt.

5. Disconnect the leads from the temperature and pressure sending units at the top of the torque converter.

6. Disconnect all necessary electrical and mechanical items from the torque converter. Make a visual inspection to make sure everything has been disconnected and out of the way to allow removal of the torque converter.

7. Fully support the torque converter with a suitable slifting device and remove the capscrews and lock washers securing the torque converter to the engine.

8. Slide the torque converter STRAIGHT BACK from the engine to disengage the torque converter disconnect clutch assembly from the clutch drive gear.

9. Remove the torque converter and clutch as an assembly. This assembly weighs approximately 600 lbs.

CAUSE	REMEDY
A. LOW CONVERTER CHARGING PRESSURE	
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 equipment
8. Stator stalled 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

Table 4C-1. Converter Troubleshooting (Part 1 of 2)

CAUSE	REMEDY
E. LOSS OF POWER	
1. Stator installed without rollers (low stall speed) 2. Low converter charging pressure 3. Low engine speed, at converter stall	1. Disassemble converter and install rollers 2. Refer to A, above 3. Refer to D, above
F. MANUAL INPUT DISCONNECT CLUTCH SLIPPAGE	
1. Clutch facing wear 2. Grease on faces	1. Adjust clutch 2. Clean parts

Table 4C-1. Converter Troubleshooting (Part 2 of 2)

Rotation	Designed to operate with right hand rotating engine
Torque multiplication ratio at stall	3.44 to 1
Integral charging oil pump capacity	19 gpm (71 lpm) at 1800 RPM converter input speed
Converter-in oil pressure Minimum at full throttle stall condition Maximum at full throttle stall Maximum at full throttle no load	 50 psi (345 kPa) 80 psi (552 kPa) 120 psi (827 Kpa)
Main oil pressure (clutch pressure valve)	140-175 psi (965-1206 kPa)
Converter oil outlet max. temperature	250°F (121°C)
Oil cooled by	Heat exchanger
Converter oil capacity	5-1/2 gal (20.8 Litres)
Number of stages	1
Number of phases	2
Number of elements	3 (pump, turbine, stator)
Output shaft	Industrial
Flywheel housing	SAE 1

Table 4C-2. Specifications and Data

Tools, Equipment

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.

SPECIAL TOOLS. Table 4C-3 on page 4C-14 lists the special tools, their part numbers and their use. Special tools are

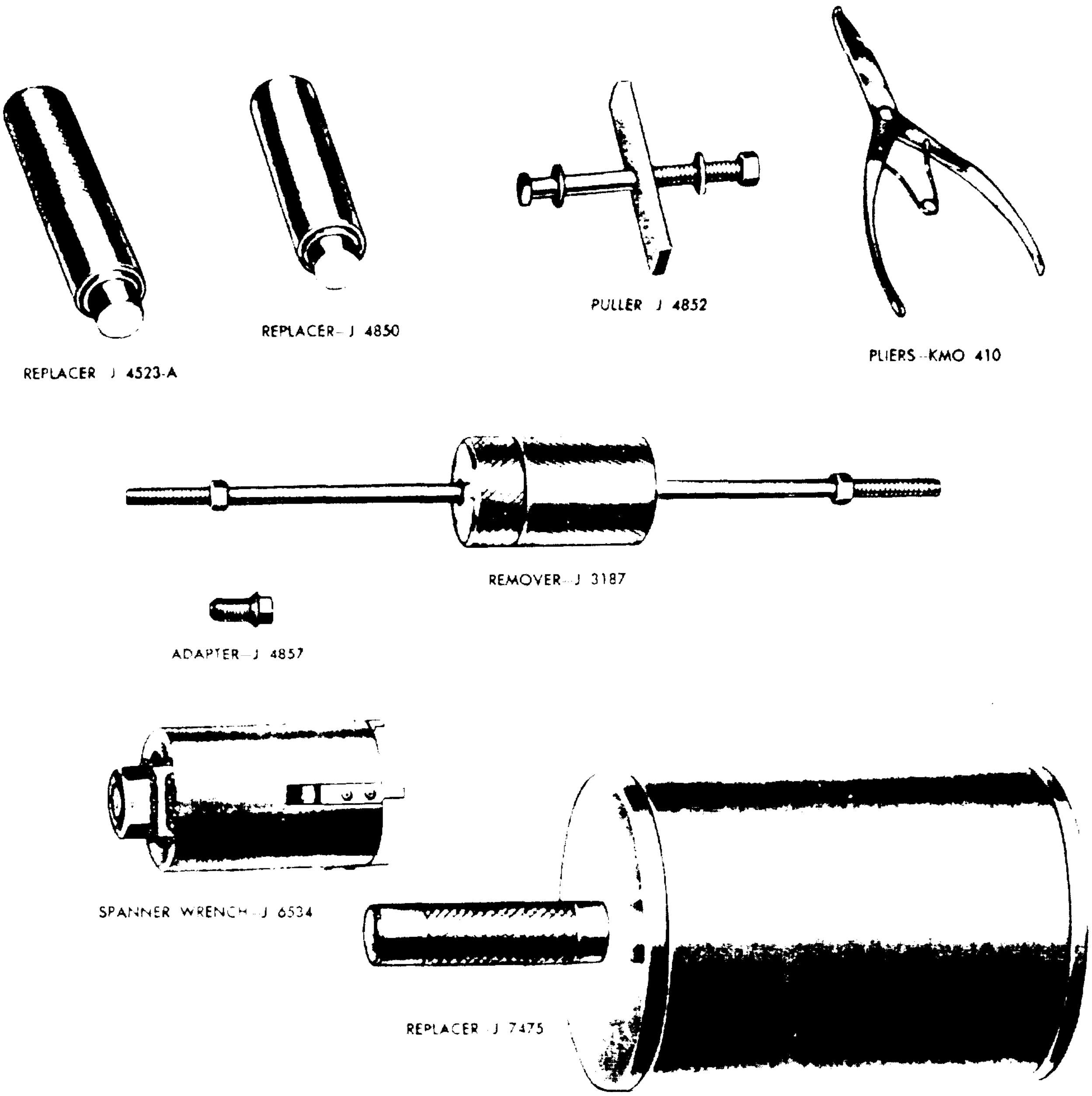


Figure 4C-5. Special Tools for Torque Converter Overhaul

available through the Kent-Moore Tool Division, 1501 S. Jackson St., Jackson, MI 49203. Refer to figure 4C-5 on page 4C-10 for these tools. Refer to Figure 4C-6 on page 4C-11 through Figure 4C-9 on page 4C-13 for other special tools that can be fabricated locally.

Parts Care

HANDLING. Handle the converter parts with care. Nicks, scratches or dents caused by careless handling of parts can cause subsequent converter failure.

NEW PARTS NEEDED. Replace all gasket, worn seal rings and cotter pins. If the converter has been subjected to excessive heat, replace all springs and rubber seals. Handle rubber and metal seal rings with care to prevent damage.

Cleaning and Inspection

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 the converter. When metal particles are

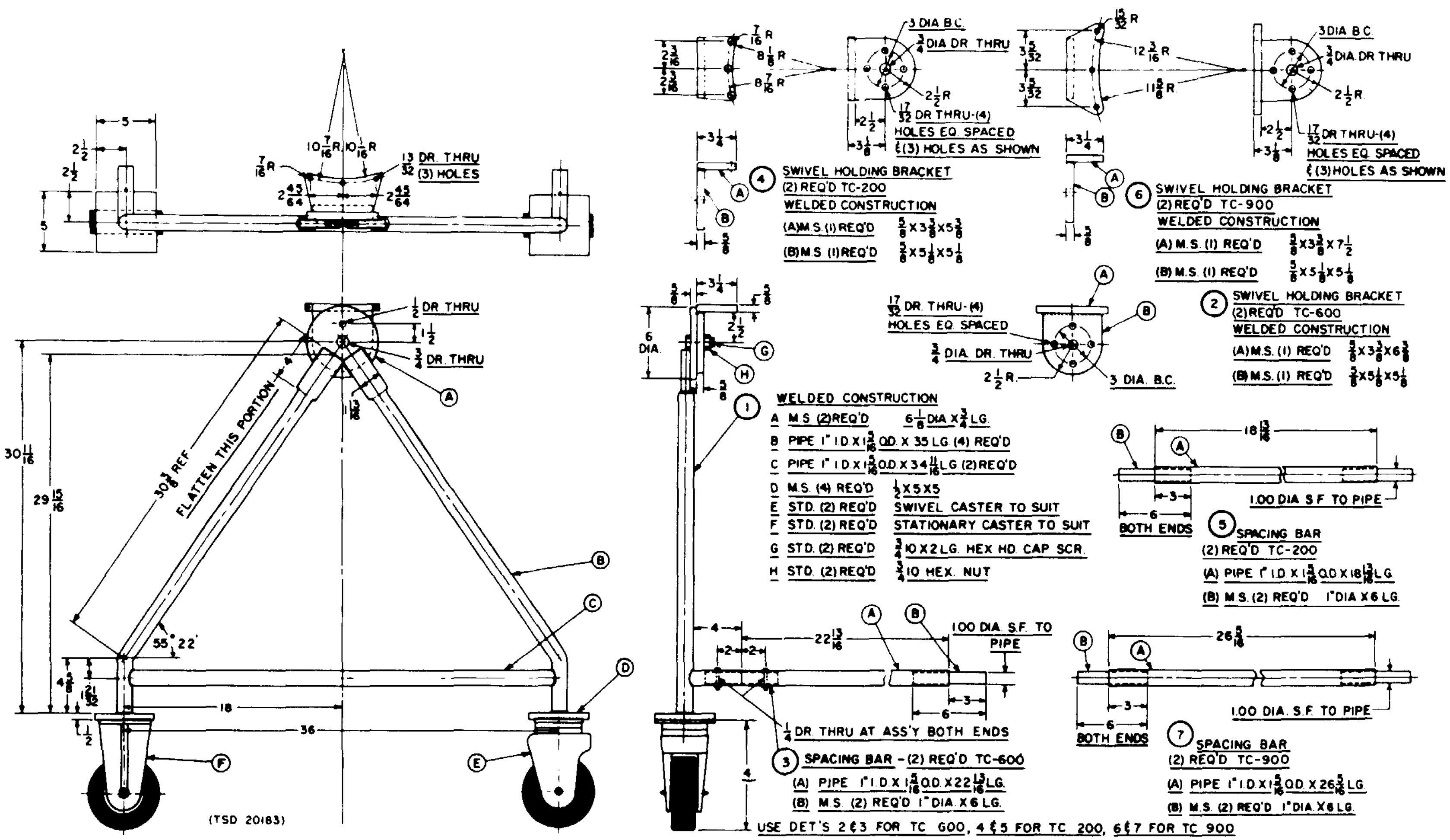


Figure 4C-6. Converter Overhaul Stand

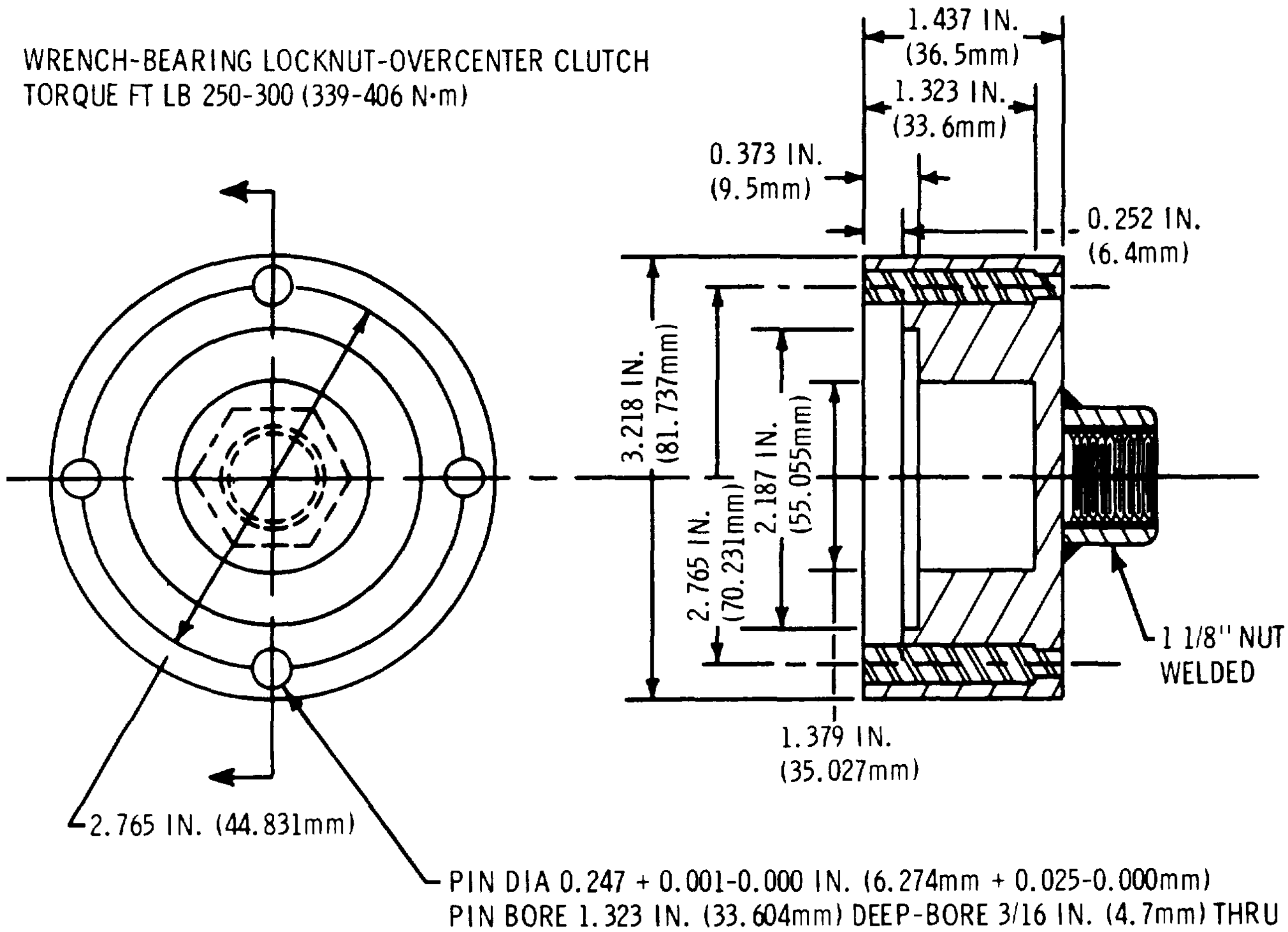


Figure 4C-7. Spanner Wrench for Input Disconnect Clutch Lock Nut

found, the converter must be thoroughly cleaned. All oil lines and cooler passages should be cleaned.

CLEANING PARTS. All metallic parts except bearings should be cleaned thoroughly with dry cleaning solvent, volatile mineral spirits, paint thinner, or by the steam cleaning method.

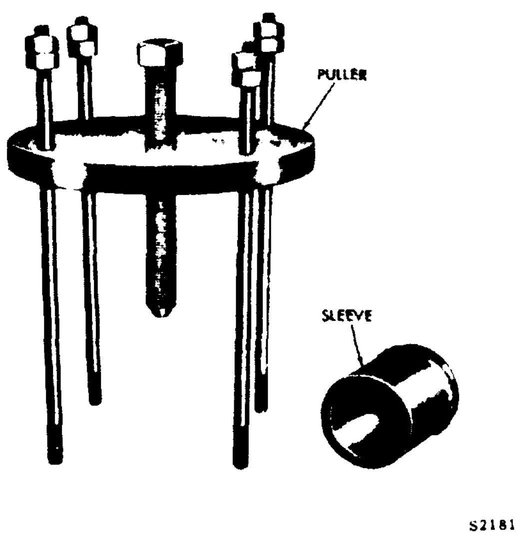


Figure 4C-8. Puller and Sleeve for Converter Pump Bearing

Parts should be dried with compressed air. Steam cleaned parts should be oiled immediately after drying.

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.

Examine parts, especially oil passages, after cleaning to make certain they are entirely clean. Reclean them if necessary.

CLEANING BEARINGS. Thoroughly wash bearings that have been in service in dry cleaning solvent, volatile mineral spirits or paint thinner.

If the bearings are particularly dirty or filled with hardened grease, soak them in solvent before trying to clean them.

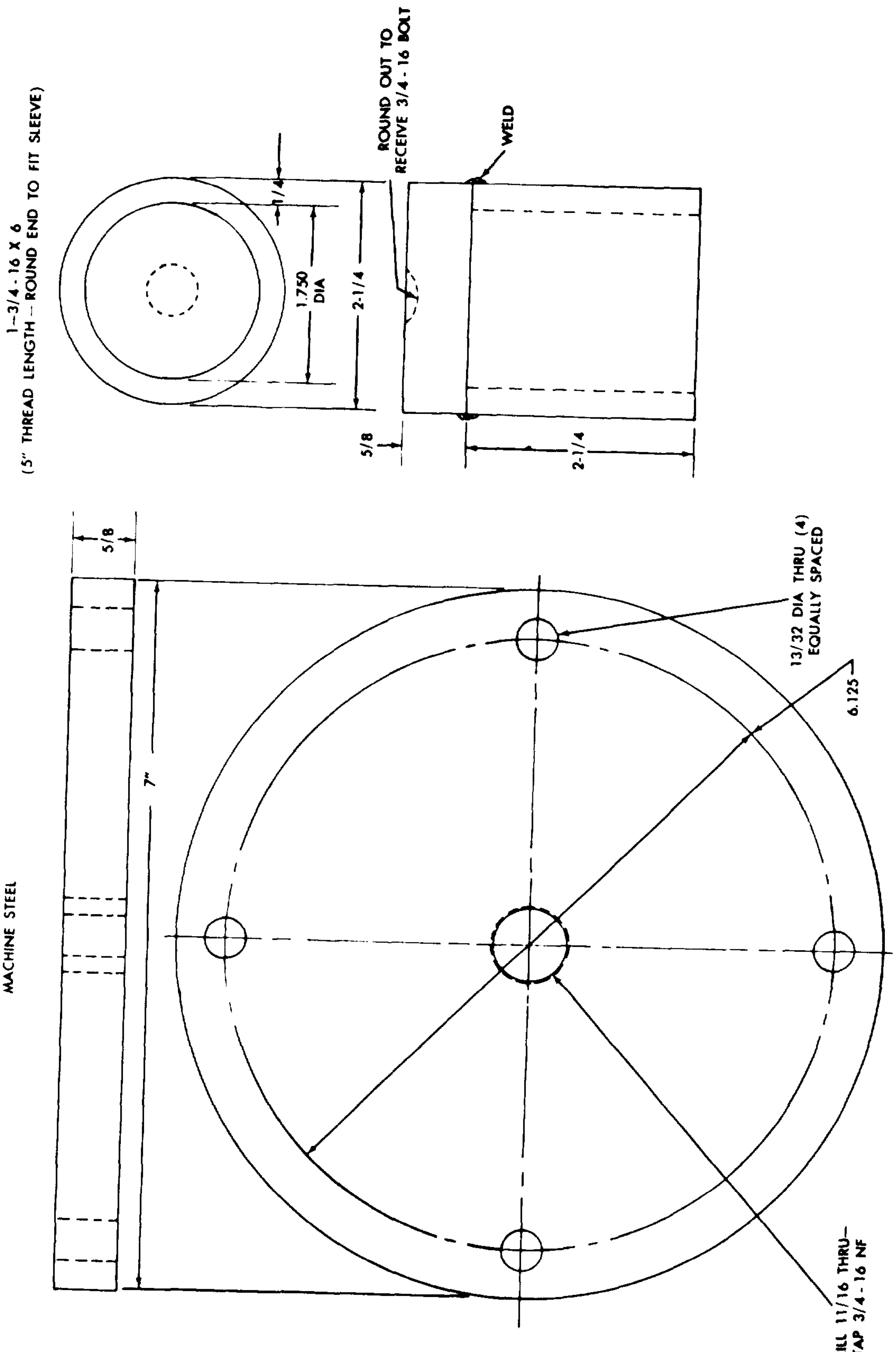


Figure 4C-9. Sketch of Puller and Sleeve

Before inspection, oil bearings with the same type of oil that will be used in the converter.

NOTE

Never dry bearings with compressed air. Do not spin bearings while they are not lubricated.

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:

- Do not remove the wrapper from new bearings until ready to install them.
- Do not remove the grease in which new bearings are packed.
- Do not lay bearings on a dirty workbench; place them on clean paper.

NAME	NUMBER	USE
Charging oil pump needle bearing replacer	J 4850	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	To install drive shaft needle bearing in pump body
Snap ring pliers	J 8039	To remove and install snap rings
Charging oil pump rear bearing sleeve puller	J 4852	To remove oil pump rear bearing sleeve from oil charging pump
Charging oil pump idler gear shaft remover (slide hammer puller)	J 23907-1	Used with adapter J 8117 to remove charging oil pump idler gear shaft from converter housing
Charging oil pump idler ear shaft remover (adapter)	J 8117	Used with puller J 23907-1 to remove charging oil pump idler gear from converter housing
Converter pump hub seal replacer	J 7475	To press pump hub oil seal into converter housing
Spanner wrench	J 6534-02	To remove and install stator roller race retainer nut
Converter overhaul	TSD 20183	To support converter during overhaul
Overcenter disconnect clutch lock nut wrench	TSD 20231	To remove and install overcenter disconnect clutch lock nut
Puller and sleeve for converter pump bearing		To remove converter pump bearing

Table 4C-3. Special Tools

- If assembly is not to be completed at once, wrap or cover the exposed bearings with clean paper or cloth to keep out dust.

INSPECTING CAST PARTS, MACHINED SURFACES. 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.

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.

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.

Inspect threaded openings for damaged threads. Chase damaged threads with the correct size used tap.

CAUTION

A new tap can cut oversize.

Inspect all machined surfaces for damage that could cause oil leakage or other malfunction of the part. Rework or replace the defective parts.

INSPECTING BEARINGS. Inspect bearings for roughness of rotation. Replace a bearing if its rotation is still rough after cleaning and oiling.

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 if found, replace the bearing.

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 shaft. If the damage cannot be repaired with crocus cloth, replace the defective part.

When installing a bearing on a shaft, heat the bearing to 300°F (149°C) on an electric hot plate or in an oil bath. Coat the mating surface with white lead and use the proper size installation sleeve and an arbor press to seat the bearing.

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 hammer, driving against the supported race.

INSPECTING BUSHING, THRUST WASHERS. 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.

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.

INSPECTING OIL SEALS, GASKETS. Inspect seal rings for cuts, hardness or other indications of deterioration. Replace the seal rings if these defects are found.

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 of the seal to help prevent oil leaks.

Replace all composition gaskets.

Inspect hook type seal rings for wear, broken hooks and distortion.

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.

INSPECTING GEARS. Inspect gears for scuffed, nicked, burred or broken teeth. If the defect cannot be removed with a soft stone, replace the gear.

Inspect gear teeth for wear that may have destroyed the original tooth shape. If this condition is found, replace the gear.

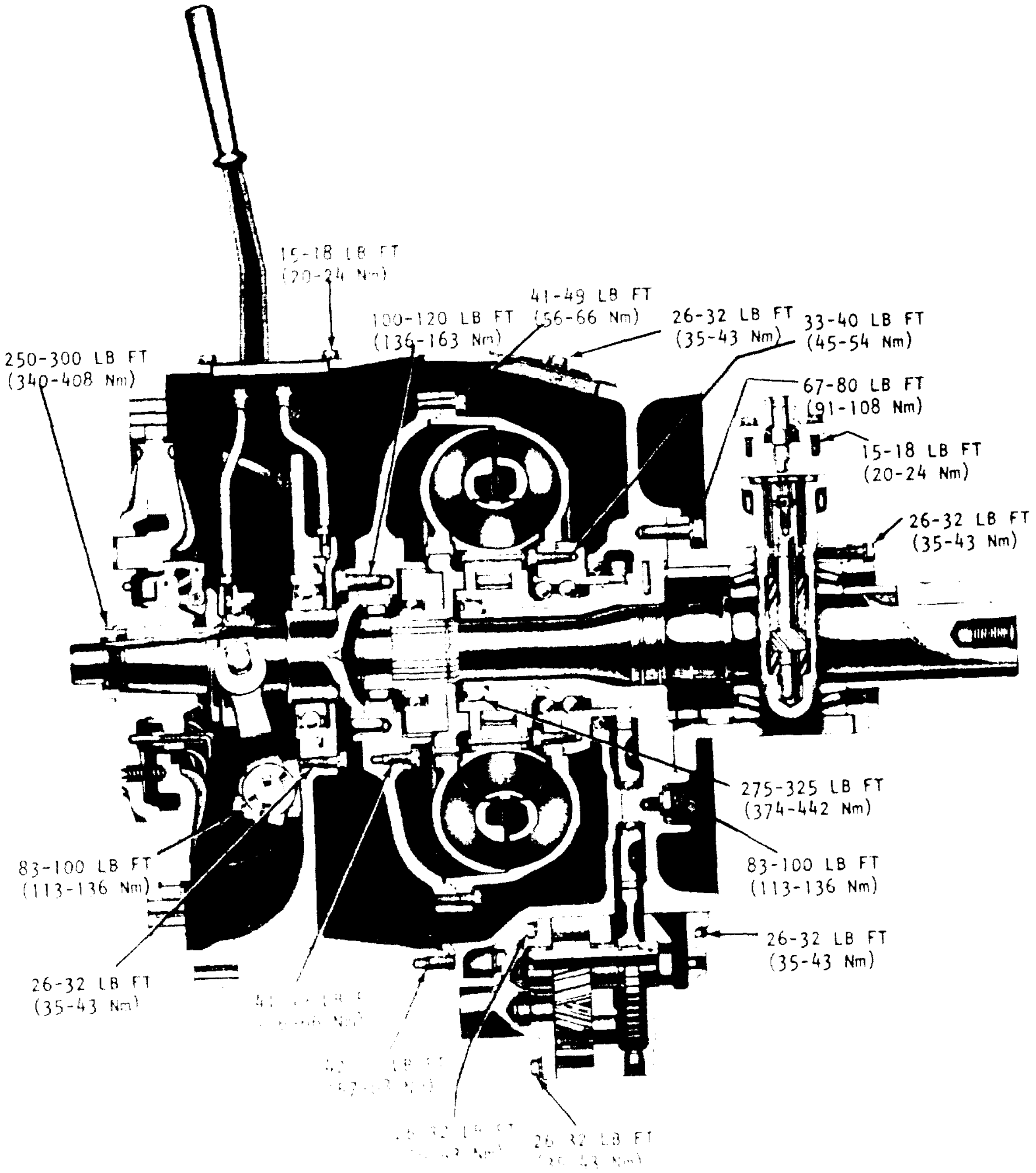


Figure 4C-10. Torque Specifications

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.

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.

INSPECTING THREADED PARTS. Inspect parts for burred or damaged threads. Remove burrs with a soft stone or fine file. Replace damaged parts.

INSPECTING SNAP RINGS. Inspect all snap rings for nick, distortion and excessive wear. Replace the part if one of these defects is found. the snap ring **MUST** snap tight in its groove for proper functioning.

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.

Disassembly

REMOVAL OF CHARGING OIL PUMP. To remove the charging oil pump, proceed as follows:

1. Position the converter, on the disconnect clutch end, on the disassembly table.

2. Remove the six bolts and lock washers from the pump assembly. Remove the assembly and gasket (see Figure 4C-11).

REMOVAL OF OVERCENTER DISCONNECT CLUTCH ASSEMBLY. To remove the clutch assembly, proceed as follows:

1. Remove two bolts (5, Figure 4C-38 on page 4C-33) and lockwashers (6) that retain the converter housing access cover (4).

2. Remove cover (4) and Gasket (3).

3. Remove 36 converter pump--to--converter drive housing bolts (12, Figure 4C-39 on page 4C-34).

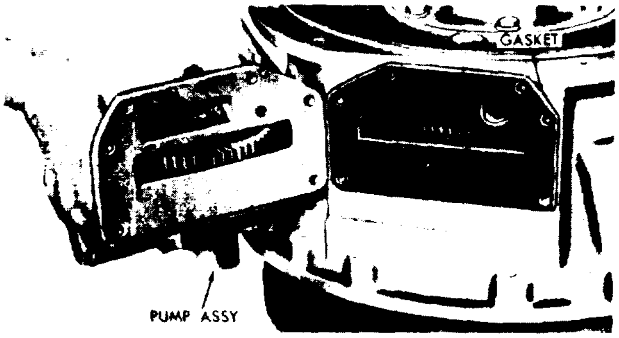


Figure 4C-11. Removing (or Installing) Charging Oil Pump

4. Remove eleven converter housing--to--disconnect clutch housing bolts (24, Figure 4C-38 on page 4C-33) and lock washers (25).

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.

REMOVAL OF CONVERTER ELEMENTS. To remove the converter elements, proceed as follows:

1. Remove snap ring (9, Figure 4C-40 on page 4C-35) from converter output shaft (3, Figure 4C-27 on page 4C-22).

2. Remove the inner race of bearing (10, Figure 4C-40 on page 4C-35) and turbine assembly with over-running clutch (14 through 18).

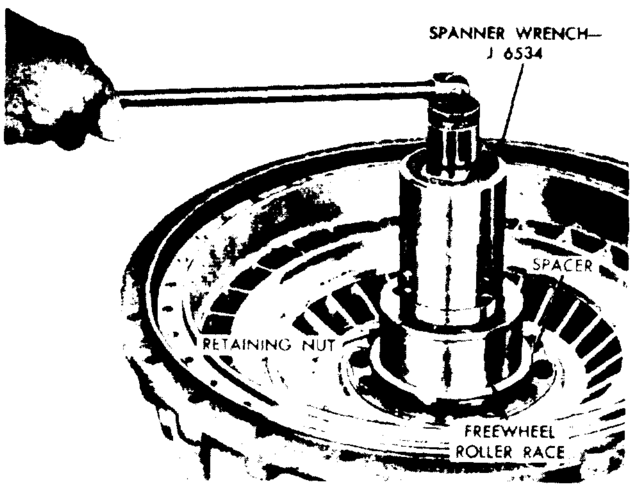


Figure 4C-12. Removing (or Installing) Freewheel Roller Race Retaining Nut

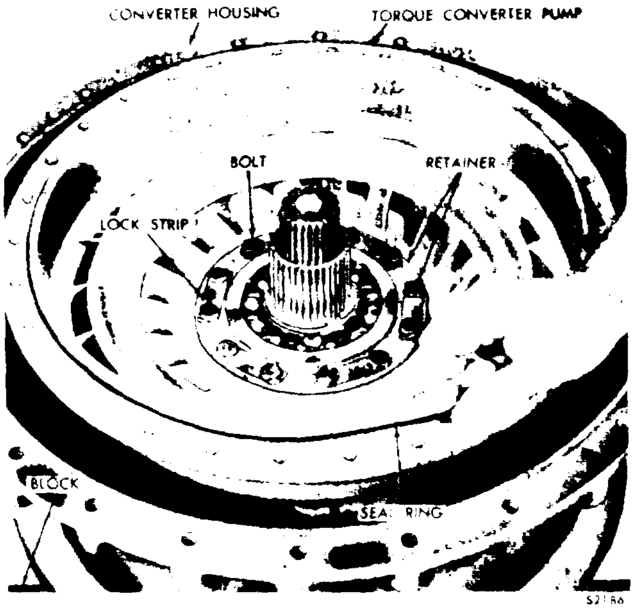


Figure 4C-13. Removing (or Installing) Lock Strips

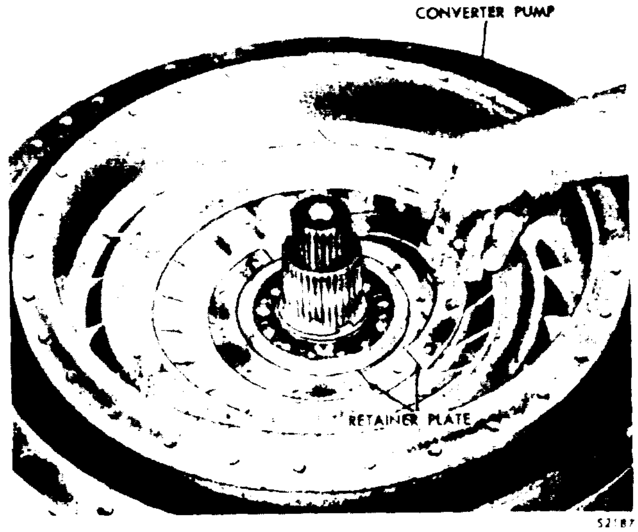


Figure 4C-14. Removing (or Installing) Split Retainer Plate

3. Remove snap ring (19) from converter output shaft (3, Figure 4C-27 on page 4C-22).

4. Remove stator assembly (2 through 4, Figure 4C-39 on page 4C-34).

5. Straighten the staked section of the freewheel roller race retaining nut (13).

6. Using spanner wrench J 6534, remove the retaining nut (see Figure 4C-12 on page 4C-17).

7. Remove freewheel roller race and spacer.

8. Remove 12 bolts, six lock strips and the split retainer that retains the converter pump (see Figure 4C-13 and Figure 4C-14).

9. Remove the converter pump.

10. The converter pump hub and bearing may come off with the converter pump. If not, remove the hub and bearing (see Figure 4C-15 on page 4C-19).

11. Remove seal rings from ground sleeve (see Figure 4C-16 on page 4C-19).

REMOVAL OF OUTPUT SHAFT. To remove the output shaft, proceed as follows:

1. Position the converter housing with the output shaft up (see Figure 4C-17 on page 4C-19).

2. Remove the eight bolts and lock washers from the bearing retainer.

3. Remove the retainer and the shims from the bearing housing. If necessary, use jackscrews.

4. Remove the six bolts and lock washers from the bearing housing.

5. Using jackscrews, remove the bearing housing and gasket from the converter housing (see Figure 4C-18 on page 4C-19).

6. The output shaft may come out with the bearing housing. Remove the bearing housing from the shaft. If the output shaft does not come out when the bearing housing is removed, remove the output shaft (see Figure 4C-19 on page 4C-20). A sleeve, two seal rings and two roller bearings will come off with the shaft.

Rebuild of Subassemblies

TORQUE CONVERTER HOUSING. To rebuild the torque converter, proceed as follows (see Figure 4C-38 on page 4C-33):

1. Remove the square head plug, seal ring and lock washer from the rear of the converter housing.

2. Install the slide hammer remover J3187 and adapter J4857 in the threaded hole in

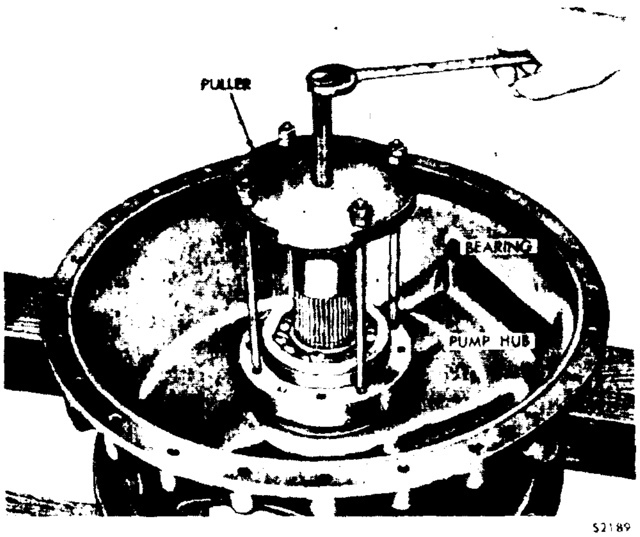


Figure 4C-15. Removing Converter Pump Hub and Bearing

the oil pump idler gear shaft (see Figure 4C-21 on page 4C-20)

3. Remove the shaft, being careful that the oil pump idler gear does not drop out of the housing.

4. Remove the oil pump idler gear assembly (see Figure 4C-22 on page 4C-21).

5. Oil pump drive gear (2, Figure 4C-38 on page 4C-33) 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.

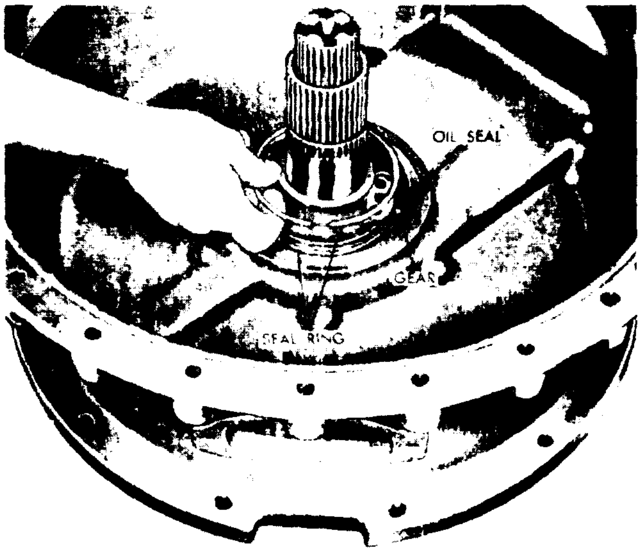


Figure 4C-16. Removing (or Installing) Seal Rings from Ground Sleeve

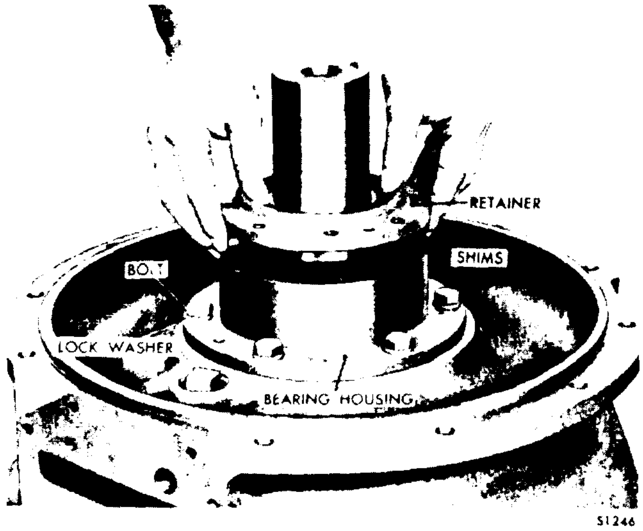


Figure 4C-17. Removing (or Installing) Bearing Retainer and Shims

6. 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 (see Figure 4C-23 on page 4C-21). Remove the ground sleeve key and dowel pin from the ground sleeve.

7. Clean and inspect parts as explained under “Cleaning and Inspection” on page 4C-10.

8. If the ground sleeve was removed, install dowel pin (16, Figure 4C-38 on page 4C-33) in ground sleeve key (17) and install the key on the new ground sleeve (18) so that the end of the key is

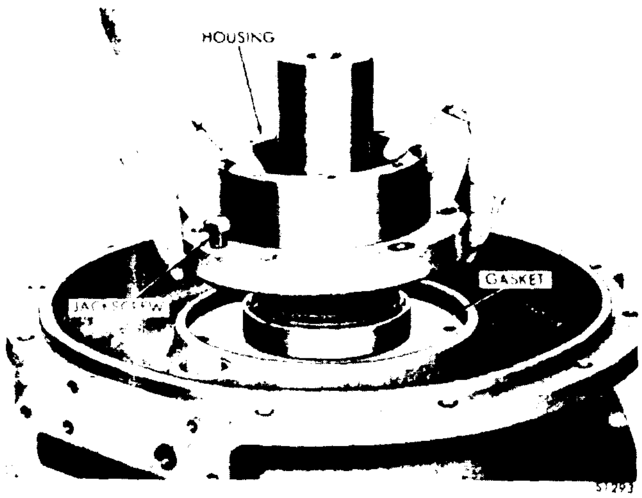


Figure 4C-18. Removing Bearing Housing

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 (see Figure 4C-24 on page 4C-21).

9. If oil pump drive gear (2, Figure 4C-38 on page 4C-33) 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.

10. Position the converter on the table with the rear end up.

11. Install the charging oil pump idler gear assembly by positioning the gear in the housing bore (see Figure 4C-22 on page 4C-21) and installing oil pump idler gear shaft (12 Figure 4C-38 on page 4C-33) in its bore. Use a soft drift or a bolt of the proper size threaded into the shaft and tap the shaft into place.

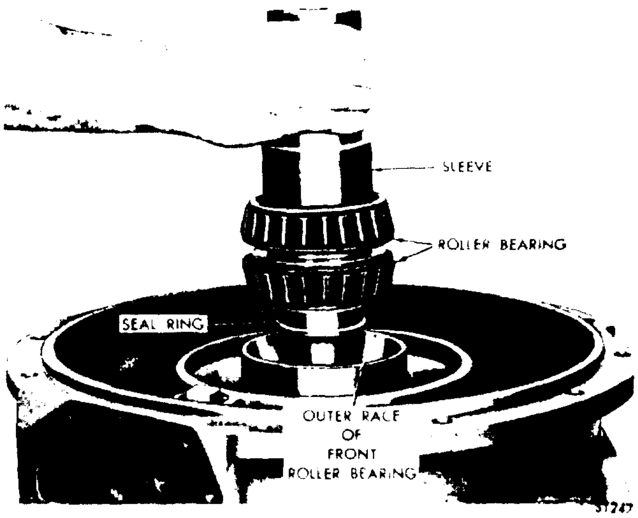


Figure 4C-19. Removing (or Installing) Output Shaft

12. Install the lock washer, seal ring and square head plug into the oil pump idler gear shaft bore (see Figure 4C-20). Torque the plug to 80-100 ft-lbs.

CONVERTER PUMP AND HUB ASSEMBLY. To rebuild the converter pump and hub, proceed as follows (see Figure 4C-39 on page 4C-34):

1. The converter pump was removed when the converter was disassembled into subassemblies. No further disassembly is necessary.

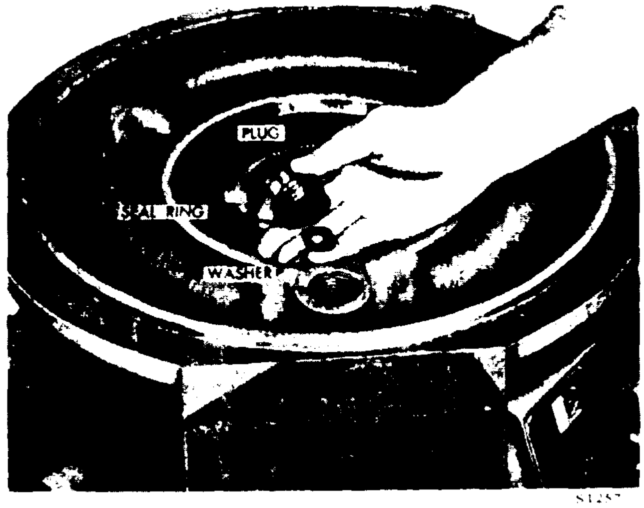


Figure 4C-20. Removing (or Installing) Plug from Converter Housing

2. Remove seal ring (16, Figure 4C-39 on page 4C-34) from converter pump hub (17).

3. Press double row ball bearing assembly (8) from converter pump hub (17).

4. Clean and inspect parts as explained under “Cleaning and Inspection” on page 4C-10.

5. Install double row ball bearing assembly (08), seal ring, groove side up, into bearing pump hub (17). Press the bearing until it is firmly seated in the hub.

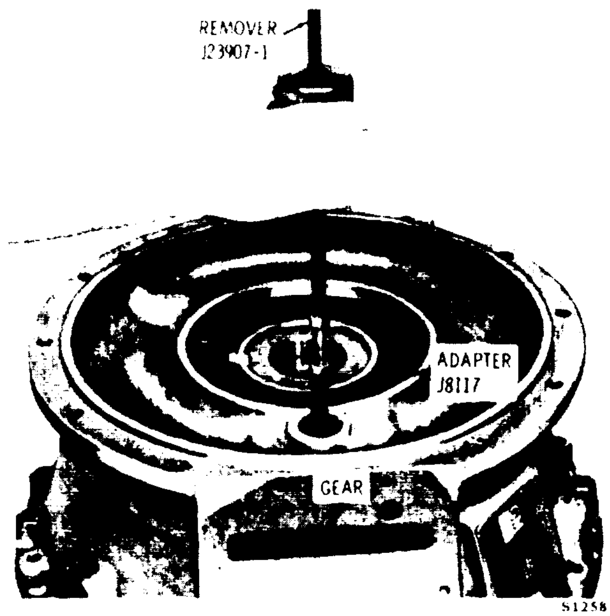


Figure 4C-21. Removing Oil Pump Idler Gear Shaft

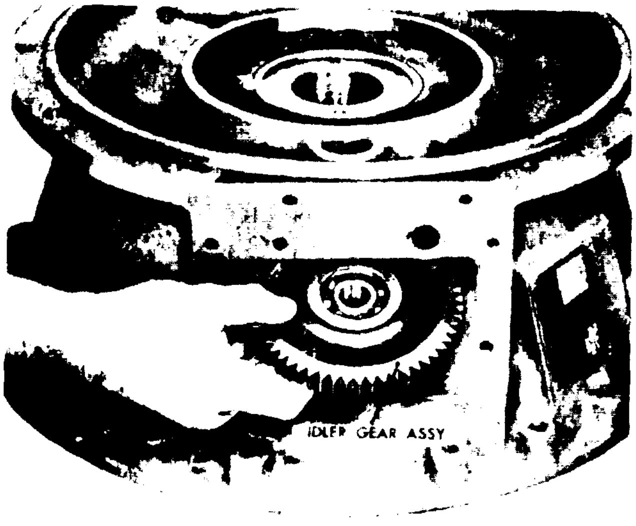


Figure 4C-22. Removing (or Installing) Oil Pump Idler Gear

6. Install seal ring (16) onto pump hub (17).

STATOR. To rebuild the stator, proceed as follows (see Figure 4C-39 on page 4C-34):

1. Remove rollers (4) and springs (3) from stator (2).

2. 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.

3. Clean and inspect parts as explained under “Cleaning and Inspection” on page 4C-10.

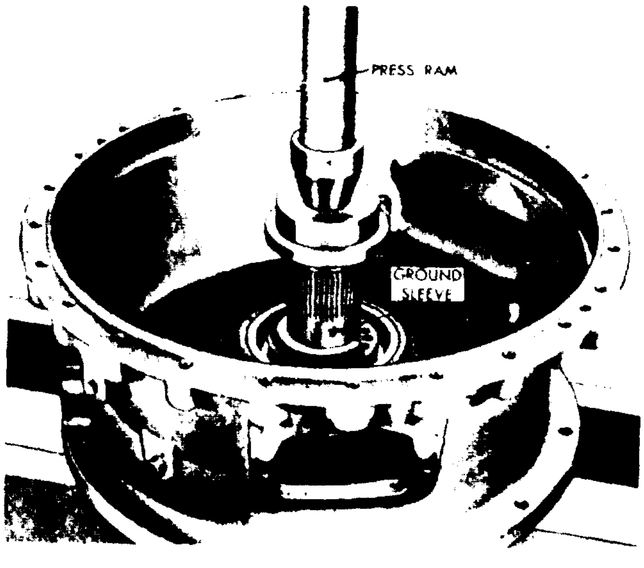


Figure 4C-23. Removing Ground Sleeve

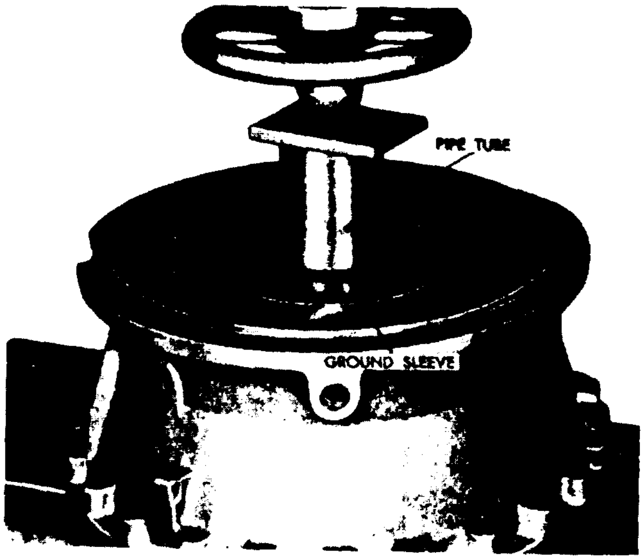


Figure 4C-24. Removing Ground Sleeve from Housing

4. Install the freewheel rollers and springs into the stator cam (see Figure 4C-25 on page 4C-22). Rollers and springs may be retained with a heavy coating of oil soluble grease.

5. 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 (see Figure 4C-26 on page 4C-22).

CONVERTER TURBINE ASSEMBLY. To rebuild the turbine assembly, proceed as follows (see Figure 4C-40 on page 4C-35):

1. Remove snap ring (14) from converter turbine (1, Figure 4C-39 on page 4C-34).

2. Remove sprag clutch race (17) with bearing assembly (15) and retainer (16).

3. Press bearing assembly (15) from race (17) and remove retainer (16).

4. Remove sprag assembly (18) from converter turbine (1, Figure 4C-39 on page 4C-34).

5. Do not remove the rivets from the turbine. If the turbine assembly is worn or damaged, the assembly must be replaced.

6. Clean and inspect parts as explained under “Cleaning and Inspection” on page 4C-10.

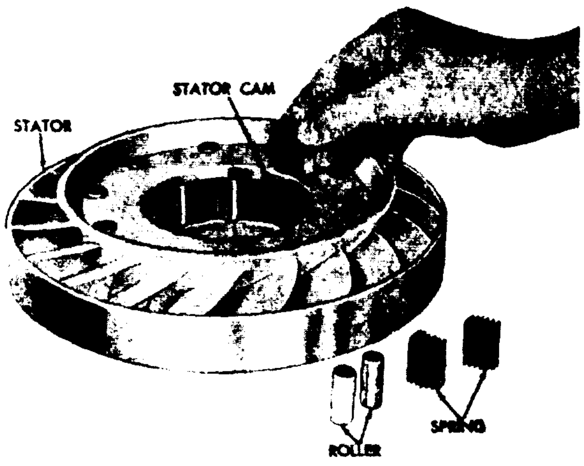


Figure 4C-25. Installing Stator Springs and Rollers

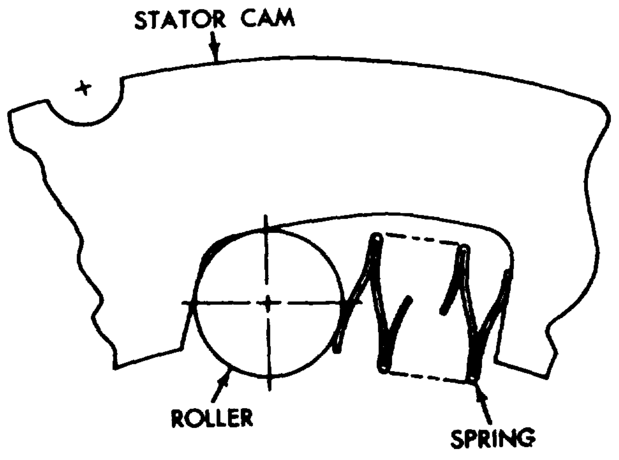


Figure 4C-26. Spring and Rollers in Stator Cam

7. Install retainer (16) in sprag race (17).

8. Install bearing assembly (15) in sprag race (17). Press the bearing until it is firmly seated against the retainer in the race.

9. Install sprag clutch assembly (18), flange side out, onto converter turbine (1, Figure 4C-39 on page 4C-34).

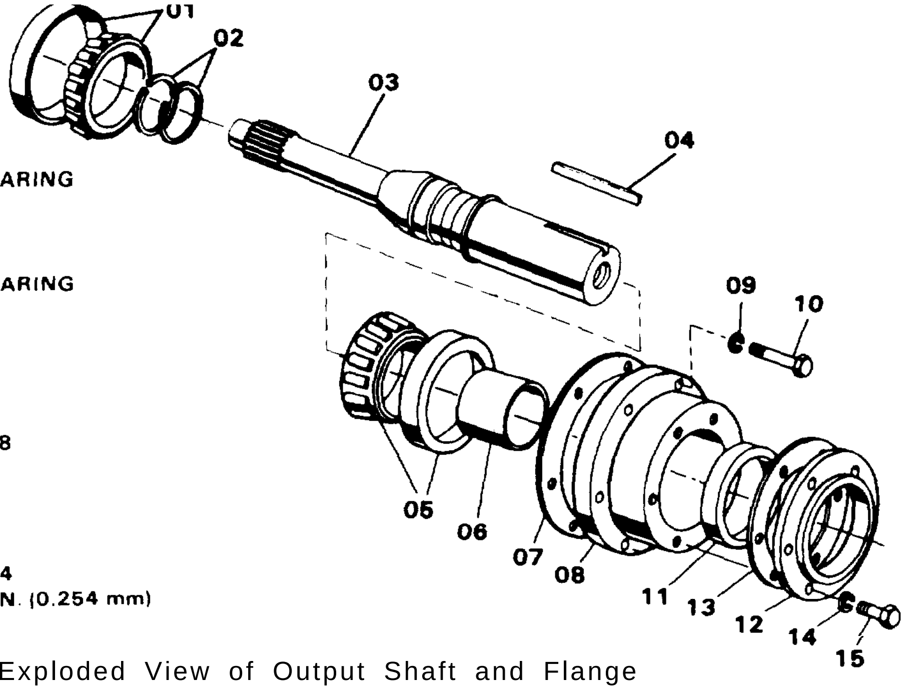
10. Install the bearing with the race and retainer onto the turbine assembly. Press the bearing until it is firmly seated against the shoulder on the turbine assembly.

11. Install snap ring (14).

OUTPUT SHAFT AND BEARING RETAINER. To rebuild the output shaft, proceed as follows (see Figure 4C-27):

1. Remove two hook type seal rings (2) from output shaft (3).

2. When it is necessary to replace roller bearing assemblies (1) and (5), 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



01. SEPARABLE OUTER RACE ROLLER BEARING
02. HOOK-TYPE SEAL RINGS
03. CONVERTER OUTPUT SHAFT
04. KEY
05. SEPARABLE OUTER RACE ROLLER BEARING ASSEMBLY
06. SLEEVE
07. GASKET
08. BEARING RETAINER HOUSING
09. LOCKWASHER, 1/2
10. HEXAGON-HEAD BOLT, 1/2-13 x 1-7/8
11. DUAL OIL SEAL
12. BEARING RETAINER
13. GASKET
14. LOCKWASHER, 3/8
15. HEXAGON-HEAD BOLT, 3/8-16 x 1-1/4
16. SHIM — 0.005 IN. (0.127 mm), 0.010 IN. (0.254 mm) and 0.025 IN. (0.635 mm)

Figure 4C-27. Exploded View of Output Shaft and Flange rests on the plates. Press the shaft out of the front roller bearing.

3. If the rear bearing must be removed, use a hammer and chisel to crack sleeves (6) over the key way 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.

4. Do not remove lip type oil seal (11) from bearing retainer (12) unless replacement is necessary. If necessary, remove the seal.

5. Clean and inspect the parts as explained under “Cleaning and Inspection” on page 4C-10.

6. If oil seal (11) was removed from bearing retainer (12), 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 chamfered.

7. If roller bearings (1 and 5) were removed, support shaft (3), 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 of the shaft.

8. Turn the shaft end for end and press the other roller bearing onto the shaft in the same manner.

9. Heat sleeve (6) to approximately 35O°F and press it onto the shaft until it is seated against the bearing.

10. Install two hook type seal rings (2) on the output shaft.

CHARGING OIL PUMP. To rebuild the charge pump, proceed as follows (see Figure 4C-41 on page 4C-36):

1. Remove the converter pressure regulator valve plug, gasket, spring and valve from the pump cover (see Figure 4C-28 on page 4C-24).

2. Remove 6 bolts and lock washers retaining pump cover.

3. Remove the pump cover and gasket.

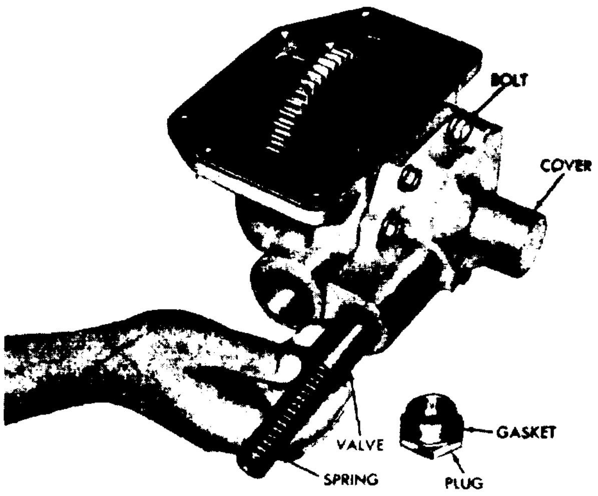


Figure 4C-28. Removing (or Installing) Converter Pressure Regulating Valve

4. Remove the snap ring, clutch pressure regulator valve and spring from the pump cover (see Figure 4C-29 on page 4C-24).

5. Do not remove the needle roller bearing from the pump cover unless replacement is necessary. If necessary, collapse the bearing, being careful to not damage the bearing bore in the cover and remove the bearing.

6. Remove the oil pump driven gear and bearing as an assembly (see Figure 4C-30 on page 4C-24) Do not remove the bearing from the gear unless replacement is necessary. If necessary, remove the bearing.

7. Remove charging pump driving gear shaft and driving gear (see Figure 4C-31 on page 4C-25).

8. Remove the hook type seal ring from the shaft gear.

9. Do not remove the O-ring seal or needle roller bearing from the oil pump housing unless replacement is necessary. If necessary, 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 (see Figure 4C-32 on page 4C-25).

10. Do not remove sleeve (25, Figure 4C-41 on page 4C-36) from the oil pump body unless replacement is neces sary. If necessary, drive the sleeve out of the pump body (see Figure 4C-33 on

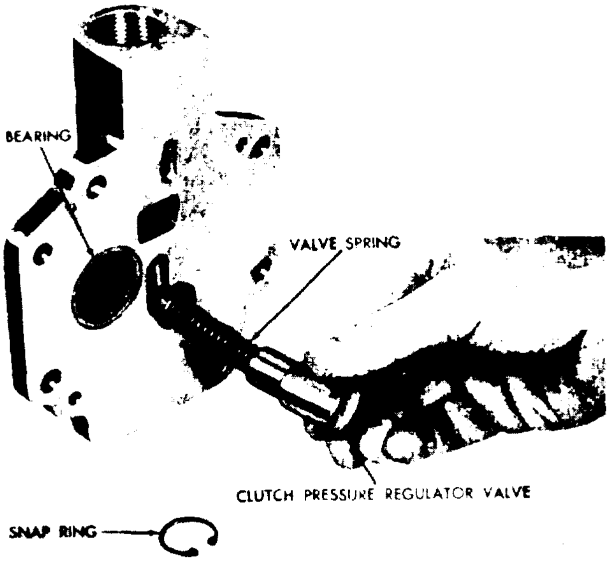


Figure 4C-29. Removing (or Installing) Clutch Pressure Regulating Valve

page 4C-25). Use puller J4852 or a steel disk 1/4 x 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.

11. Do not remove plugs (28, 29, 30 and 31 Figure 4C-41 on page 4C-36) from body
(27) unless replace is necessary or for cleaning purposes. If necessary, remove the plugs.

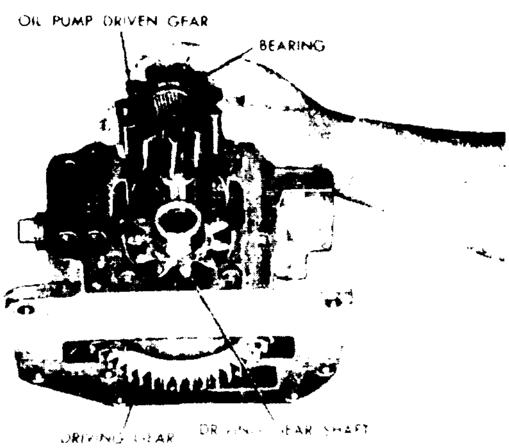


Figure 4C-30. Removing (or Installing) Oil Pump Driven Gear

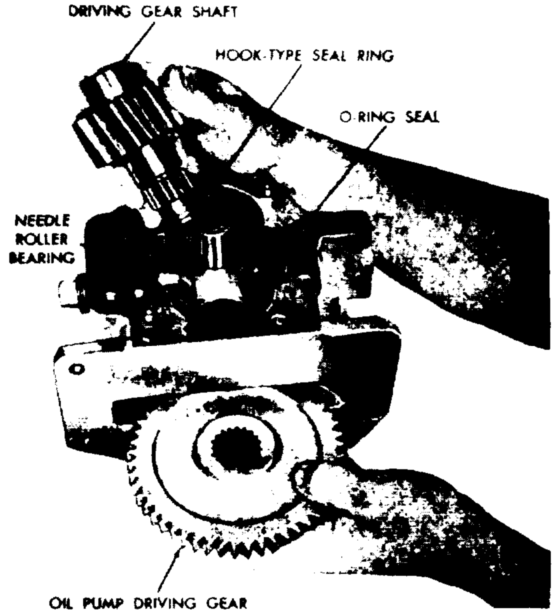


Figure 4C-31. Removing (or Installing) Drive Gear and Shaft

12. Clean and inspect the parts as explained under “Cleaning and Inspection on page 4C-10.

13. 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 for installing the sleeve.

14. If bearing assembly (23) 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.

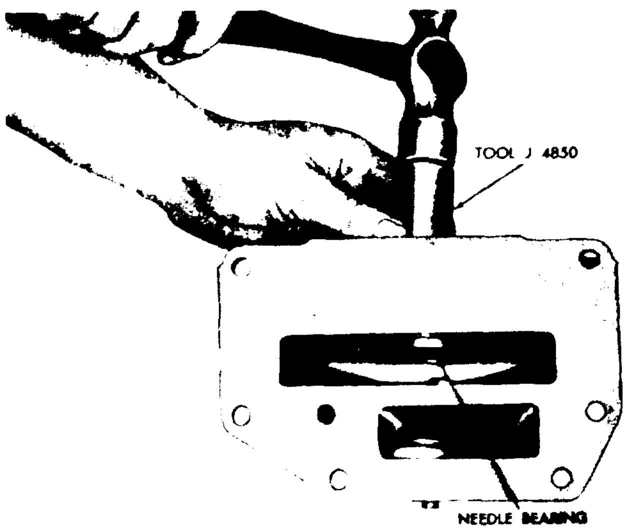


Figure 4C-32. Removing Needle Bearing from Pump Body

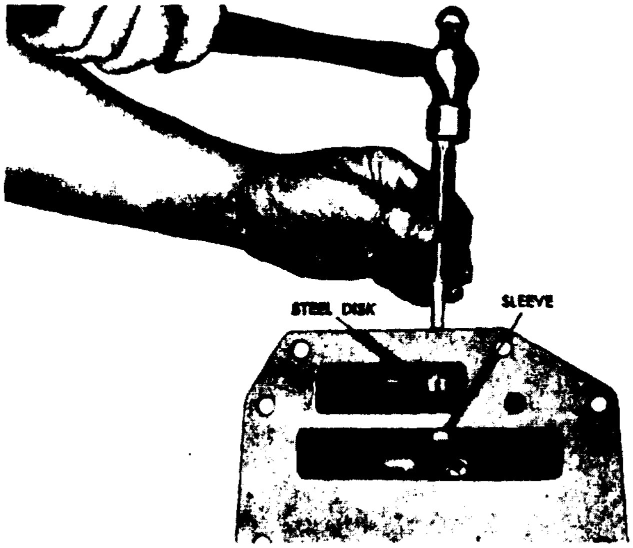


Figure 4C-33. Removing Oil Pump Bearing Sleeve

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.

15. Install the hook type seal ring onto the pump drive shaft.

16. install oil pump driving gear and while holding it in position, install the driving gear shaft (see Figure 4C-31).

17. If needle roller bearing 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.

18. Install the assembled gear and bearing into the oil pump body (see Figure 4C-30 on page 4C-24).

19. If the needle roller bearing 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.

20. Install the clutch pressure regulator valve spring, valve and snap ring in the oil pump body cover (see Figure 4C-29 on page 4C-24).

21. Install the oil pump body cover gasket and assembled cover onto the oil pump body and secure with six bolts and lock washers.

22. Install converter pressure regulator valve, spring, gasket and plug in pump cover (see Figure 4C-28 on page 4C-24).

23. Install plugs (28, 29, 30 and 31, Figure 4C-41 on page 4C-36).

INPUT DISCONNECT CLUTCH. To rebuild the disconnect clutch, proceed as follows (see Figure 4C-34 on page 4C-26):

1. Using a bearing puller, remove ball bearing assembly (51) from the end of the converter drive shaft.

2. Remove four bolts (32) and lock washers (33) securing access cover (34).

3. Disconnect the two grease fittings (25 and 36) and nuts (26 and 37) from the bearing lube tubes (27 and 38). Remove access cover (34).

4. Using wrench TSD 20231, remove spanner lock nut (1) from the front end of the converter drive shaft.

5. Using caution not to damage the bearing diameter, drive or press converter drive shaft (4, Figure 4C-40 on page 4C-35) rearward out of clutch assembly (4) and ball bearing (35). Remove converter drive housing assembly (7, Figure 4C-40 on page 4C-35), but DO NOT disassemble the drive shaft from the drive housing, since it was partially machined after assembly.

6. Remove key (2), clutch assembly (4) and attached bearing lube tube (27).

7. If necessary for parts replacement, remove elbow (28) and bearing lube tube (27) from shift collar (18).

8. Remove eight bolts (40) and lock washers (41) from bearing retainer (39).

9. Remove bearing retainer (39) and attached bearing lube tube (38).

10. Remove ball bearing (35) from clutch housing (30).

11. Remove bearing lube tube (38) from bearing retainer (39).

12. Loosen two bolts (47) and lock washers (48) in clutch shifter yoke.

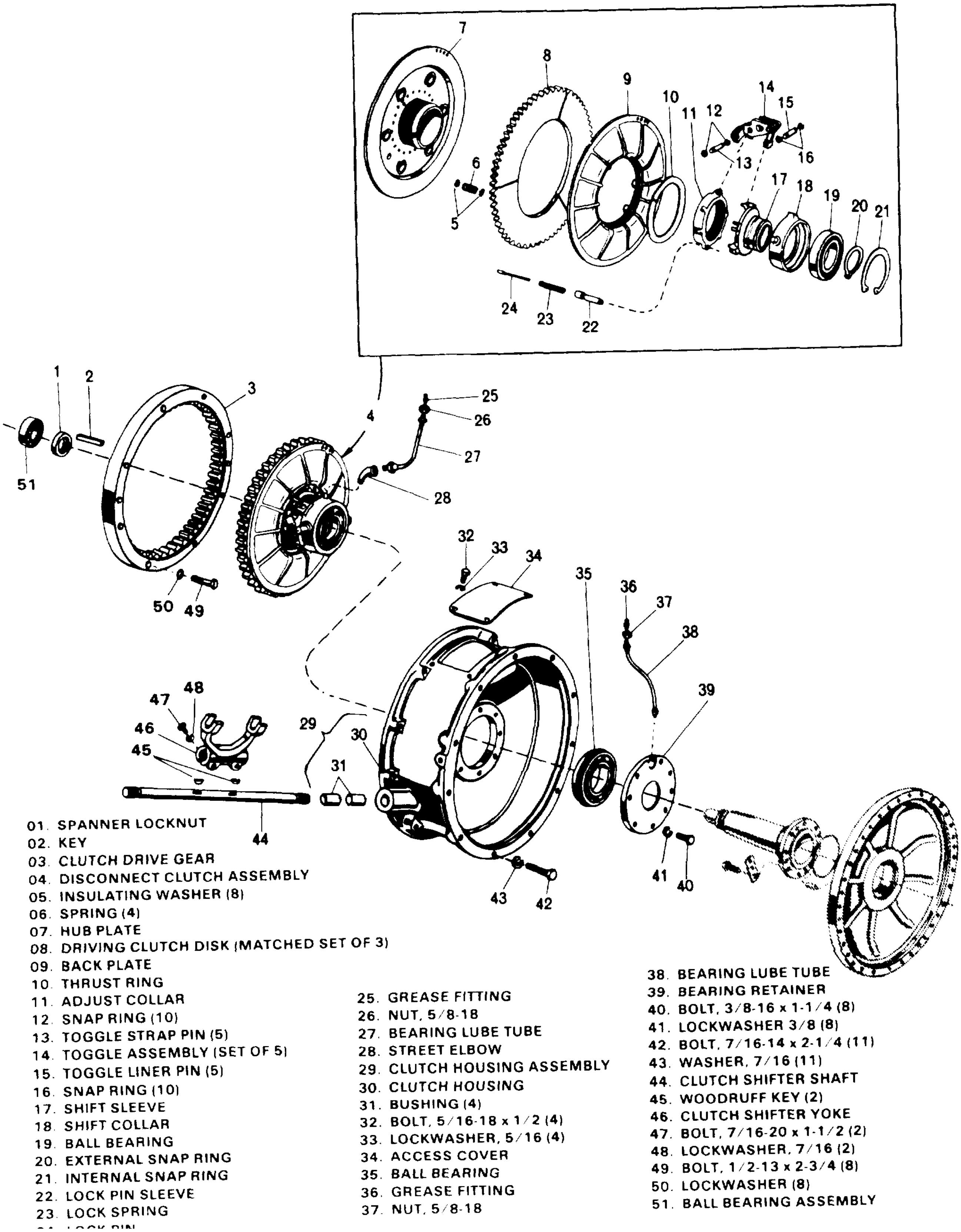


Figure 4C-34. Exploded View of Input Disconnect Clutch

13. Tap shifter shaft (44) out of shifter yoke (46), and remove two keys (45). Remove the shifter shaft and yoke from housing (30).

14. Clean and inspect parts as explained under “Cleaning and Inspection” on page 4C-10.

15. Hold clutch shifter yoke (46) in position inside housing (30). Slide shaft (44) into housing (30) and insert two Woodruff keys (45) in their slots in shaft (44). Slide the shaft into the yoke and into the housing.

16. Position yoke (46) centrally over Woodruff keys and tighten retaining bolts (47) and lock washers (48) on the yoke.

17. Install bearing lube tube (38) on bearing retainer (39).

18. Install ball bearing (35) in housing (30).

19. Secure bearing retainer (39) to housing (30) with eight bolts (40) and lock washers (41).

20. Press or drive the converter drive shaft into the retainer side of ball bearing (35) 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.

21. 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 the elbow.

22. Install clutch assembly (4), engaging the two pins on the throw out bearing in the yoke as the clutch assembly is slid into place. Be sure to place tube (27) toward the clutch housing access cover opening.

23. Install key (2) between the clutch assembly and converter drive shaft.

24. Install spanner lock nut (1, Figure 4C-40 on page 4C-35) and torque to 250 to 300 pound feet (340 to 408 Nm), using spanner wrench TSD 20231. Bend a section of the lock nut into the shaft groove.

25. Install grease fittings (25 and 36) into tubes (27 and 28). Push the upper ends of the tubes through holes in the housing. Install nuts (26 and 37) onto the tubes.

26. Secure access cover (34) with four bolts (32) and lock washers (33).

27. Press single row ball bearing assembly (51), with numbered side out, onto the converter drive shaft.

OIL PUMP IDLER GEAR. To rebuild the oil pump idler gear, proceed as follows (see Figure 4C-38 on page 4C-33):

1. 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 washer (23). Drive the rivets from the gear and remove the washers and bearing.

2. Clean and inspect parts as explained under “Cleaning and Inspection” on page 4C-10.

3. Install the bearing into the idler gear hub. Assemble the washer onto 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 4C-35 on page 4C-28.

Assembly

TORQUE CONVERTER OUTPUT SHAFT. To install the output shaft, proceed as follows:

1. Position the converter housing assembly, rear end up, on the assembly table.

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 (see Figure 4C-19 on page 4C-20).

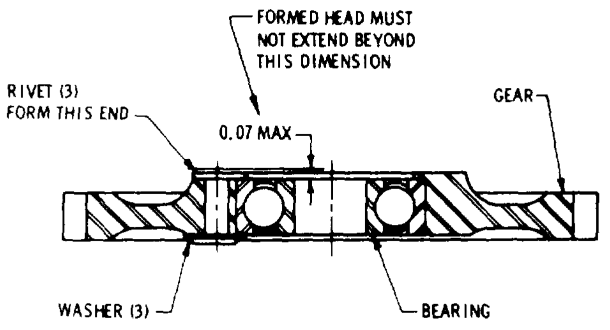


Figure 4C-35. Idler Gear and Bearing Assembly

3. Install the output shaft so that the front roller bearing engages with its outer race.

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 the bolts to 67 to 80 pound feet (91-108 Nm) torque.

6. If the outer race of the rear roller bearing was removed, install it, thin edge down, in the bearing retainer housing.

INSTALL BEARING RETAINER. To install the bearing retainer, proceed as follows:

1. Install the bearing retainer on the output shaft and seat it against the rear bearing by tapping it lightly with a soft hammer (see Figure 4C-17 on page 4C-19).

2. Using a feeler gauge inserted between bearing retainer and bearing retainer housing, measure the space between those two parts.

3. Add 0.006 inch (0.1524 mm) to the measurement obtained above. This is the calculated shim thickness. Make up a shim pack and install it between the retainer and housing.

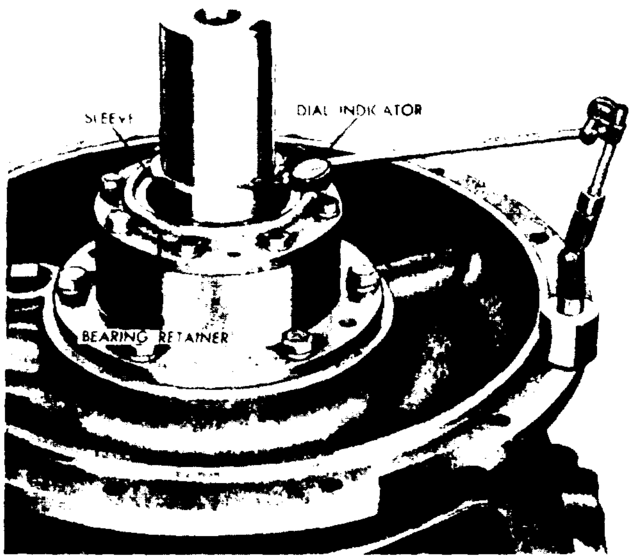


Figure 4C-36. Checking End Play-Weight Resting on Housing

4. Secure the retainer with eight 3/8-16 x 1-1/4 inch bolts and lock washers. Tighten the bolts to 26 to 32 pound feet (35 to 43 Nm) torque.

CHECKING END PLAY OF OUTPUT SHAFT. Check output shaft end play as follows:

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 the rear end of the oil seal sleeve on the output sleeve (see Figure 4C-36).

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 (see Figure 4C-37 on page 4C-29).

4. The indicator reading is the end play of the output shaft. 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 mm), 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 end play exceeds 0.006 inch (0.1525 mm), remove sufficient amounts of shims from the shim

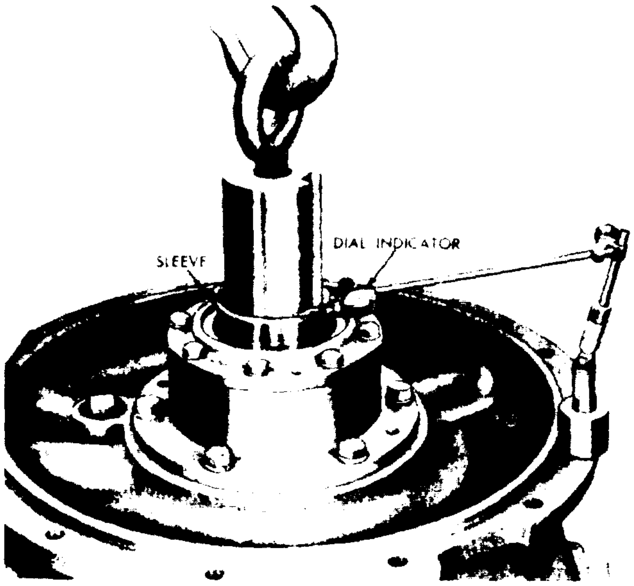


Figure 4C-37. Checking End Play-Weight Suspended

pack to bring the end play within the required limits.

INSTALLING TORQUE CONVERTER ELEMENTS. To install the torque converter elements, proceed as follows:

1. Install the seal rings on the converter ground sleeve (see Figure 4C-16 on page 4C-19).

2. Install converter pump hub (17, Figure 4C-39 on page 4C-34), double row ball bearing assembly (08) and seal ring (10) as an assembly onto the converter ground sleeve.

CAUTION

Index tangs on pump hub (17) with the slots in charging pump drive gear (2, Figure 4C-38 on page 4C-33).

3. Install the converter pump assembly (see Figure 4C-14 on page 4C-18).

4. Install the split retainer.

5. Secure the converter pump with six lock strips and 12 3/8-24 x 1-3/8 inch bolts (see Figure 4C-13 on page 4C-18). Tighten bolts to 33 to 40 pound feet (45 to 54 Nm) torque. Bend a corner of lock strip against each of the bolt heads.

6. Install plate (15, Figure 4C-39 on page 4C-34) onto the converter output shaft.

7. Place stator (2) on the assembly table, thick edge vane side up.

8. Install ten rollers (4) and ten springs (3) in stator (2). Retain the rollers and springs in the stator with a heavy coating of oil soluble grease.

NOTE

Springs should be in the deep end of the cam pocket and the other in the shallow end. Note that the open end of the spring next to the roller is toward the bore of the stator.

9. Install freewheel roller race (14, Fi ure 4C-39 on page 4C-34) into stator (2), splined end of the race first.

10. Install the assembled stator with roller race onto the converter output shaft, splined end of the race first.

NOTE

Stator should rotate freely in a clockwise direction, but lock up when attempt is made to rotate it in the opposite direction.

11. Using spanner wrench J 6534, install freewheel roller race retainer nut. Tighten the nut to 275-325 lb-ft (374-442 Nm) torque and stake securely (see Figure 4C-12 on page 4C-17).

12. Install snap ring (19, Figure 4C-40 on page 4C-35) onto converter output shaft (03, Figure 4C-27 on page 4C-22).

13. Install the assembled turbine, sprag and bearing assembly onto the converter output shaft.

14. Install the inner race of roller bearing (10, Figure 4C-40 on page 4C-35) onto the converter output shaft and secure with snap ring (9).

INSTALL DISCONNECT CLUTCH. To install the disconnect clutch, proceed as follows:

1. Position the converter housing on its output end.

2. Install a headless guide bolt in the converter drive shaft housing (7, Figure 4C-40 on page 4C-35).

3. Using a sling, install the clutch assembly onto the converter, using the headless guide bolt to align the drive shaft housing bolt holes with the holes in converter pump (11, Figure 4C-39 on page 4C-34). 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 x 1-1/4 inch bolts. Tight bolts to 41 to 49 pound feet (56 to 66 Nm) torque.

5. Install 11 converter housing to disconnect clutch housing bolts (24, Figure 4C-38 on page 4C-33) with lock washers (25).

6. Install converter housing access cover (4) and gasket (3) and secure with two 3/8-16 x 3/4 inch bolts and lock washers. Tighten the bolts to 26 to 32 pound feet (35 to 43 Nm) torque.

INSTALL CHARGING OIL PUMP. To install the charging oil pump, proceed as follows:

1. Install the oil pump body gasket and oil pump on converter housing (see Figure 4C-11 on page 4C-17).

2. Secure the pump to the converter housing with six 3/8-16 x 1-3/8 inch bolts and lock washer. Tighten the bolts to 26 to 32 pound feet (35 to 43 Nm) torque.

CAUTION

Be sure the oil pump turns freely after is is bolted to the converter housing.

3. Install the converter housing access cover gasket (3, Figure 4C-38 on page 4C-33) 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 the bolts to 26 to 32 pound feet (35 to 43 Nm) torque.

INSTALLATION

To install the torque converter, proceed as follows:

1. Using a suitable lifting device, set the torque converter into the machine.

2. Align the torque converter input disconnect clutch with the clutch drive gear (it may be necessary to remove the inspection cover from the torque converter to line the clutch and gear up).

3. Slide the torque converter forward. Install the capscrews and lock washers. Tighten the hardware to standard torque values (capscrews are 7/16”-14 UNC x 2-1/4” long).

4. Attach the clutch operating mechanism, but do not adjust at this time.

5. Attach the propeller shaft.

6. Connect the temperature and pressure leads to the senders.

7. Connect all hydraulic lines.

8. Fill the torque converter oil reservoir to the proper level. See the Operators Manual.

9. Remove the inspection cover from the top of the torque converter. Adjust the clutch as follows:

A. Disengage the clutch. Rotate the clutch assembly until the adjustment collar lock pin is accessible.

B. Release the adjustment collar lock pin by pulling out the pin, Rotate the adjustment collar and tighten until the engagement force is 1150-1580 in-lbs (130-179 Nm). The engagement force should be checked by attaching a torque wrench to the clutch cross shaft.

CAUTION

Always be sure the adjustment collar lock pin is engaged in one of the 24 holes in the hub plate or the clutch will come out of adjustment.

10. Adjust the clutch actuator (see Subsection 4B).

11. Install the torque converter access cover.

12. Lubricate the clutch bearing. See the Operators Manual.

Wear Limits Data

GENERAL. The wear limits shown in Table 4C-4 on page 4C-32 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 table is based on field service experience and is intended only as a guide to parts replacement. Use this table in conjunction with "Cleaning and Inspection" on page 4C-10.

BEARINGS, JOURNALS AND BORES. The application of bearings to any product is based on the recommendations of the bearing manufacturer and, therefore, no diametral dimensional deviation should be permitted on the bearings or mating pieces. Bearing should be carefully checked for signs of distress before reinstalling in the. torque converter.

GEARS. Gears should be inspected for load patterns 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.

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.

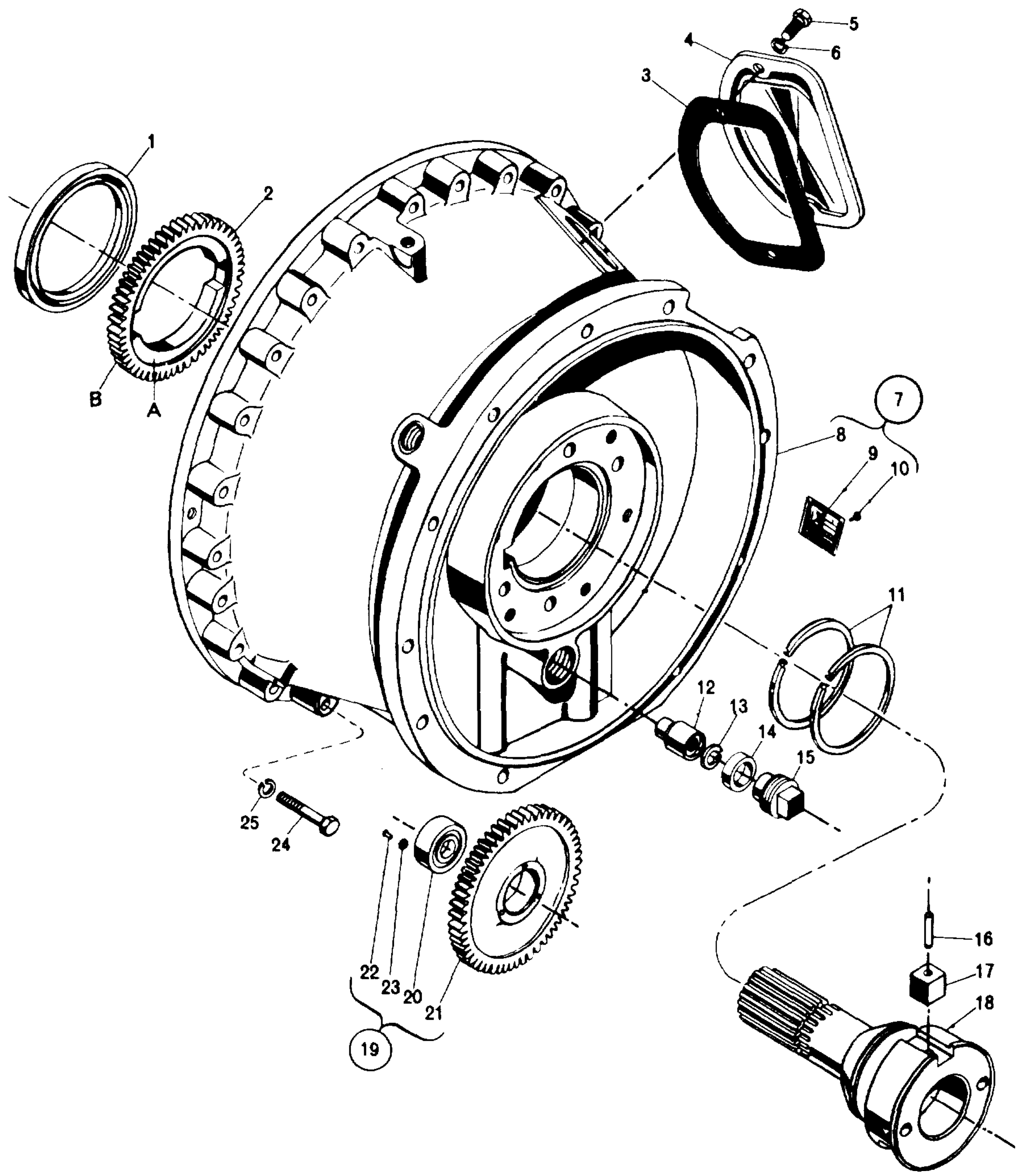
OIL SEALS. Seals should be replaced if there are signs of excessive hardening, scoring or other indications of deterioration.

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.

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 microinch), and square with the axis of rotation within 0.002 inch (0.051 Nm). 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.

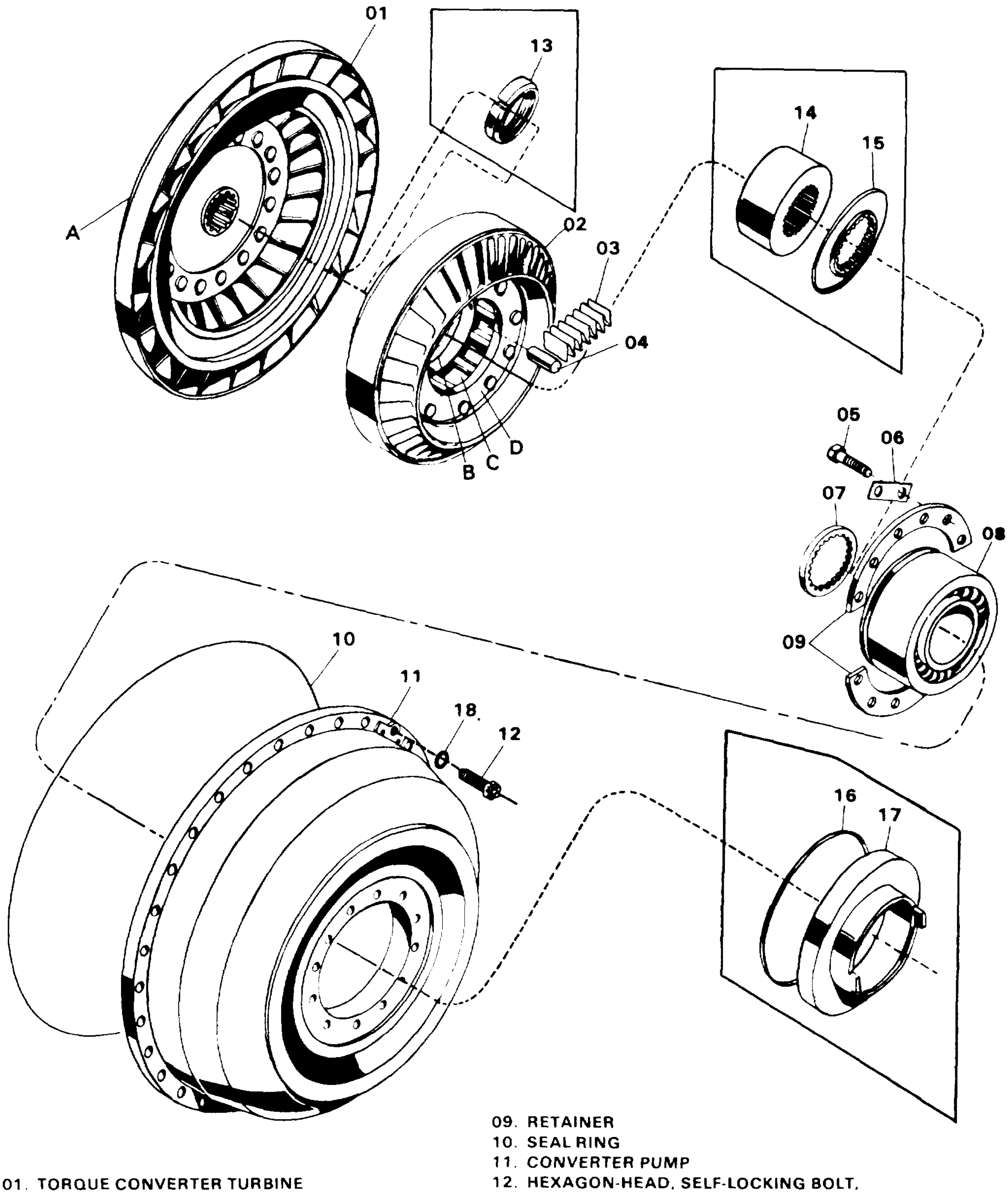
DESCRIPTION	DIMENSION-INCH(MM)	WEAR LIMIT-INCH(MM)
CONVERTER HOUSING ASSEMBLY Oil Pump Drive Gear Oil Pump Drive Gear Thickness (Gear may be reversed to equalize wear)	 4.162 (105.715) Each Face	 4.172 (105.969) 0.006 (0.152)
TURBINE AND STATOR ASSEMBLY Turbine Hub Depth-Min Turbine Hub Depth-Max Roller Thrust Washer Thick-Min Roller Thrust Washer Thick-Max Stator Side Washer Thick-Min Stator Side Washer Thick-Max All Stator Washers-Min All Stator Washers-Max Stator Back Plate Thick-Min Stator Back Plate Thick-Max	 0.650 (16.51) 0.652 (16.56) 0.023 (0.584) 0.027 (0.686) 0.340 (8.636) 0.360 (9.144) 4.010 (101.854) 4.014 (101.956) 0.334 (8.4834) 0.338 (8.5854)	 0.641 (16.281) 0.022 (0.559) 0.032 (8.128) 4.016 (102.006) 0.324 (8.230)
CHARGING OIL PUMP Clutch pressure regulating valve-clearance with oil pump cover Gear and clearance Clutch pressure spring-Free height (Length under force of 24 to 28 pounds or 106.78 to 124.55 is 1.75 inch or 79.9 mm) Converter pressure regulating valve clearance with oil pump cover Converter pressure spring-Free height (Length under force of 91.2 to 100.8 pounds or 408.35 to 448.38 is 3.420 inch or 86.868 mm)	 2.397 (60.884) 4.72 (119.888)	 0.004 (0.102) 0.010 (0.254) 0.006 (0.152)

Table 4C-4. Wear Limits Data



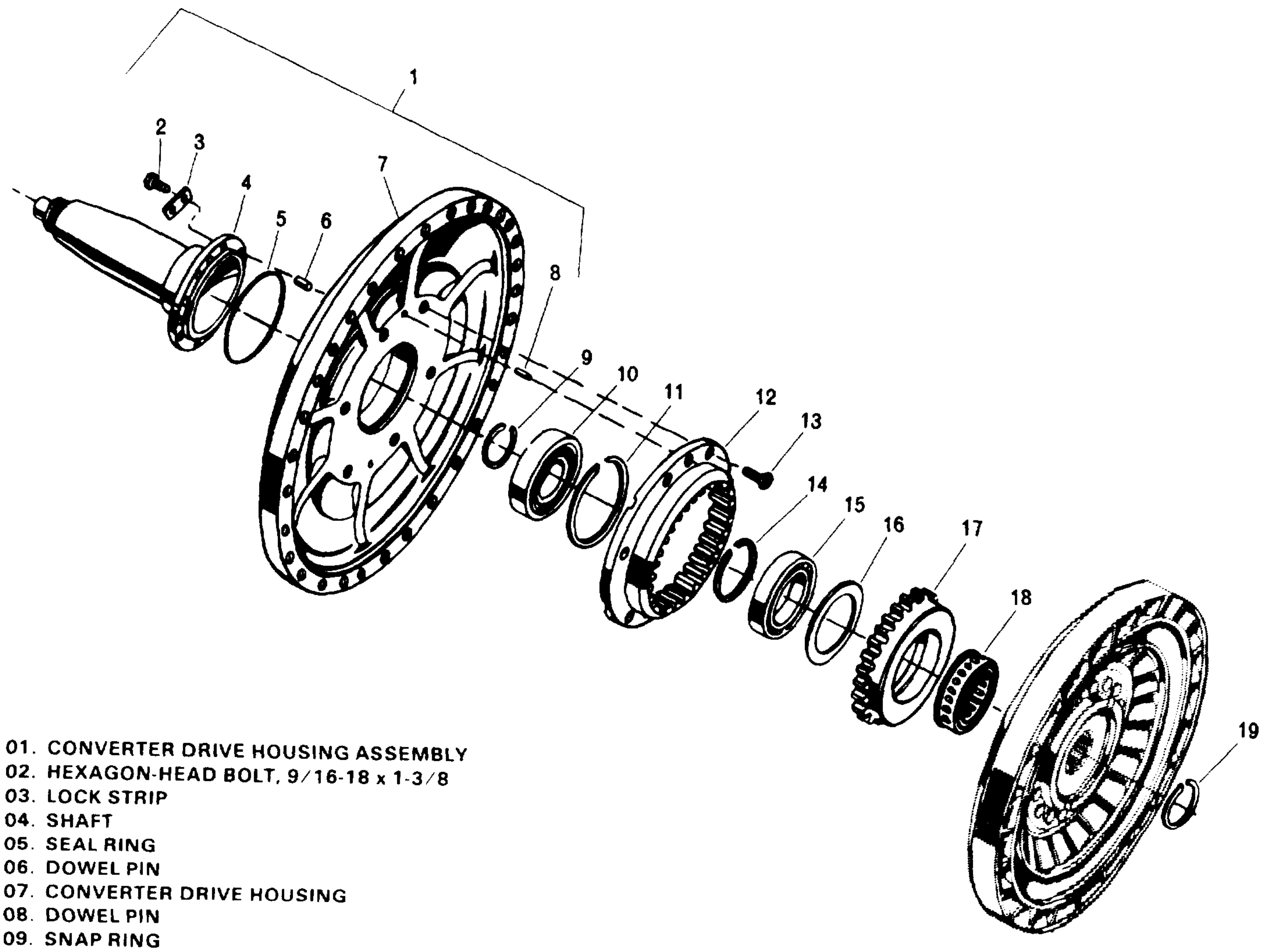
01. OIL SEAL
02. CHARGING OIL PUMP DRIVE GEAR
03. GASKET
04. CONVERTER HOUSING COVER
05. HEXAGON-HEAD BOLT, 3/8-16 x 3/4
06. LOCKWASHER, 3/8
07. CONVERTER HOUSING ASSEMBLY
08. CONVERTER HOUSING
09. NAMEPLATE
10. DRIVE SCREW, 4 x 1/4
11. HOOK-TYPE SEAL RING
12. PUMP IDLER GEAR SHAFT
13. LOCKWASHER, 1/2
14. SEAL RING
15. PLUG, 1 INCH
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. WASHER
24. HEXAGON-HEAD BOLT, 7/16-14 x 2-1/4
25. LOCKWASHER, 7/16

Figure 4C-38. Exploded View Converter Housing



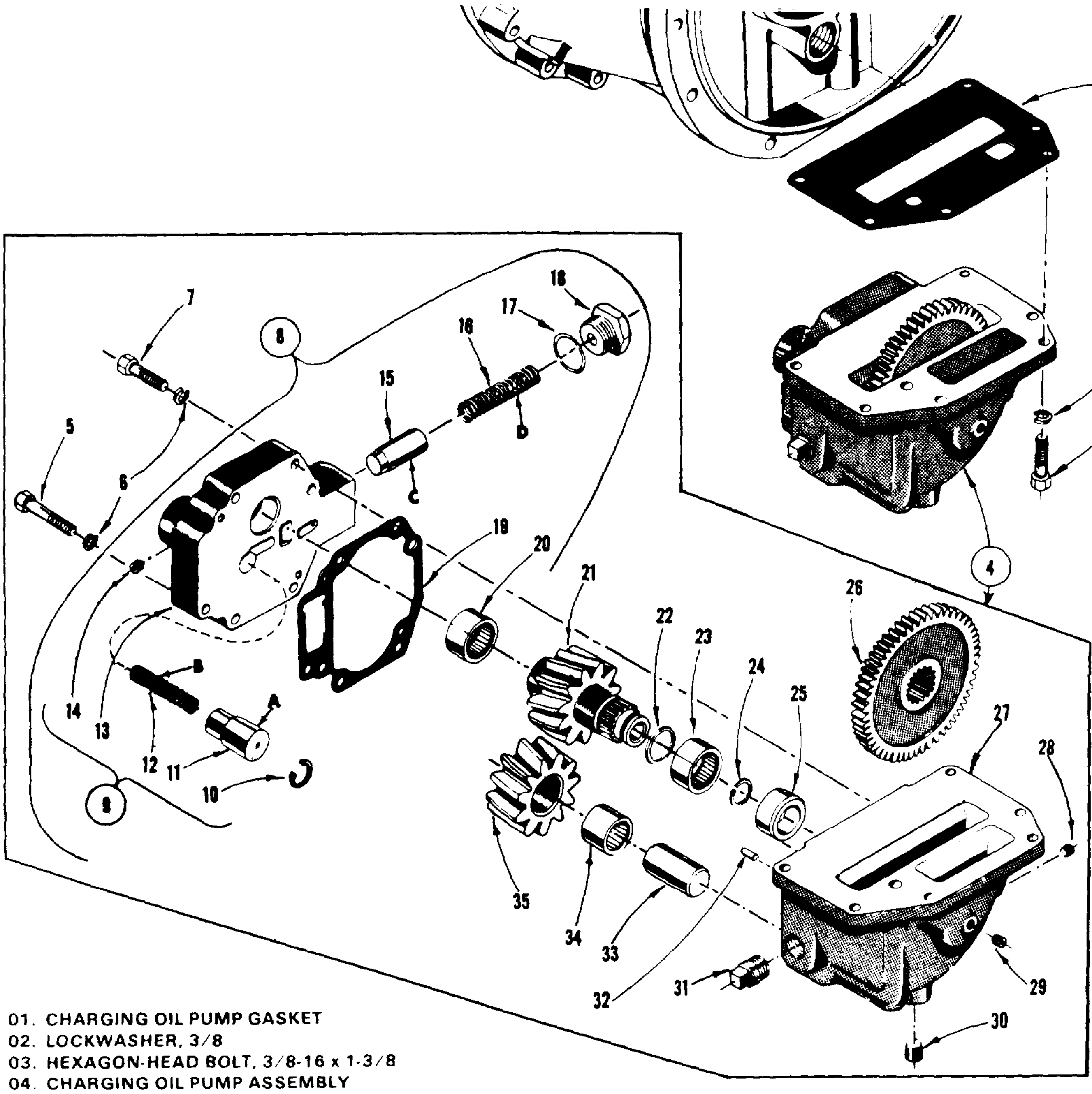
01. TORQUE CONVERTER TURBINE
02. STATOR
03. FREEWHEEL ROLLER SPRING
04. FREEWHEEL ROLLER
05. HEXAGON-HEAD BOLT, 3/8-24 x 1-3/8
06. LOCK STRIP
07. SPACER
08. DOUBLE-ROW BALL BEARING ASSEMBLY
09. RETAINER
10. SEAL RING
11. CONVERTER PUMP
12. HEXAGON-HEAD, SELF-LOCKING BOLT, 3/8-24 x 1-1/4
13. NUT
14. STATOR FREEWHEEL ROLLER RACE
15. STATOR BACK PLATE
16. SEAL RING
17. CONVERTER PUMP HUB
18. WASHER

Figure 4C-39. Exploded View of Torque Converter



01. CONVERTER DRIVE HOUSING ASSEMBLY
02. HEXAGON-HEAD BOLT, 9/16-18 x 1-3/8
03. LOCK STRIP
04. SHAFT
05. SEAL RING
06. DOWEL PIN
07. CONVERTER DRIVE HOUSING
08. DOWEL PIN
09. 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. SPRING CLUTCH OUTER RACE
18. SPRAG ASSEMBLY
19. SNAP RING

Figure 4C-40. Exploded View of Converter Drive and Sprag Clutch



01. CHARGING OIL PUMP GASKET
02. LOCKWASHER, 3/8
03. HEXAGON-HEAD BOLT, 3/8-16 x 1-3/8
04. CHARGING OIL PUMP ASSEMBLY
05. HEXAGON-HEAD BOLT, 3/8-16 x 1-3/8
06. LOCKWASHER, 3/8
07. HEXAGON-HEAD BOLT, 3/8-16 x 2
08. CHARGING OIL PUMP COVER ASSEMBLY
09. CHARGING PUMP COVER ASSEMBLY
10. SNAP RING
11. CLUTCH PRESSURE REGULATOR VALVE
12. CLUTCH PRESSURE REGULATOR VALVE SPRING
(6770417, STANDARD)
(6773896, OPTIONAL)
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, 1/8
29. PIPE PLUG, 1/8
30. PIPE PLUG, 3/8
31. PIPE PLUG, 3/4
32. DOWEL PIN
33. PUMP DRIVING GEAR SHAFT
34. NEEDLE ROLLER BEARING ASSEMBLY
35. PUMP DRIVEN GEAR

Figure 4C-41. Exploded View of Charging Oil Pump

SUBSECTION 4D

PROPELLER SHAFTS

GENERAL

The information contained in this subsection covers the removal, repair and installation of the propeller shafts. Repair of these propeller shafts is limited to the replacement of the parts furnished in the service kits for these propeller shafts. See the Replacement Parts Manual.

PROPELLER SHAFT (102683)

GENERAL. This propeller shaft is used to connect the torque converter to the worm gear. The propeller shaft is flange yoke mounted at both ends.

REMOVAL. To remove the propeller shaft, proceed as follows (see Figure 4D-1):

CAUTION

If the slip joint is removed from the propeller shaft it must be assembled to the propeller shaft in the original position. The matchmarking arrows on the shaft and sleeve must be visible before disassembly. If the arrow marks are not visible, mark both members before disassembling them.

1. Remove the bolts which secure the flange yokes to the companion flanges at both ends of the propeller shaft

2. Slide the propeller shaft free of the companion flanges and remove it from the machine.

DISASSEMBLY. To disassemble the universal joint, proceed as follows (see Figure 4D-1):

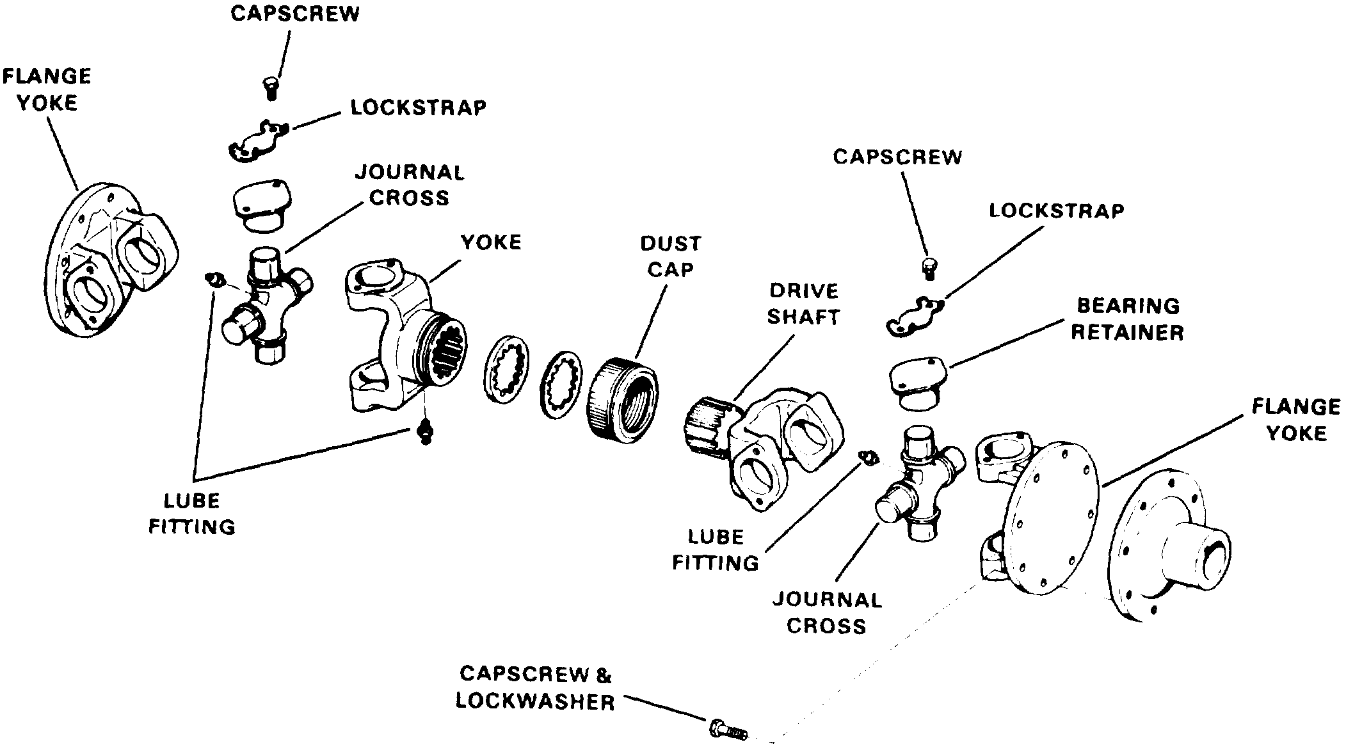


Figure 4D-1. Propeller Shaft (10Z563)

1. Bend the tabs on the lockstraps and remove the capscrews holding the bearing retainers in place.

2. Drive on the end of one bearing cap until the opposite bearing cap comes out.

3. Turn the joint over and tap the exposedend of the journal cross with a soft drift until the opposite needle bearing cap is free.

4. Remove the journal cross by sliding it to the side of the yoke and tilting it over the top of the yoke lug.

REPAIR. Repair of the universal joint is limited to replacing the journal cross, bearings, and lock straps contained in the repair kit. Check yoke cross holes for alignment or raised metal. Check for alignment by sliding a bar the same diameter as the cross holes. The bar should slide through both cross holes simultaneously. If not the yoke is distorted and the U-joint must be replaced. Remove raised metal from the yoke cross holes using a rat tail or half round file.

ASSEMBLY. To assemble the bearing assemblies, proceed as follows:

1. Tilt the journal cross and insert it in the yoke.

2. Lubricate the bearings with multi-purpose grease as indicated in Section III.

3. Insert the bearings from outside of the yoke. Press or tap the bearings into place with a soft drift.

4. Place the bearing retainer in position and secure with the capscrews. Bend the tabs up on the capscrews to keep them from working loose.

INSTALLATION. The complete assembly is now ready to be installed in the machine. To install the propeller shaft, proceed as follows:

1. Place the propeller shaft in the machine and align the flange yokes with the companion flanges.

2. Install and tighten the attaching bolts, lockwashers, and nuts.

PROPELLER SHAFT (10Z553)

GENERAL. This propeller shaft is used to connect the engine to the propel pump drive. The propeller shaft is flange yoke mounted at both ends.

REMOVAL. To remove the propeller shaft, proceed as follows (see Figure 4D-2):

CAUTION

If the slip joint is disassembled, it must be assembled in the original position. The match marking arrows on the sleeve must be visible before disassembly. If the arrow marks are not visible, mark both members before disassembling them.

1. Remove the bolts which secure the flange yokes to the companion flanges at both ends of the propeller shaft.

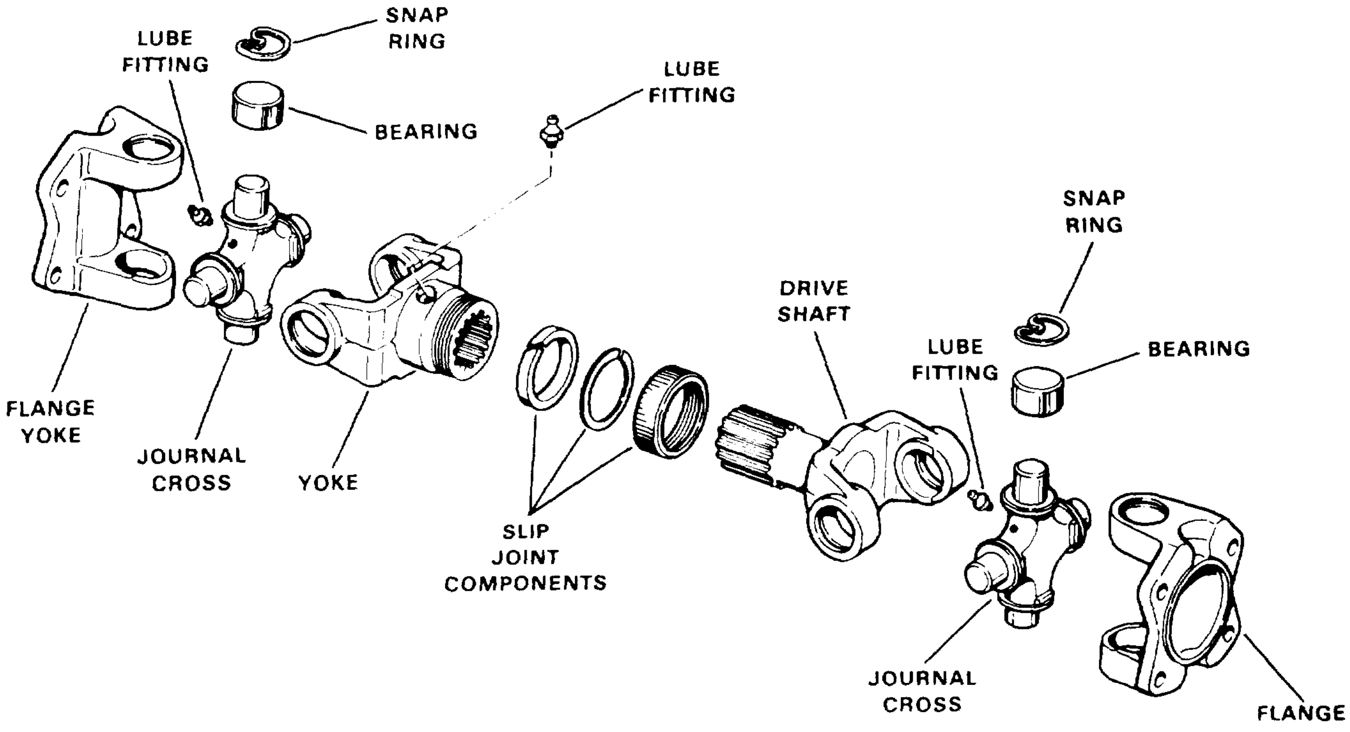


Figure 4D-2. Propeller Shaft (10Z553)

2. Slide the propeller shaft free of the companion flanges and remove it from the machine.

DISASSEMBLY. To disassemble the universal joint, proceed as follows (see Figure 4D-2):

1. Remove the snap rings by pinching the ends together. If a ring does not readily snap out of the groove in the yoke. tap the end of the bearing cap lightly to relieve the pressure against the ring.

2. Drive on the end of one bearing cap until the opposite bearing cap comes out.

3. Turn the joint over and tap the exposed end of the journal cross with a soft drift until the opposite needle bearing cap is free.

4. Remove the journal cross by sliding it to the side of the yoke and tilting it over the top of the yoke lug.

REPAIR. Repair of the universal joint is limited to replacing the journal cross, bearings, and snap rings contained in the repair kit.

ASSEMBLY. To assemble the bearing assemblies, proceed as follows (see Figure 4D-2):

1. Tilt the journal cross and insert it in the Yoke.

2. Lubricate the bearings with multi-purpose grease as indicated in Section III.

3. Insert the bearings from outside of the yoke. Press or tap the bearings into place with a soft drift.

4. Insert the snap rings and make sure they are secure in the snap ring groove.

INSTALLATION. To install the propeller shaft, proceed as follows:

1. Place the propeller shaft in the machine and align the flange yokes with the companion flanges.

2. Insert and align the adapter plate (218P756) between the flange yoke and the input flange of the propel pump drive.

3. Install and tighten the attaching hardware.

SUBSECTION 4E

CHAINS AND IDLER SHAFTS

GENERAL

This subsection covers the troubleshooting, removal and installation of the chains. In addition it covers the removal, repair and installation of the idler shaft.

TROUBLESHOOTING

A troubleshooting chart at the end of this subsection lists some of the difficulties which may be experienced with the chains. Remedies are given which may be used to correct a specific problem.

CHAIN (20Z1017)

REMOVAL. To remove the chain, remove the chain case cover and gasket. Turn the drive until the connecting link is fully engaged with one of the sprockets, so as to relieve the tension of the connecting link pins. Loosen chain tension, then remove the connecting link and lift the chain off the sprockets.

INSPECTION AND REPAIR. A chain, like any other operating equipment, requires inspection to obtain long life and satisfactory performance. Inspect the chain as follows:

1. Check for wear on the sides of the sprocket teeth and on the link plates. Such wear indicates misalignment.

2. Check for wear on the working faces of the sprocket teeth. As the drive runs in, these faces should develop a bright, polished appearance. Scratches, galls, grooves, or visible changes in tooth form are signs of trouble, probably caused by sluggish roller action due to lubrication problems.

3. An elongation of as much as three percent indicates that the chain is riding near its limit of allowable height on the sprocket teeth. Gradual increases in chain length are the result of normal wear.

4. Check the chain and the sprocket teeth for accumulations of dirt or foreign materials and for evidence of corrosion. Foreign material packed into the chain or sprocket teeth may cause chain or sprocket breakage.

5. Check the lubricant level in the chain case. See the Operator's Manual for the method of checking the level.

6. To cut a roller chain, alternately strike the two pins of a link out of its link plate. Be sure to alternately strike the pins to avoid distortion of the roller link plates. If the Pins are "headed". grind off the'heads before driving them through the link plates.

INSTALLATION. To install a chain, wrap the chain around the sprockets, bringing the free ends together on one sprocket. Insert the pins of the connecting link in the two end links of the chain; then install the free plate of the connecting link, and fasten the plate using the cotter, spring clip or other fasteners supplied. After the fasteners have been inserted, it is important that the ends of the chain pins be tapped back so that the fasteners come up snugly against the outside of the connecting link plate.

CHAIN TENSION ADJUSTMENT. To check and adjust the chain, proceed as follows (see Figure 4E-1):

1. Remove the chain case inspection plate. Loosen four idler capscrews (see Figure 4E-2).

2. Loosen the jam nut "A" and turn adjusting nut "B" against yoke to adjust.

3. Adjust the chain tension so that there is approximately 1/2 inch total midspan deflection at point "X" as indicated in Figure 4E-1. To tighten the chain, turn adjusting nut "B" to the right; to loosen turn nut in opposite direction.

CAUTION

Do not adjust the chain too tight as this will cause excessive wear to the chain and sprocket.

4. Tighten jam nut "A" against adjusting nut "B". Tighten four idler capscrews (see Figure 4E-2).

5. Repeat the above procedure for the chain on the opposite side of the chain case.

NOTE

Both chains must be adjusted evenly to obtain the same amount of slack.

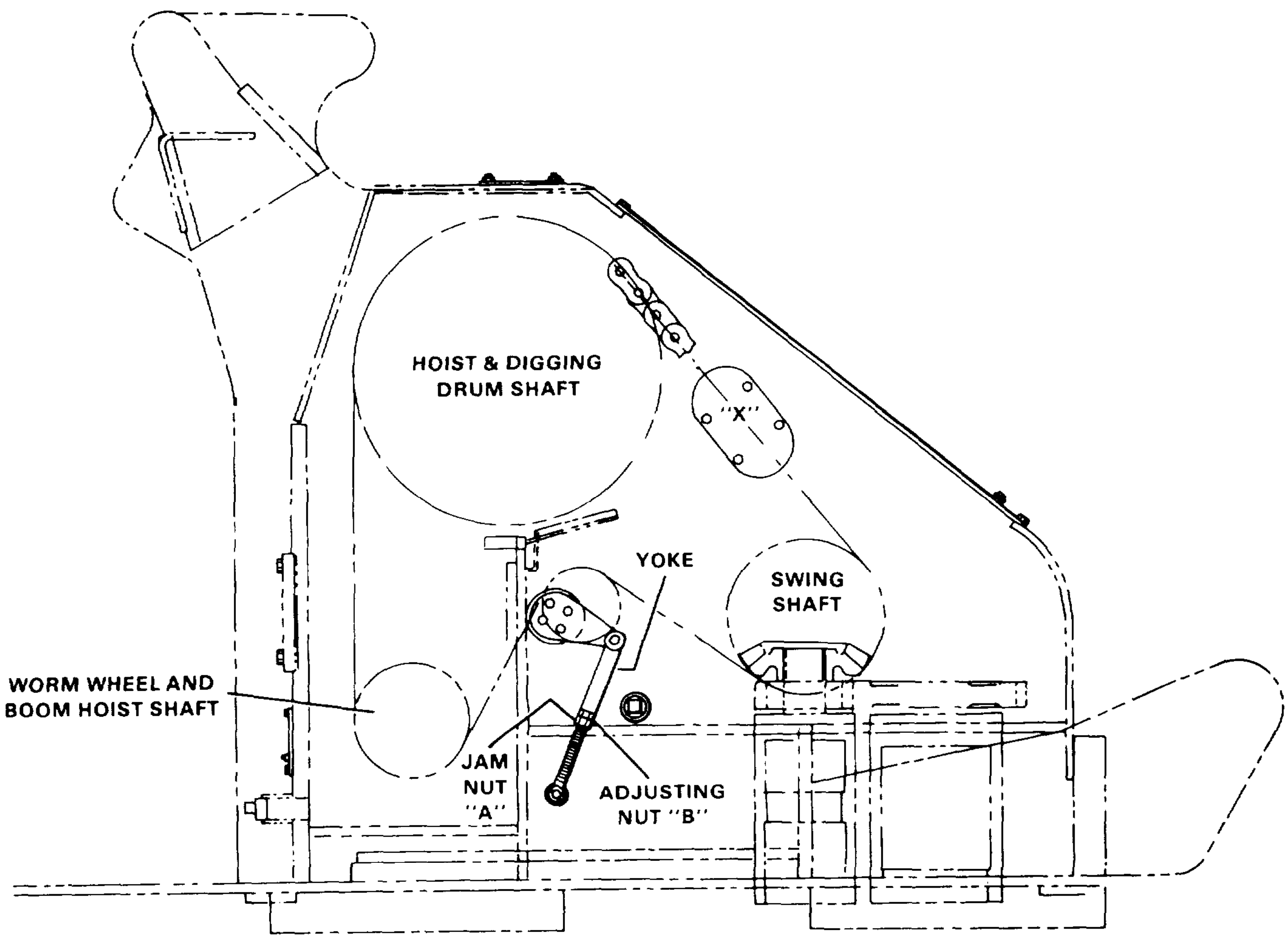


Figure 4E-1. Chain Case and Idler Shaft (2100J1389 and 2100J515F1)

IDLER SHAFT (2100N515F1)

REMOVAL AND DISASSEMBLY. To remove and disassemble the idler shaft, proceed as follows (see Figure 4E-2):

1. Remove the chain case cover, gasket and chain.

2. Separate the chain tightener yoke from lever arm.

3 Remove four capscrews and lever arm.

4. Reach inside the chain case and remove the idler sprocket and shaft.

5. Remove O-ring from shaft. Discard O-ring.

6. Remove sprocket retaining ring and slide bearing and sprocket off the shaft.

7. Remove one of the bearing retaining rings from the sprocket and press or tap the bearing out of the sprocket.

INSPECTION AND REPAIR. Prior to assembly, inspect the idler parts as follows:

1. Inspect the bearing for wear or damage. Replace if necessary.

2. Check for wear on the sides and on the working face of the sprocket teeth. Scratches, galls, grooves or visible changes in tooth form are signs of wear. Replace the sprocket if necessary.

3. Check the sprocket teeth for accumulations of dirt or foreign materials and for evidence of corrosion.

4. Check the lever arm for corrosion in area where it enters the gear case. Clean or replace as necessary.

5. Install the bearing into the sprocket and secure with the bearing retaining rings.

6. Install the bearing on the shaft and secure with the sprocket retaining ring.

7. Lubricate the O-ring and install on the shaft.

8. Lubricate the bearing before installation.

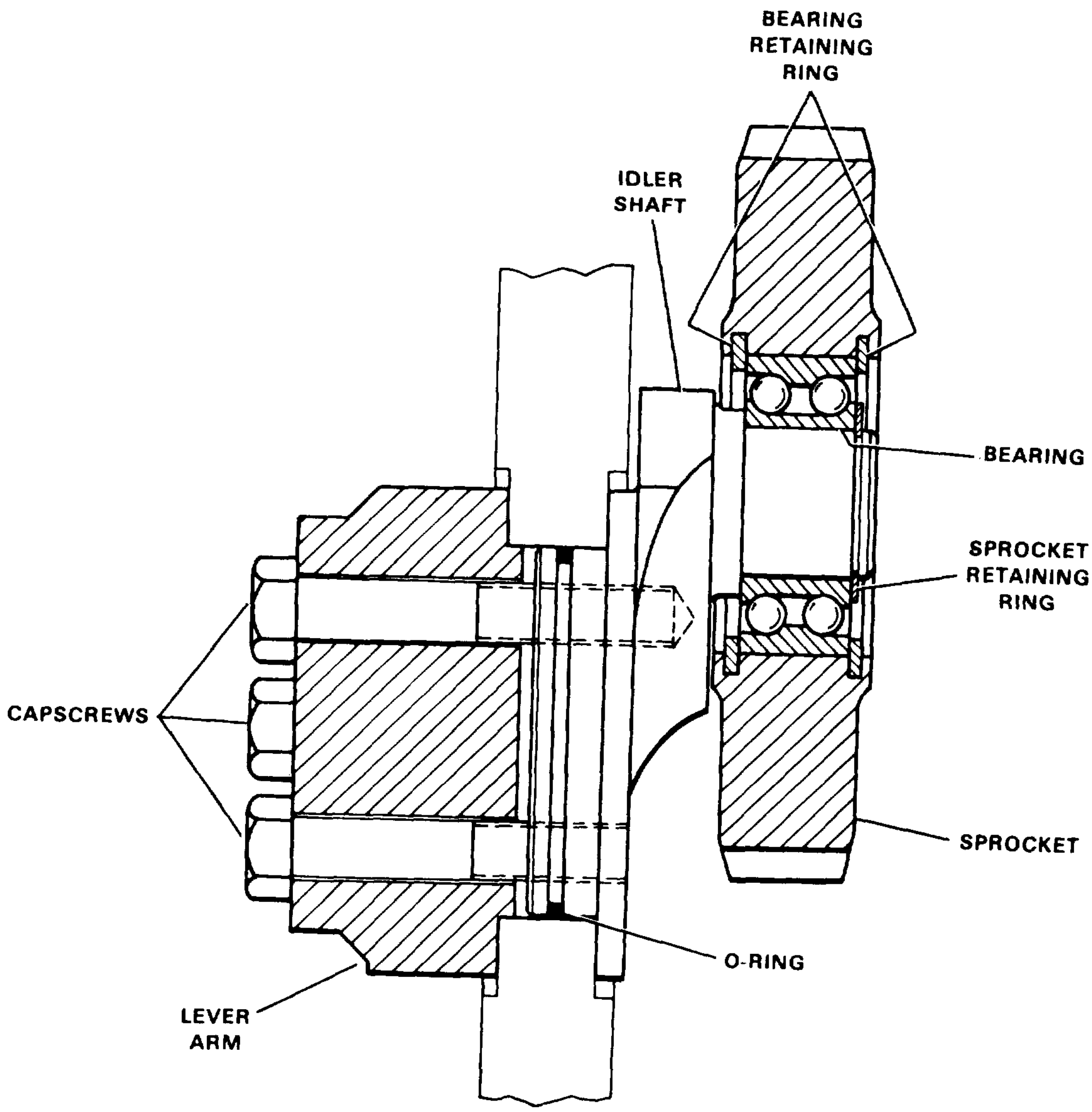


Figure 4E-2. Idler Shaft (2100N515F1)

INSTALLATION. To install the idler shaft, proceed as follows (see Figure 4E-2):

1. From inside the chain case, install the idler sprocket and shaft. Use care not to cut the O-ring.

2. Install the lever arm and capscrews. Do not tighten the capscrews at this time.

3. Attach the chain tightener yoke assembly to the lever arm.

4. Install the chain and adjust it as described under the topic Chain Tension Adjustment.

5. Tighten the idler shaft capscrews and install the chain case cover and gasket.

CHAIN TROUBLESHOOTING GUIDE

CAUSE	SYMPTOM: EXCESSIVE NOISE	SYMPTOM: CHAIN GETS STIFF	SYMPTOM: CHAIN CLIMBS SPROCKETS	SYMPTOM: CHAIN CLINGS TO SPROCKETS	SYMPTOM: BROKEN PINS, BUSHINGS OR ROLLERS	RECOMMENDED REMEDY
Misalignment	X	X				Check alignment and correct.
Improper slack adjustment	X		X			Adjust the rear idler shaft for proper slack.
Lack of lubrication	X	X			X	Check chain case oil level. Fill with proper lubricant. See Section III.
Loose casings or bearings.	X					Torque bearing bolts to specifications.
Chain badly worn	X		X			Replace the chain.
Sprocket badly worn	X			X	X	Replace the sprocket.
Material build-up in sprocket tooth pockets			X	X	X	Remove material build-up.
Heavy shock or sudden loads					X	Ease up on starts.
Chain or sprocket corrosion		X			X	Check for moisture in the system. Change oil.
Improper lubricant				X		Drain and flush the chain case. Replace the lubricant. See Section III.
Stiff chain joint(s)						Replace stiff link(s).
Uneven chain wear						Replace the chain.
Chain climbing the sprocket teeth						Adjust slack. Replace the chain and/or sprocket if worn excessively.
Vibration						Eliminate the cause of vibration.
Oil level too high						Return the oil to the proper level. See the Operators Manual.
Chain or shafts rubbing an obstruction	X					Remove obstruction.

SECTION V

HYDRAULIC CONTROL SYSTEM

SUBSECTION PAGE

SUBSECTION 5A

HYDRAULIC SYSTEM

GENERAL

The hydraulic control system, as defined for this manual, includes all the hydraulic control components on the upper of the machine and the crawler extension system, The items included in this system are the pump, control valves, actuating cylinders, and related components. The propel hydraulics is covered in Section IX.

A hydraulic schematic of the complete hydraulic control system, along with a description of system operation, is at the rear of this subsection.

FLUSHING THE HYDRAULIC SYSTEM

If any evidence of hydraulic system contamination, such as dirt, sludge, and/or metallic particles is discovered, flush and clean the system as follows. If the cause of the contamination is due to a faulty component the component must be repaired or replaced before the hydraulic system is flushed.

NOTE

The hydraulic oil should be warmed before the reservoir is drained.

1. Locate the machine on a flat, level surface.

2. Remove the drain plug and drain the oil into a suitable container. Allow sufficient time for all the oil to drain from the walls of the reservoir.

3. Install the dram plug. Fill the reservoir with a 50-50 mixture of kerosene and clean hydraulic oil.

4. Cycle the machine through all crane functions. It is important that all valves be operated so that the new oil goes through all lines.

5. Circulate the oil through the system until inspection shows the equipment to be in satisfactory condition, or until it is obvious that the system will have to be disassembled and cleaned manually.

6. Remove the drain plug and drain the flushing oil from the reservoir. Remove the filter from the top of the reservoir and clean the inside of the reservoir manually. Reinstall the drain plug and the reservoir filter. Refill the reservoir with clean hydraulic oil. Be sure to clean the system return filters and change the outlet filter element before refilling the system.

7. Cycle the machine through all crane functions

BLEEDING THE HYDRAULIC SYSTEM

GENERAL. When air is present in the hydraulic system, the controls will be "spongy" and will not operate efficiently. Air will enter the system if a control valve is removed or a line is broken between a control valve and hydraulic cylinder. The following statements apply to all bleeding operations:

1. Check all fittings, hoses and lines for leaks.

2. Hydraulic oil should be visible in the sight gauge of the hydraulic reservoir. Fill as necessary with the oil specified in Section III.

3. Normally it is not necessary to bleed the lines or valves (except those for the right and left drum brakes) on the control stand, all bleeding is to be done at the respective slave cylinders.

CAUTION

Hydraulic oil must not come in contact with any brake or clutch lining during bleeding operations. If this does occur, replacement of the linings will be necessary.

4. Cylinder bleeding is best accomplished by using a clear plastic hose attached to the bleeder fitting with its other end at the bottom of a partially filled jar or can of hydraulic oil to prevent air from entering the bleeder hose. The bleeder fittings should only be opened when the cylinders are under some amount of pressure.

5. After the bleeding operation is completed, recheck the oil level. Refill the reservoir to bring oil levels to the upper half of the sight gauge with all hydraulic cylinders fully retracted and the engine off.

6. The procedure as described is for bleeding the entire hydraulic control system. If only a portion of this circuit requires bleeding, only the steps which apply must be followed to bleed that portion of the circuit.

BLEEDING BRAKES AND CLUTCHES To bleed brakes and clutches, proceed as follows,

1. Starr the engine and build up pressure in the control system.

2. Shut the engine off and actuate the control valve to relieve most of the pressure. The pressure gauge should show only a small amount of pressure remaining in the system.

3. Begin wrth the lowest hydraulic cylinder and work toward those cylinders at the highest point. The appropriate valve will have to be actuated when bleeding the cylinders.

4. Close the bleeder fitting when the air has been removed frorn that Iine.

5. Remove the bleeder hose and repeat the procedure on the next highest cylinder.

6. All clutches should be rotated so that the cylinders are at their highest position.

GENERAL MAINTENANCE

The following points should be kept in mind when working on the hydraulic system or any hydraulic component.

1. Any structure has limits of strength and durability. To prevent the failure of structural parts of hydraulic components, an unloading valve which limits pressure to safe operating limits for the accumulator and a relief valve which Iimits pressure to safe operating limits for crawler extension are included in the hydraulic circuit. *The setting of these valves must never be changed.*

2. Tolerances of working parts in the hydraulic system are very close. Even small amounts of dirt or foreign material in the system can cause wear or damage to components, as well as generally faulty operation of the system. Every precaution must be taken to assure absolute cleanliness of the hydraulic oil.

3. Samples of hydraulic oil should be drawn from the reservoir every six months. These samples should be about two quarts, and should be taken while the oil is warmed through normal operation. If possible, the sample should be analyzed by a qualified lubrication specialist to determine whether it is suitable for further use. The interval between oil changes depends on operating conditions and on the care used in keeping the oil clean.

4. Whenever there is a hydraulic component malfunction which gives reason to believe that there are metal particles or other foreign materials in the system, drain and flush the entire system and replace the filter cartridges. A complete change of hydraulic oil must be made under these circumstances.

5. Whenever the hydraulic system is drained, check the magnetic drain plug for metal particles. If metal particles are present, flush the system and add a new change of oil. The presence of metal particles also may indicate the possibility of imminent component malfunction.

6. Do not use synthetic or fire resistant oils in this machine. The packings in this system are designed for a good grade mineral oil.

7. All containers and funnels used in handling hydraulic oil must be absolutely clean. Use a funnel with a 200 mesh screen for filling the hydraulic oil reservoir. and fill the reservoir only through the filler opening. The use of cloth to strain the oil should be avoided to prevent lint from getting into the system.

8. When removing any hydraulic component, be sure to cap and tag all hydraulic lines involved. Also plug the ports of the removed components.

9. All hydraulic components must be disassembled and assembled in spotlessly clean surroundings. During disassembly, pay particular attention to the identification of parts to assure proper reassembly. Clean all metal parts in a clean mineral oil solvent. Be sure to thoroughly clean all internal passages. After the parts have been dried thoroughly lay them on a clean, lint-free surface for inspection.

10. Replace all O-rings, back-up rings, and seals when overhauling any component. Lubricate all parts with clean hydraulic oil before reassembly. Use small amounts of petroleum jelly to hold O-rings in place during reassembly.

11. Be sure to replace any lost hydraulic oil when completing the installation of the repaired component, and bleed any air from the system when required.

12. All hydraulic connections must be kept tight. A loose connection in a pressure line will permit the oil to leak out or air to be drawn into the system. Air in the system can cause damage to the components and noisy or erratic system operation.

TROUBLESHOOTING GUIDE

GENERAL. The troubleshooting charts and maintenance hints that follow are of a general nature, but should provide an intuitive feeling for a specific system.

KNOWING THE SYSTEM. Probably the greatest aid to troubleshooting is knowing the system Every component has a purpose in the system. The construction and operating characteristics of each should be understood. Know how the system works and what the valve settings and pump output should be.

The crawler extension circuit has a relief valve pressure gauge port to allow checking of pressure. Always set and check the pressure with a gauge that is known to be accurate. The question may arise as to what the correct operating pressure of this circuit is. If it is not specified, the correct operating pressure is the lowest pressure which will allow adequate performance of the system function and still remain below the maximum rating of the components. Once the correct pressures have been determined, note them for future references.

DEVELOPING SYSTEMATIC PROCEDURES. Analyze the system and develop a logical sequence of looking for trouble. Ask the operator how the machine performed when it started to malfunction or if there is anything unusual about it. Operate the machine to see if gauges are reading properly, that all controls operate smoothly, and check for unusual noises. Visually inspect the machine looking for oil leaks. Examine filters and all lines checking for heat, loose connections, or collapsed hoses. Develop a cause andeffect troubleshooting guide similar to the charts which follow. The initial time spent on such a project could save hours of downtime.

RECOGNIZING TROUBLE INDICATIONS. The ability to recognize trouble indications in a specific system is usually acquired with experience. However, a few general indications can be discussed.

1. Excessive heat means trouble. A misaligned pump places an excessive load on bearings and can be readily identified by the heat generated. A warmer than normal return line indicates that the system is operating at the unloading valve (or relief valve) setting. Hydraulic oils which have a low viscosity will increase the internal leakage of components resulting in a heat rise. Cavitation and slippage in a pump will also generate heat.

2. Excessive noise means wear. misalignment, cavitation or air in the oil. Contaminated oil can cause an unloading valve (or relief valve) to stick and chatter. These noises may be the result of dirty filters, or fluid, high fluid viscosity, excessive drive speed, low reservoir level, or loose intake lines

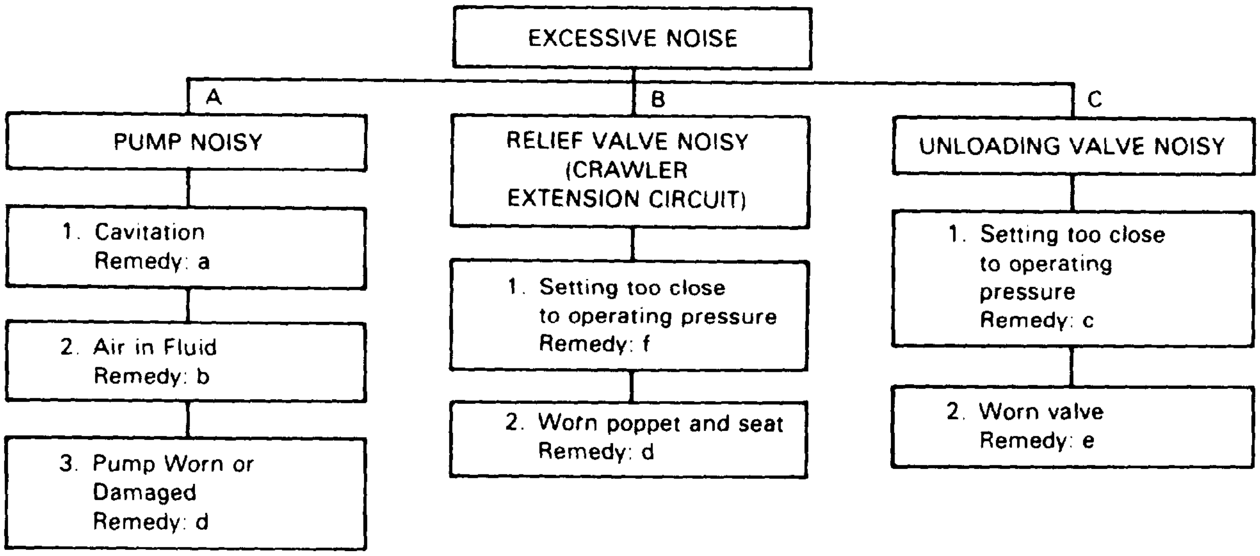
MAINTENANCE. Three simple maintenance procedures have a great effect on hydraulic system performance, efficiency, and life. They are:

1. Change (or clean) filters.

2. Maintain a sufficient quantity of clean hydraulic fluid of the proper type and viscosity in the reservoir.

3. Keep all connections tight, but not to the point of distortion, so that air is excluded from the system.

Chart 5A-1 Excessive Noise



REMEDIES:

a. Any or all of the following: Replace dirty filters - Clean clogged inlet line - Clear reservoir breather vent - Change system fluid

b. Any or all of the following: Tighten leaky inlet connections - Fill reservoir to proper level - Replace pump shaft seal

c. Install pressure gauge and adjust to correct pressure

d. Overhaul or replace

e. Replace

f. Install pressure gauge and adjust to correct pressure

Chart 5A-2 Excessive Heat

EXCESSIVE HEAT

A — PUMP HEATED

1. Fluid heated
   Remedy: See column c
2. Cavitation
   Remedy: a
3. Air in fluid
   Remedy: b
4. Unloading valve set too high
   Remedy: d
5. Excessive load
   Remedy: c
6. Worn or damaged pump
   Remedy: e

B — UNLOADING VALVE OR RELIEF VALVE

1. Fluid heated
   Remedy: See column c
2. Valve setting incorrect
   Remedy: d
3. Worn or damaged valve
   Remedy: g

C — FLUID HEATED

1. Accumulator pre-charge pressure too high
   Remedy: d
2. Unloading valve (or relief valve) set too high
   Remedy: d
3. Fluid dirty or low supply
   Remedy: f
4. Incorrect fluid viscosity
   Remedy: f
5. Worn pump, accumulator valve, cylinder or other component
   Remedy: e

REMEDIES:

a. Any or all of the following: Replace dirty filters - Clean clogged inlet line - Clean reservoir breather vent - Change system fluid

b. Any or all of the following: Tighten leaky inlet connections - Fill reservoir to proper level - Replace pump shaft seal

c. Check drive and condition of seals and bearing - Locate and correct mechanical binding

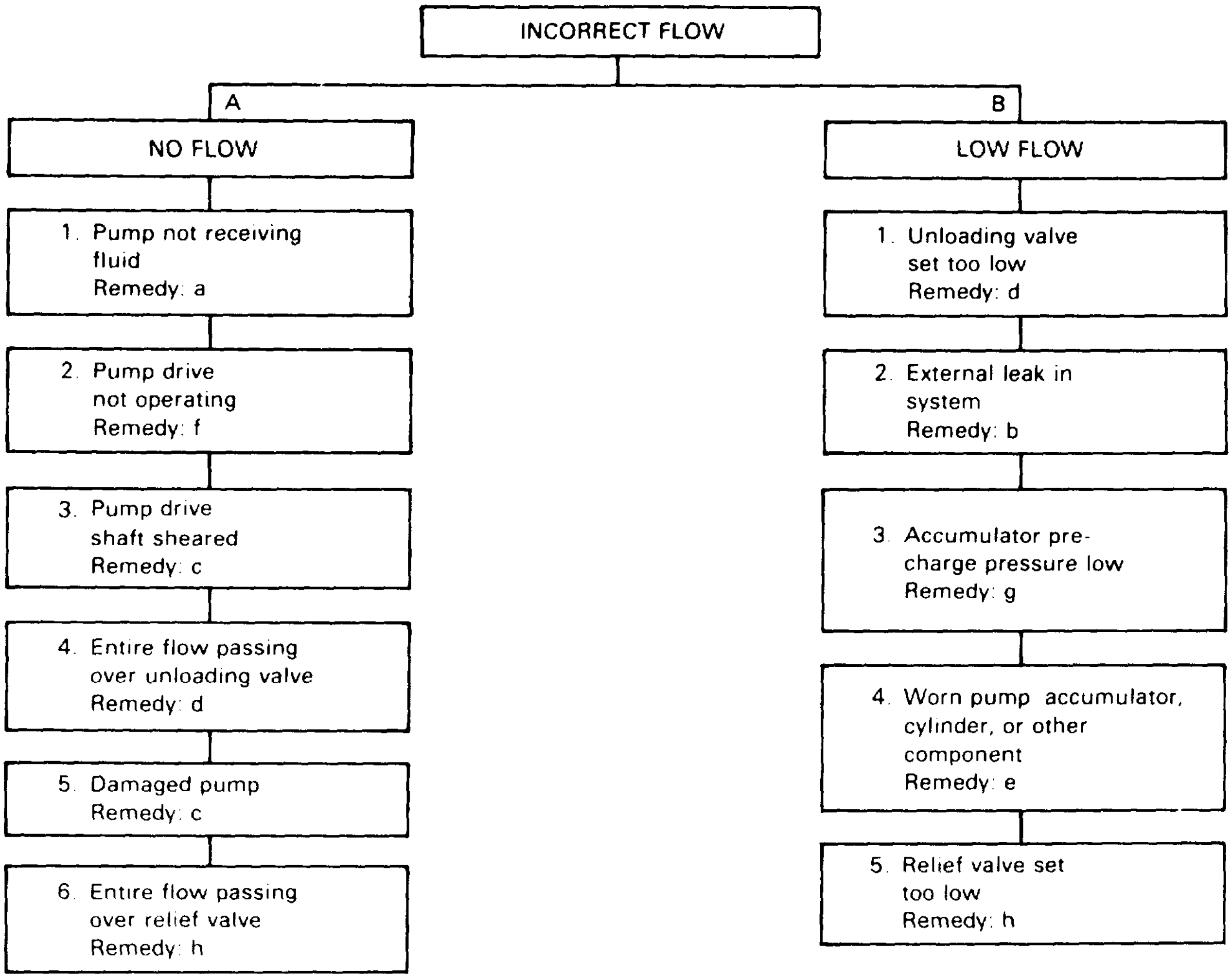
d. Install pressure gauge and adjust to correct pressure (unloading valve may not be adjusted)

e. Overhaul or replace

f. Change filters and also system fluid if of improper viscosity - Fill reservoir to proper level

g. Replace (relief valve may be repaired)

Chart 5A-3. Incorrect Flow



REMEDIES:

a. Any or all of the following: Clean dirty filters in tank - Clean clogged inlet line - Clean reservoir breather vent - Fill reservoir to proper level

b. Tighten leaky connections

c. Check for damaged pump or pump drive

d. Replace unloading valve

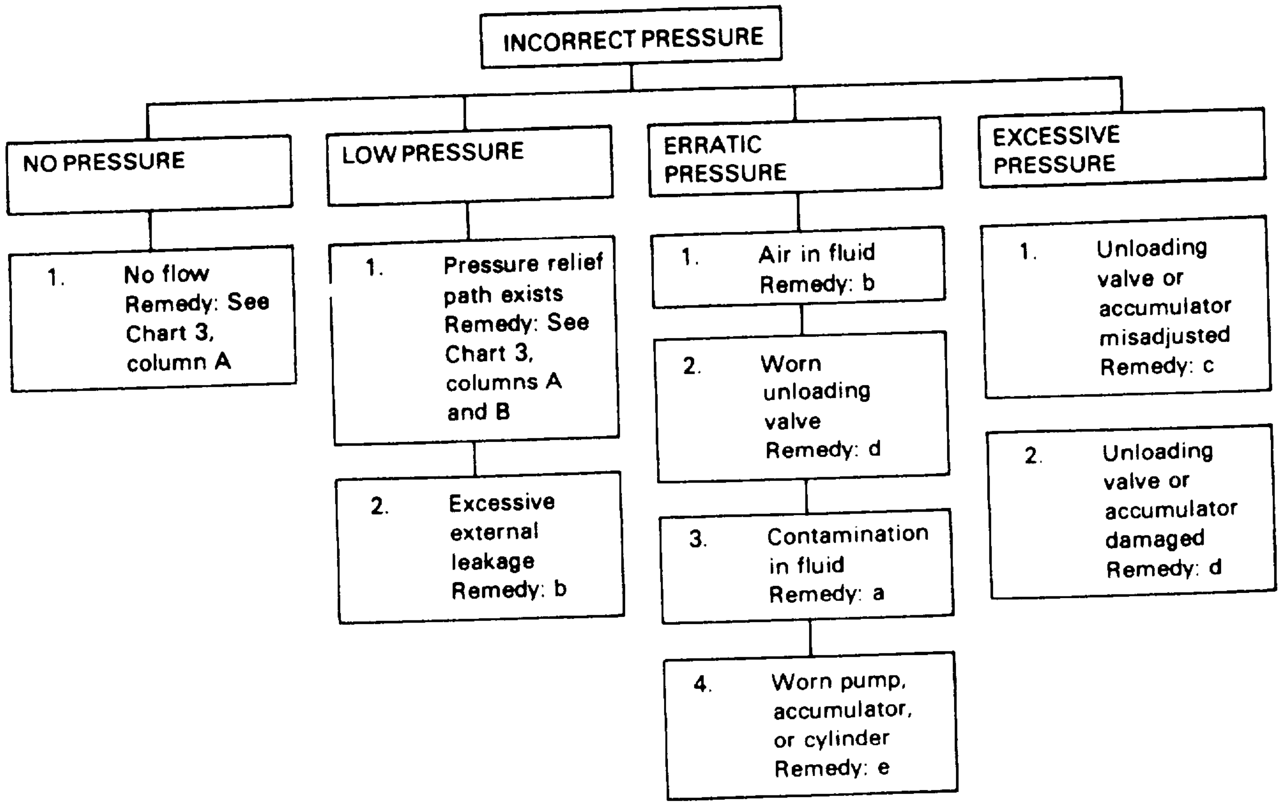
e. Overhaul or replace

f. Check pump drive - Repair if necessary

g. Check accumulator precharge

h. Adjust

Chart 5A-4. Incorrect Pressure



REMEDIES:

a. Replace dirty filters and system fluid

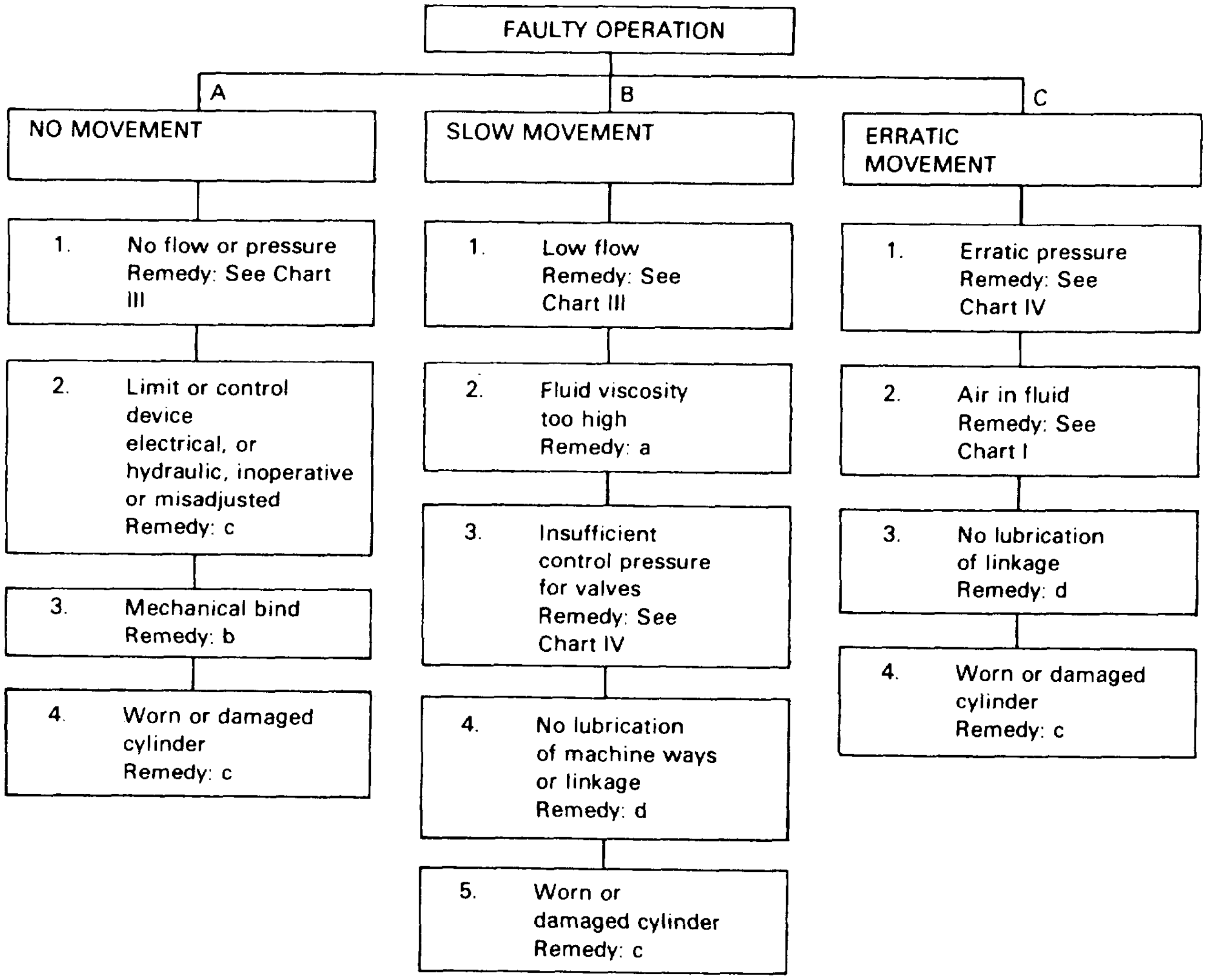
b. Tighten leaky connections — Fill reservoir to proper level

c. Adjust

d. Replace

e. Overhaul or replace

Chart 5A-5. Faulty Operation



REMEDIES:

a. Fluid may be too cold or should be changed to clean fluid of correct viscosity

b. Locate bind and repair

c. Overhaul or replace

d. Lubricate

SYSTEM DESCRIPTION

GENERAL. The descrrptron below covers the hydraulic control circuit of the machine it includes the optional third drum circuit as well as all basic items. The items described are shown schematically in Figure 5A-1.

PUMPING CIRCUIT. The pumping circuit consists of the reservoir, suction filter, pump, high pressure filter, combination solenoid valve, and accumulator

The pump is mounted on and driven by the engine. When the pump is driven, oil is drawn from the reservoir through the tank suction filter and is forced out into the system. The oil leaving the pump flows through a high pressure filter, into the combination solenoid valve and then to the accumulator. In the combination solenoid valve, the oil pressure IS controlled by the built in relief valve.

If the diverting valve is in the “lower” position, hydraulic oil is available to the crawler extension circuit. Oil flows to the crawler control valves, but if they remain in neutral, oil is returned to the reservoir.

If the diverting valve, which is part of the combination valve, is in the “upper” position, oil flows to the accumulator. The oil will continue to fill the accumulator until maximum operating pressure is reached. When the accumulator reaches maximum operating pressure, the unloading valve will open and direct pump output back to the reservoir.

The oil will continue to circulate back to the reservoir as long as the control valves are in the neutral (or off) position. When the operator actuates the controls, oil will be drawn from the accumulator causing accumulator pressure to drop to the low end of operating pressure. At this point the unloading valve will close and the pump will again recharge the accumulator to maximum operating pressure. This charging and discharging of accumulator pressure will show up on the main pressure gauge as a gradual decrease in pressure, followed by a rapid increase to maximum operating pressure.

BOOM HOIST CIRCUIT. To raise the boom, the operator pulls the control lever back. In this position, hydraulic oil passes from the accumulator, through the control valve, boom hoist limit valve, shuttle valve and to the boom hoist clutch and brake cylinders. Oil flow to the boom hoist brake cylinders causes the cylinder pistons to extend and release the boom hoist brake. Oil to the boom hoist clutch cylinder causes the cylinder to extend and engage the clutch to lift the boom.

The boom hoist limit device is de-energized whenever the boom reaches maximum boom angle. At this point, oil is returned to tank from the boom hoist brake and clutch cylinders, stopping the boom at the preset maximum angle.

To lower the boom, the operator pushes the control lever forward. In this position oil is fed through the boom hoist Interlock valve to the boom hoist planetary brake cylinder, boom hoist planetary pawl cylinder, and through a shuttle valve to the boom hoist brake cylinder. This action engages the planetary brake, engages the boom hoist planetary pawl, disengages the boom hoist pawl, and releases the boom hoist brake to lower the boom.

The boom hoist Interlock valve IS energized whenever the ignition switch IS ON and the torque converter clutch is engaged to allow the boom to be lowered only when power IS available.

When the master switch IS OFF the interlock valve is de-energized. In this position the interlock valve will block the flow of oil to the boom hoist lowering circuit, if the circuit lever should be moved.

SWING CIRCUIT. Swing operation IS performed by two pressure regulating valves and the swing brake is released by hydraulic pressure. To release the swing brake, the operator moves the swing lock switch to the left. In this position, hydraulic oil passes from the accumulator through the swing brake lock valve, to the swing brake cylinder. Oil flowing into the swing brake cylinder will cause the cylinder piston to extend and release the swing brake.

To apply the swing brake, the swing lock switch is moved to the right. This allows oil to flow out of the swing brake cylinder through the swing lock valve, to the reservoir. Oil flowing out of the swing brake cylinder will cause the cylinder to retract and allow springs to apply the swing brake.

To swing the upper, either to the left or to the right, move the control lever forward or backward respectively. When the swing control lever is moved forward, oil from the accumulator passes through the left hand swing valve to the left hand swing clutch cylinder. This pressure is regulated by the swing valve, that is, the further forward the lever is pushed, the greater the pressure to the clutch cylinders. The upper will move towards the boom in this mode.

When the swing control lever IS pulled back, the same condition as described above exists in the right hand circuit. The upper will move away rom the boom in this mode.

HOIST CIRCUIT. The hoist circuit Includes the left and right drum brakes, planetary brakes, brake locks, drum pawls, and clutch controls. To lift a load the operator pushes the brake lock switch to the OFF posrtion. pushes the pawl switch to the OFF position and pulls the drum lever back. In these positions, hydraulic oil passes from the accumulator, through the brake lock valve, to the drum brake lock cylinder. Oil also flows from the accumulator through the pawl valve to the pawl cylinder. Oil also flows through the drum control valve, to the drum clutch cylinder. Oil flowing into the drum brake lock cylinder will cause the cylinder piston to extend and release the drum brake. Oil flowing into the pawl cylinder will cause the cylinder piston to extend and release the drum pawl. Oil flowing into the drum clutch cylinder will cause the cylinder piston to extend, apply the clutch and lift the load.

To stop drum rotation, depress the drum brake pedal and move the drum control lever to neutral. In these positions, hydraulic oil passes from the accumulator, through the drum brake valve, to the drum brake cylinder. Oil will also flow out of the drum clutch cylinder, through the drum control valve, to the reservoir. Oil flowing into the drum brake cylinder will cause the cylinder piston to extend and apply the drum brake to stop rotation of the drum. Oil flowing out of the drum clutch cylinder will cause the cylinder piston to retract and allow springs to release the drum clutch.

The load may be lowered by gravity or powered down. To lower a load by gravity, the operator slowly releases the brake pedal. This allows oil to flow out of the brakecylinder, through the drum brake valve, to the reservoir. Oil flowing out of the brake cylinder will cause the cylinder piston to retract, allowing springs to release the drum brake and lower the load.

To power down a load, the operator moves the drum control forward and slowly releases the drum brake pedal. In these positions hydraulic oil passes from the accumulator, through the planetary brake valve, to the planetary brake cylinder. Releasing the brake pedal allows oil to flow out of the brake cylinder, through the brake valve, to the reservoir. Oil flowing into the planetary brake cylinder causes the cylinder piston to extend applying the planetary brake to power down a load. Oil flowing out of the brake cylinder will cause the cylinder to retract, allowing springs to release the drum brake.

THIRD DRUM CIRCUIT. The third drum circuit includes the third drum brake and clutch control. To lift a load, the operator pulls the lever back. In this position, hydraulic oil passes from the accumulator, through the control valve, to the third drum clutch. Oil also passes through a shuttle valve to the third drum brake. Oil flowing into the third drum brake cylinder will cause the cylinder piston to extend and release the drum brake. Oil flowing into the third drum clutch cylinder will cause the cylinder piston to extend applying the clutch and lifting the load.

To stop drum rotation, move the third drum control to neutral. In this position, hydraulic oil will flow out of the third drum clutch and brake cylinders to the reservoir. Oil flowing out of the clutch cylinder will cause the cylinder piston to retract and allow springs to release the drum clutch. The third drum brake will spring set when oil flows out of the brake cylinder.

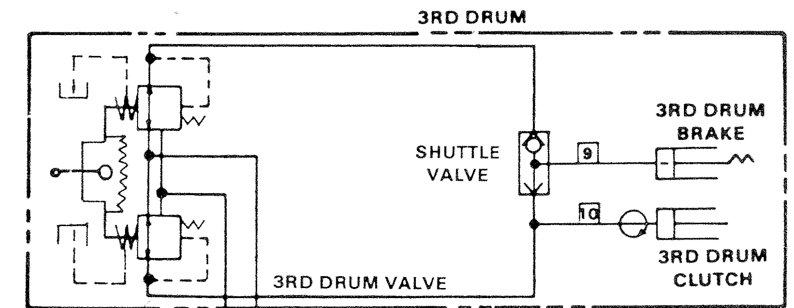
To lower a load, the operator pushes the lever forward. In this position hydraulic oil passes from the accumulator, through the control, through a shuttle valve, to the third drum brake cylinder. Oil flowing into the brake cylinder will cause the cylinder piston to extend, releasing the third drum brake and allowing gravity to lower the load.

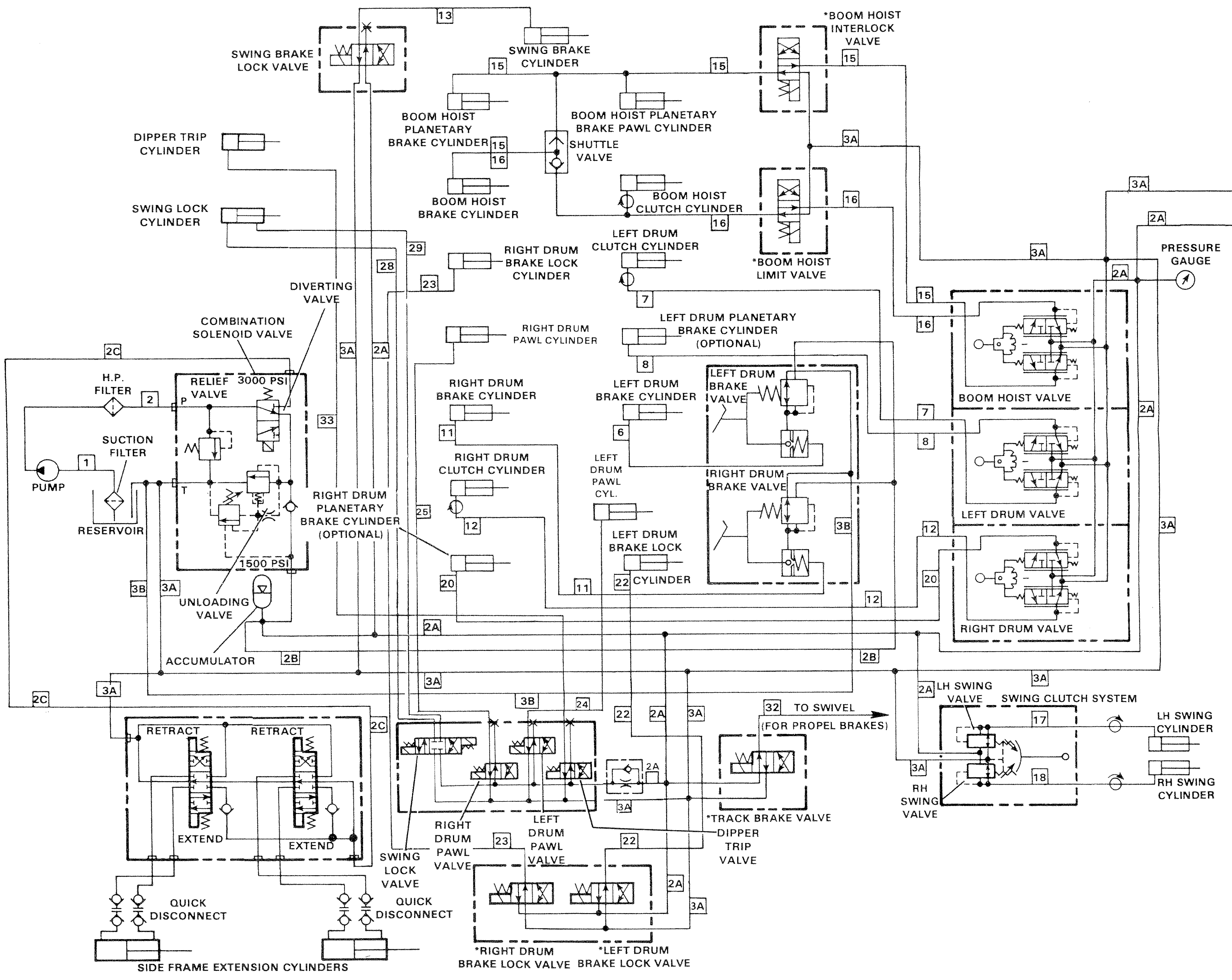
PROPEL BRAKE CIRCUIT. The propel brake circuit consists of the propel brake switch and valve. To release the propel brake, the operator moves the switch to the OFF position. In this position hydraulic oil passes from the accumulator, through the brake valve, through the swivel, and to the propel brakes. Oil flowing into the brake chambers forces the piston against the brake springs, releasing the pressure on the brake disc plates, allowing the brake discs to rotate.

To apply the propel brake the operator moves the switch to the ON position. In this position hydraulicoilflowsoutof the brake chambers and returns to the reservoir. Oil flowing out of the brake chambers allows springs tocompressthebrake discs between the brake disc plates. The brake disc plates are prevented from rotating.

CRAWLER EXTENSION AND RETRACTION CIRCUIT. This circuit includes the two quick connect hoses on the underside of the revolving frame and one control on the left front side of the upper. To extend the crawler tracks the operator moves the control to the “extend” position. In this position hydraulic oil from the pump is directed to the blind end of the extension cylinders causing the piston rods to extend. Hydraulic fluid from the head end of the cylinders is directed back to the reservoir.

To retract the crawler tracks the operator moves the control to the “retract” position. In this position hydraulic oil from the pump is directed to the head end of the extension cylinder causing the piston rods to retract. Hydraulic fluid from the blind end of the cylinders is directed back to the reservoir.





HYDRAULIC LINES DESIGNATION		
LINE NO.	FROM	TO
1	RESERVOIR	HYD. PUMP (SUCTION)
2A	ACCUMULATOR	DISTRIBUTOR (PRESSURE)
2B	ACCUMULATOR	DRUM BRAKE VALVES
2C	COMB. SOL. VALVE	SIDE FRAME EXT. VALVE
3A	DISTRIBUTOR	TANK RETURN
3B	BRAKE VALVE	TANK RETURN
6	LEFT BRAKE VALVE	LEFT DRUM BRAKE CYL.
7	DISTRIBUTOR	LEFT DRUM CLUTCH CYL.
8	DISTRIBUTOR	LEFT DRUM PLAN. CLUTCH
9	DISTRIBUTOR	3RD DRUM BRAKE
10	DISTRIBUTOR	3RD DRUM CLUTCH
11	RIGHT BRAKE VALVE	RIGHT DRUM BRAKE CYL.
12	DISTRIBUTOR	RIGHT DRUM CLUTCH CYL.
13	SOLENOID VALVE	SWING BRAKE CYL.
15	DISTRIBUTOR	B.H. DRUM BRAKE CYL.
16	DISTRIBUTOR	B.H. DRUM CLUTCH CYL.
17	LH SWING VALVE	LH SWING CYL.
18	RH SWING VALVE	RH SWING CYL.
20	DISTRIBUTOR	RIGHT DRUM PLAN. CLUTCH
22	SOLENOID VALVE	LEFT DRUM LOCK CYL.
23	SOLENOID VALVE	RIGHT DRUM LOCK CYL.
24	SOLENOID VALVE	LEFT DRUM PAWL CYL.
25	SOLENOID VALVE	RIGHT DRUM PAWL CYL.
26	LEFT DRUM PAWL CYL.	SOLENOID VALVE
27	RIGHT DRUM PAWL CYL.	SOLENOID VALVE
28	SOLENOID VALVE	SWING LOCK CYL.
29	SOLENOID VALVE	SWING LOCK CYL.
32	SOLENOID VALVE	PROPEL HYD. BRAKE
33	SOLENOID VALVE	DIPPER TRIP CYL.

*SOLENOID VALVES SHOWN DE-ENERGIZED

Figure 5A-1. Hydraulic Control Schematic (2105J238)

The load may be lowered by gravity or powered down. To lower a load by gravity, the operator slowly releases the brake pedal. This allows oil to flow out of the brake cylinder, through the drum brake valve, to the reservoir. Oil flowing out of the brake cylinder will cause the cylinder piston to retract, allowing springs to release the drum brake and lower the load.

To power down a load, the operator moves the drum control forward and slowly releases the drum brake pedal. In these positions hydraulic oil passes from the accumulator, through the planetary brake valve, to the planetary brake cylinder. Releasing the brake pedal allows oil to flow out of the brake cylinder, through the brake valve, to the reservoir. Oil flowing into the planetary brake cylinder causes the cylinder piston to extend applying the planetary brake to power down a load. Oil flowing out of the brake cylinder will cause the cylinder to retract, allowing springs to release the drum brake.

THIRD DRUM CIRCUIT. The third drum circuit includes the third drum brake and clutch control. To lift a load, the operator pulls the lever back. In this position, hydraulic oil passes from the accumulator, through the control valve, to the third drum clutch. Oil also passes through a shuttle valve to the third drum brake. Oil flowing into the third drum brake cylinder will cause the cylinder piston to extend and release the drum brake. Oil flowing into the third drum clutch cylinder will cause the cylinder piston to extend applying the clutch and lifting the load.

To stop drum rotation, move the third drum control to neutral. In this position, hydraulic oil will flow out of the third drum clutch and brake cylinders to the reservoir. Oil flowing out of the clutch cylinder will cause the cylinder piston to retract and allow springs to release the drum clutch. The third drum brake will spring set when oil flows out of the brake cylinder.

To lower a load, the operator pushes the lever forward. In this position hydraulic oil passes from the accumulator, through the control, through a shuttle valve, to the third drum brake cylinder. Oil flowing into the brake cylinder will cause the cylinder piston to extend, releasing the third drum brake and allowing gravity to lower the load.

PROPEL BRAKE CIRCUIT. The propel brake circuit consists of the propel brake switch and valve. To release the propel brake, the operator moves the switch to the OFF position. In this position hydraulic oil passes from the accumulator, through the brake valve, through the swivel, and to the propel brakes. Oil flowing into the brake chambers forces the piston against the brake springs, releasing the pressure on the brake disc plates, allowing the brake discs to rotate.

To apply the propel brake the operator moves the switch to the ON position. In this position hydraulic oil flowsoutof the brake chambers and returns to the reservoir. Oil flowing out of the brake chambers allows springs tocompress the brake discs between the brake disc plates. The brake disc plates are prevented from rotating.

CRAWLER EXTENSION AND RETRACTION CIRCUIT. This circuit includes the two quick connect hoses on the underside of the revolving frame and one control on the left front side of the upper. To extend the crawler tracks the operator moves the control to the “extend” position. In this position hydraulic oil from the pump is directed to the blind end of the extension cylinders causing the piston rods to extend. Hydraulic fluid from the head end of the cylinders is directed back to the reservoir.

To retract the crawler tracks the operator moves the control to the “retract” position, In this position hydraulic oil from the pump is directed to the head end of the extension cylinder causing the piston rods to retract. Hydraulic fluid from the blind end of the cylinders is directed back to the reservoir.

SUBSECTION 5B

PUMPS

GENERAL

This subsection contains the information necessary to remove, disassemble, repair, assemble, and install the pumps used in the hydraulic control system.

TROUBLESHOOTING

Table 5B-1 lists some of the difficulties which may be experienced with gear type hydraulic pumps. The table lists the possible causes and possible remedies for the problems iisted. This guide should be helpful in diagnosing pump problems.

PUMP (37Z317)

DESCRIPTION

One, fixed displacement, single gear type pump is used to provide hydraulic pressure for the control system on this machine. The pump is flanged mounted on the accessory drive of the engine and driven by the camshaft.

The pump consists of four main components: the end cover, bushing assembly, gear assembly, and mounting flange. These parts are held together by four capscrews that thread into the mounting flange.

The bushing gear assembly is pressure loaded against the end cover and the bushings are pressure balanced to prevent tilt. These features ensure that internal leakage is kept to a minimum, enabling the pump to operate at high efficiency. The condition of the bushing faces adjacent to the gears is an important factor in maintaining this efficiency and, during any disassembly or assembly operations, the bushings must be handled carefully to prevent damage. It is essential that the pump is operated only in a clean system. Any foreign matter in the oil will score the bushing faces, and this will lead to shortened service life and eventual failure.

REMOVAL

To remove the control pump mounted on the engine, proceed as follows:

1. Remove all dirt from the pump and connections with a cleaning solvent.

2. Remove the hydraulic hose connections from the pump.

3. Plug the ports of the pump and cap the lines to prevent the entry of dirt into the system.

4. Remove the mounting bolts and pull the pump away from the engine.

SEAL REPLACEMENT

To replace the pump seal only, proceed as follows (see Figure 58-1):

1. Remove the four capscrews that attach the mounting flange to the body.

2. Lightly tap the mounting flange clear of the two hollow dowels in the pump body and slide it squarely off the shaft.

3. Clamp the mounting flange securely in a soft jawed vise and drive the seal out with a drift. Take care that the drift does not damage the shaft bore.

4. Ensure that the seal housing in the mounting flange is clean and free of burrs.

5. Pack the seal with a high melting point, mineral base grease.

6. Press the seal into the full depth of the recessed bore, with the spring facing the inside of the mounting flange.

7. Fit the mounting flange squarely on the shaft, start the four capscrews, and tighten them in a diagonal pattern to a final torque of 36 ft-lbs.

8. Install the pump as described under the heading INSTALLATION at the end of this subsection.

OVERHAUL

GENERAL. Disassembly should only be attempted on a bench in as clean an area as possible. The workbench, the mechanic's hands, and tools must be clean and the disassembled pump must be protected from airborne dust. During disassembly, pay particular attention to the identification of the parts in order that thepumpcan be properly assembled.

DISASSEMBLY. To disassemble the pump, proceed as follows (see Figure 58-1):

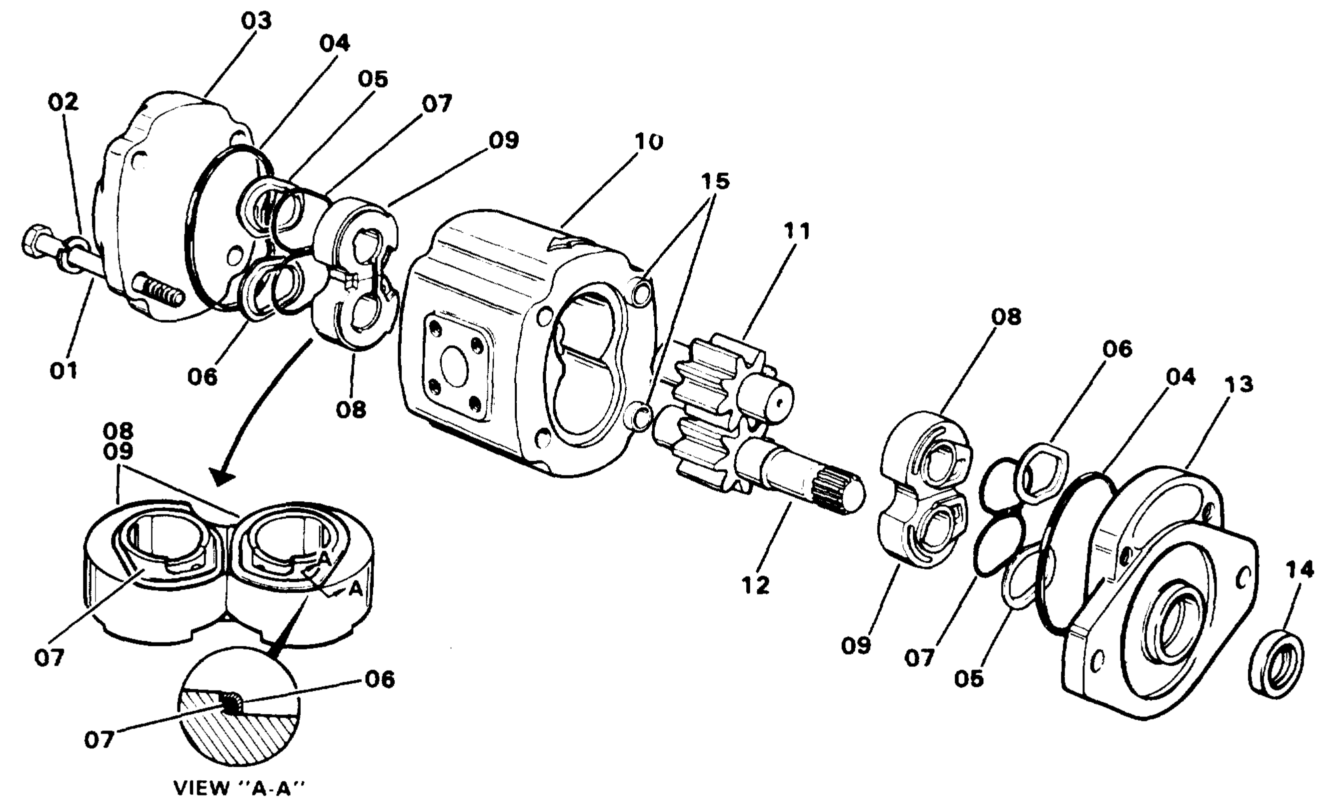
1. Remove the end cover by removing the four capscrews that attach it to the mounting flange. Remove O-ring (04) from the body of the pump.

NOTE

Lightly mark and cover, body and mounting flange (03, 10 and 13) to ensure assembly in the correct relationship and take note of the direction of rotation of the pump (counterclockwise).

Table 5B-1. Pump Troubleshooting

TROUBLE	PROBABLE CAUSE	REMEDY
1. Pump does not deliver fluid.	A. Fluid level in reservoir too low.	A. Fill the reservoir with the proper grade and type of fluid. Check for possible external leaks.
	B. Pump inlet line plugged.	B. Remove and clean. Check filters and reservoir for other possible obstructions.
	C. Air leak in pump inlet line.	C. Repair leak.
	D. Pump speed too slow.	D. Increase speed.
	E. Fluid viscosity too high.	E. Use only those fluids recommended in Section III.
	F. Broken or worn parts inside the pump or drive coupling.	F. Analyze the conditions that brought on the failure and correct them. Replace the pump, if required.
2. No pressure	A. Pump not delivering fluid.	A. Follow the remedies in Part I.
	B. Fluid recirculating back to reservoir and not going to functions.	B. Mechanical failure of some other part of the system, especially a relief valve. If contamination is involved, clean and refill the system with clean proper fluid.
3. Low or erratic pressure	A. Cold fluid.	A. Warm up system. Operate only at recommended operating temperature range. (See Operation Section.)
	B. Fluid viscosity wrong.	B. See Section III. Use only those lubricants listed.
	C. Air leak or restriction at inlet line.	C. Repair or clean.
	D. Pump speed too slow.	D. Increase speed.
	E. Internal parts of pump are worn excessively.	E. Replace pump or replace defective internal parts.
4. Pump making noise	A. Restricted or clogged inlet line.	A. Clean or repair.
	B. Air leaks in intake line or air drawn through inlet line.	B. Repair. To check for leaks pour fluid around joints and listen for a change in sound of operation.
	C. Low fluid level.	C. Fill to proper level with proper grade and type of fluid.
	D. Air in the system.	D. Check for leaks. Bleed air from the system.
	E. Fluid viscosity too high.	E. Fill only with fluids recommended in Section III.
	F. Pump speed too fast.	F. Check engine speed.
	G. Worn or broken parts.	G. Check and correct cause of parts failure. Replace pump.
5. Excessive wear	A. Abrasive contaminants or sludge in the fluid.	A. Check for cause of contaminants. Replace filter elements. Replace pump. Replace fluid with recommended grade and quantity.
	B. Viscosity of fluid too low or too high.	B. Replace fluid with proper grade and type. (See Section III.)
	C. Sustained high pressure above maximum pump rating.	C. Check for possible relief valve malfunction or other parts failures. Adjust if necessary.
	D. Air leaks or restriction in system causing cavitation.	D. Eliminate from system. Replace pump if necessary.
6. Excessive fluid leakage	A. Damaged seal or packings around drive shaft.	A. Check and replace. Check to be sure that chemicals in fluid are not destroying packing or seals. Follow recommendations on grade and type of fluid in Section III.
7. Internal parts breakage	A. Excessive pressure above maximum limits for pump.	A. Same as 5C above.
	B. Seizure due to lack of fluid.	B. Check pump inlet line.



01. CAPSCREW
02. LOCKWASHER
03. END COVER
04. O-RING
05. BACK-UP WASHER
06. BACK-UP WASHER
07. LOBE SEAL
08. BUSHING ASSEMBLY
09. BUSHING ASSEMBLY
10. BODY
11. DRIVEN GEAR
12. DRIVE GEAR SHAFT
13. MOUNTING FLANGE
14. OIL SEAL
15. DOWELS

Figure 5B-1. Control Pump (37Z317)

2. Carefully lift back-up washers (05 and 06) and lobe seal (07) from bushing assembly (08 and 09).

3. Lightly tap the mounting flange clear of the two hollow dowels in the pump body and slide it squarely off the shaft, Remove O-ring (04) from body (10).

4. Repeat step 2 for the mounting flange end of the pump.

5. Hold the pump body vertically with the mounting flange end down, support the bushings from underneath to prevent them from falling out.

6. Tap the side of the body with a leather mallet to dislodge the lower bushings and carefully slide these out of the body, Keep bushings in a matched pair.

7. Invert the body and lift out the driver and driven gears (11 and 12).

8. Remove the remaining pair of bushing assemblies and place on the end cover. Make special note of how these assemblies are installed to ensure proper assembly.

INSPECTION AND REPAIR. After the pump is disassembled, thoroughly clean all the parts and dry. Inspect for the following defects:

1. Check for eroded parts. This indicates aeration or cavitation

2. Check for blackened parts or brittle O-rings and seals. This type of damage is caused by excessive heat.

3. Check for excessive wear, sandblasting (dull finish), and scoring. Abrasive wear is caused by fine particles (not visible to the eye) or metal (coarse) particles in the oil. The system must be flushed and the filters replaced.

4. Check for broken or cracked parts. This type of damage can be caused by large metal objects or defective relief valves (high pressure).

5. If the bushings are worn, inspect the walls of the body where the gears rotate. Excessive wear in this area is cause for the replacement of the pump.

6. Inspect the gears for proper and even wear across each tooth surface. If wear to the gears is excessive, replace the pump.

7. Replace the shaft seal as described earlier in this subsection.

ASSEMBLY. Assembly is basically the reverse of disassembly. Install new O-rings, back-up washers, and lobe seals. Coat all parts with clean hydraulic oil to facilitate assembly and provide initial lubrication. Assemble the pump as follows (see Figures 5B-1 and 5B-2).

1. Layout the bushing assemblies for the mounting flange and end cover as shown in Figure 5B-2.

2. Fit the back-up washers onto lobe seals (07) of the bushing assemblies as shown in View "A-A" of Figure 5B-1.

NOTE

When fitted correctly, the back-up washers must be level and flush with the top surface of the bushing lobes.

CAUTION

No force must be used when installing the bushing assemblies into the body. If the bushing assemblies jam in the bore, remove and examine them for nicks or scratches. This type of damage can be removed with a fine grit hand stone.

3. Place the body on clean bench with the hollow dowels facing up and install the flange end bushing assemblies into the body. Note that the bushing lobes are facing in and the recessed area is opposite the hollow dowels.

4. Lay the pump on its side and slide drive gear shaft (12) through the bore so the splined end protrudes from the hollow dowel end of the body

5. Install seal (14) as previously described under the heading SEAL REPLACEMENT.

6. Install O-ring (04). then slide mounting flange (13) squarely onto the splined shaft taking care not to damage seal (14).

7. Carefully install driven gear (11).

8. Repeat steps 2 and 3 for the end cover assembly. Positioning of the bushing assembly is the same as described in step 3.

9. Install the other O-ring into the body of the pump

10. Align the marks made in disassembly and place end cover (03) against the body. Install the four capscrews with the lockwashers and torque to 36 ft-lbs.

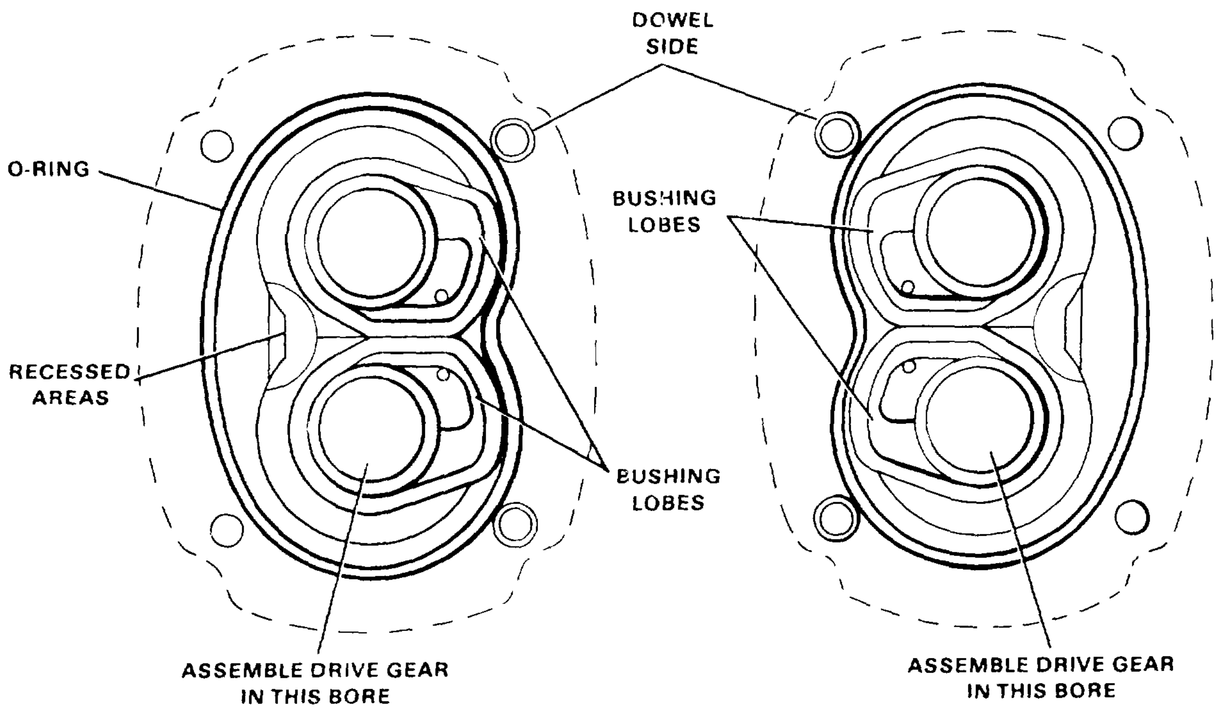


Figure 5B-2. Bushing Assembly Installation

NOTE

Tighten the capscrews in a diagonal pattern to prevent putting a strain on the end cover.

11. Pour a small quantity of hydraulic oil into one of the ports and check the pump for freedom of rotation.

INSTALLATION

To install the control pump on the engine drive, proceed as follows:

1. Install a new gasket on the mounting ftange of the pump.

2. Insert the two capscrews with the lockwashers and torque to 25 ft-lbs.

3. Connect the hydraulic lines to the proper ports of the pump.

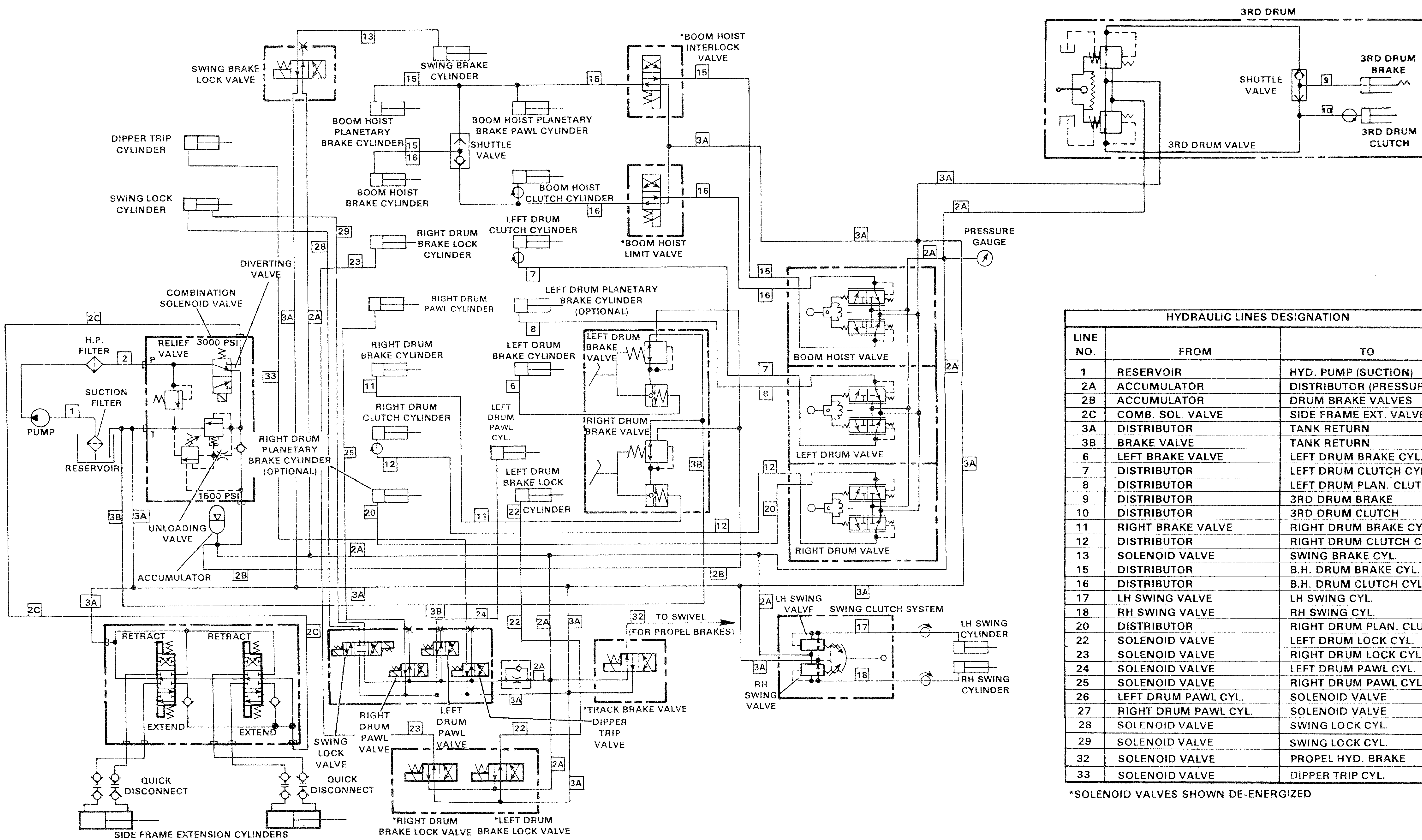
4. Refill the oil reservoir to the proper level with the recommended lubricant. Start the engine. Allow the engine to run at idle speed, with no load applied to the hydraulic system, to prime the system.

NOTE

When first starting it may be necessary to bleed air from the pump outlet line to permit priming and reduce noise. Bleed any air by loosening an outlet connection fitting. Allow fluid to flow into a container until a solid stream appears. Retighten the fitting.

5. Run the engine at moderate speed and load for a short period of time. Check the reservoir oil level and add oil if required.

6. Check the pump and its connections for leaks



HYDRAULIC LINES DESIGNATION		
LINE NO.	FROM	TO
1	RESERVOIR	HYD. PUMP (SUCTION)
2A	ACCUMULATOR	DISTRIBUTOR (PRESSURE)
2B	ACCUMULATOR	DRUM BRAKE VALVES
2C	COMB. SOL. VALVE	SIDE FRAME EXT. VALVE
3A	DISTRIBUTOR	TANK RETURN
3B	BRAKE VALVE	TANK RETURN
6	LEFT BRAKE VALVE	LEFT DRUM BRAKE CYL.
7	DISTRIBUTOR	LEFT DRUM CLUTCH CYL.
8	DISTRIBUTOR	LEFT DRUM PLAN. CLUTCH
9	DISTRIBUTOR	3RD DRUM BRAKE
10	DISTRIBUTOR	3RD DRUM CLUTCH
11	RIGHT BRAKE VALVE	RIGHT DRUM BRAKE CYL.
12	DISTRIBUTOR	RIGHT DRUM CLUTCH CYL.
13	SOLENOID VALVE	SWING BRAKE CYL.
15	DISTRIBUTOR	B.H. DRUM BRAKE CYL.
16	DISTRIBUTOR	B.H. DRUM CLUTCH CYL.
17	LH SWING VALVE	LH SWING CYL.
18	RH SWING VALVE	RH SWING CYL.
20	DISTRIBUTOR	RIGHT DRUM PLAN. CLUTCH
22	SOLENOID VALVE	LEFT DRUM LOCK CYL.
23	SOLENOID VALVE	RIGHT DRUM LOCK CYL.
24	SOLENOID VALVE	LEFT DRUM PAWL CYL.
25	SOLENOID VALVE	RIGHT DRUM PAWL CYL.
26	LEFT DRUM PAWL CYL.	SOLENOID VALVE
27	RIGHT DRUM PAWL CYL.	SOLENOID VALVE
28	SOLENOID VALVE	SWING LOCK CYL.
29	SOLENOID VALVE	SWING LOCK CYL.
32	SOLENOID VALVE	PROPEL HYD. BRAKE
33	SOLENOID VALVE	DIPPER TRIP CYL.

*SOLENOID VALVES SHOWN DE-ENERGIZED

Figure 5A-1. Hydraulic Control Schematic (2105J238)

SUBSECTION 5C

CONTROL VALVES

GENERAL

This subsection contains the information necessary to repair the directional control valves which direct-hydraulic fluid to the various actuating cylinders.

GENERAL REMOVAL

Prior to removing any of the components in this section, shut down the engine and disconnect the battery ground cable to prevent machine operation while the item is being serviced. Operate the controls to relieve all pressure in the system and also clean the area around the item being removed to prevent the entry of contaminants.

CONTROL VALVE (36Q384)

DESCRIPTION. This valve is used to control the rotation of the drums. A three stack valve is used to control the front, rear and boom hoist drums. The valves are sandwiched between an inlet and outlet section. Movement of a control handle directs any control pressure to the appropriate clutch, brake or pawl.

REMOVAL. To remove the valve stack, proceed as follows (see Figure 5C-1):

1. See General Removal at the beginning of this subsection.

2. Remove the access cover on the top of the control console. Clean the valve stack and the fittings with a suitable solvent. Dry the fittings with compressed air. This is done to prevent dirt from entering open lines when the fittings are removed.

3. Disconnect and tag the hydraulic lines at the valve stack and position the lines to avoid interference as the valve stack is removed. Cap the lines and plug the valve ports to prevent the entry of contaminants.

4. Remove the capscrews, nuts and lockwasher which secure the valve stack to the control console. Lift the valve stack out of the machine and place it on a clean work surface.

5. Remove individual valves by removing the hardware securing the valve to the manifold.

REPAIR. To repair an individual valve, proceed as follows (see Figure 5C-2):

1. Using a suitable tool, press in on gland (15) and remove retaining ring (11) from body (01).

2. Remove stem (14), gland (15), spring (09) and spool (08).

3. Remove O-ring (10), seal (12) and wiper (13) from gland (15) and replace with new parts from seal kit.

4. Turn plug (04) out of body (01), remove O-ring (03) and replace with a new O-ring.

5. Clean and inspect the other parts for damage. Any defect to, parts, other than the ones found in the seal kit, will require the replacement of the valve.

6. Lubricate the parts with clean hydraulic oil.

7. Install spool (08) into the body with the grooved end facing orifice plug (04).

8. Place spring guide (07) spring (06), and new washer (05) into the body of the valve. Then install and tighten orifice plug (04).

9. Assemble spring guide (02), spring (09), gland (15) on to stem (14) and place in the body. Carefully press gland (15) into the body to prevent damage to the wiper. Install retaining ring (11).

NOTE

The purpose of the wiper is to prevent dirt and water from entering the valve, therefore the lips face outward. The O-ring and seal prevent oil leakage from the valve.

INSTALLATION. To install the valve, proceed as follows (see Figure 5C-1):

1. Before actually installing the valve stack in the console, check the following items (see Figure 5C-3):

A. With valve handles in center (detent) position, adjust. setscrews (01) down to valve stem to within ±0.001 inch. Then tighten hex nuts (02) to 13 ft-lbs torque.

8. Adjust setscrew (03) to approximately 1/2 inch below bottom of manifold (04). Secure in place with jam nut (05).

2. Position the valve in the control console. Install and fully tighten the capscrews, nuts and lockwashers.

3. Connect the hydraulic lines.

01. CAPSCREW
02. CONNECTOR
03. TEE
04. ELBOW
05. NUT
06. REDUCER
07. REDUCER
08. NUT
09. ELBOW
10. TEE
11. CONNECTOR
12. PLUG
13. MANIFOLD
14. PIN
15. SPRING
16. BALL
17. SETSCREW
18. NUT
19. LEVER
20. KNOB
21. SWITCH
22. KNOB
23. LEVER
24. LEVER
25. O-RING
26. VALVE
27. PIN
28. SETSCREW
29. JAM NUT

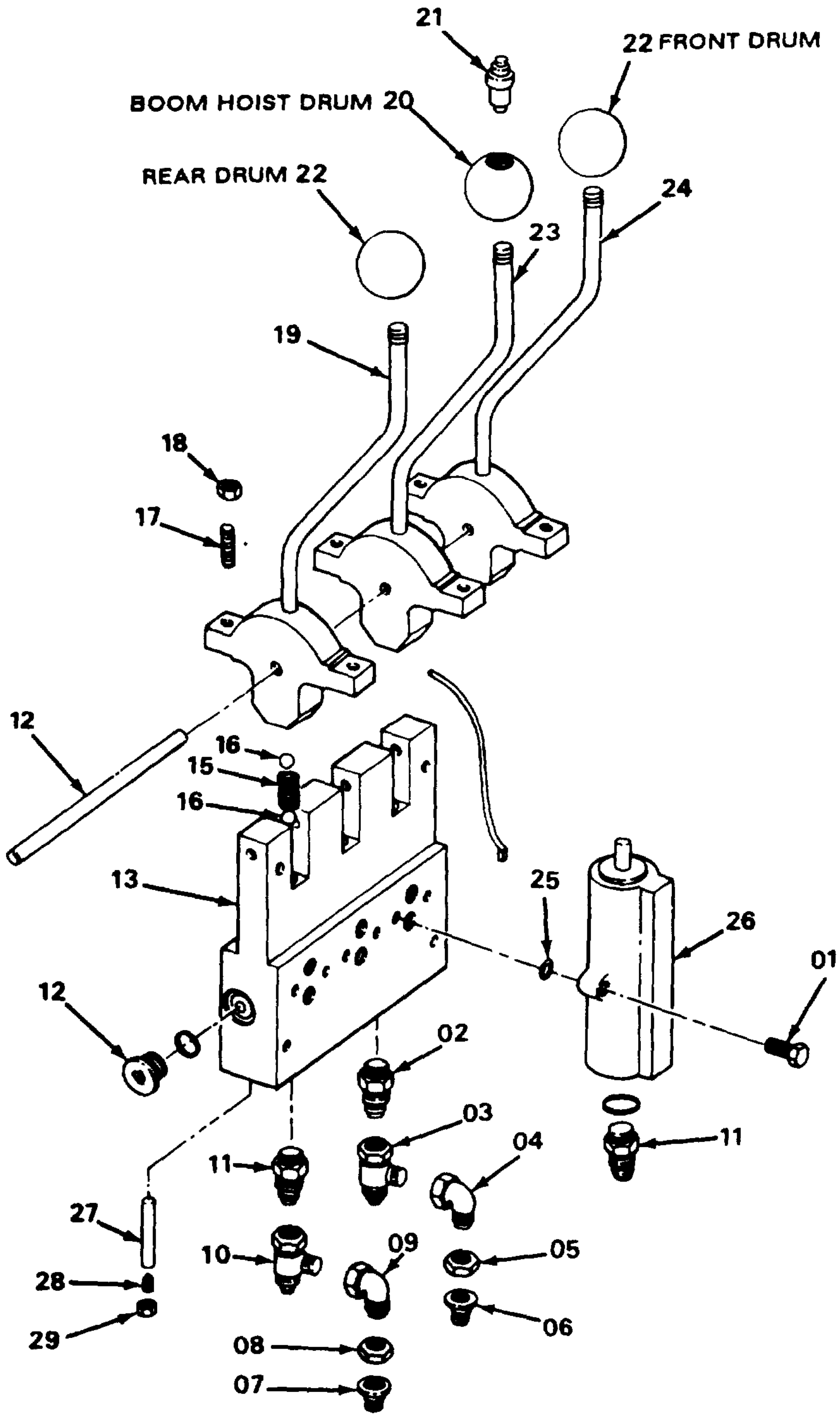


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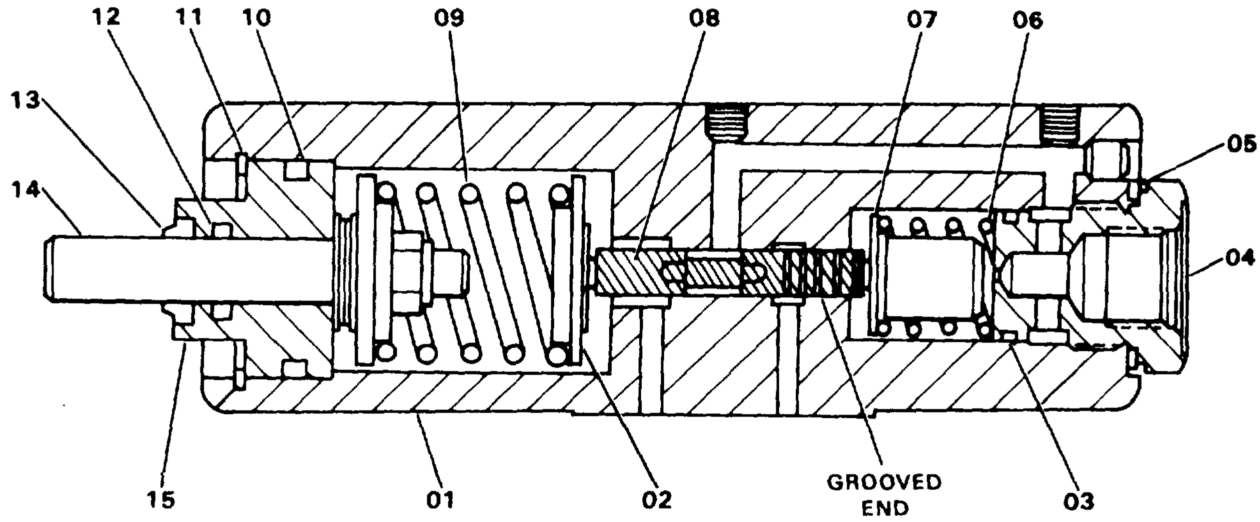
Figure 5C- 1. Control Valve Assembly

4. Connect the battery ground cable. Start the engine and operate the controls to check the operation of the valve. Check all hydraulic lines for leakage.

5. With the valve stack assembled, installed and adjusted as given in step 1, and control pressureo at 1680 psi ±40 psi. detent each valve and adjust with setscrew (03. Figure 5C-3). The force at the control handle should be 10 lbs. -0 +2 lbs to move the handle out of detent. When adjusted properly, secure in place with jam nut (05, Figure 5C-3). Tighten the jam nut to 22 ft-lbs. torque.

CRAWLER EXTEND/RETRACT VALVE (36Z1077)

DESCRIPTION. This valve is a manually operated, three-position, 4-way directional valve. When operated it controls the flow of fluid to the crawl extensrion cylinders.The valve is composed of a pressure passage used to carry fluid to the cylinder ports when the spools are shifted. There is a by-pass passage which permits flow directly to the outlet when the spools are not being operated and there is a tank passage which carries fluid to the outlet from the cylinder ports.



01. BODY
02. SPRING GUIDE
03. O-RING
04. PLUG
05. WASHER
06. SPRING
07. SPRING GUIDE
08. SPOOL
09. SPRING
10. O-RING
11. RETAINING PIN
12. SEAL
13. WIPER
14. STEM
15. GLAND

*SEAL KIT ITEMS

Figure 5C-2. Control Valve (36Q384)

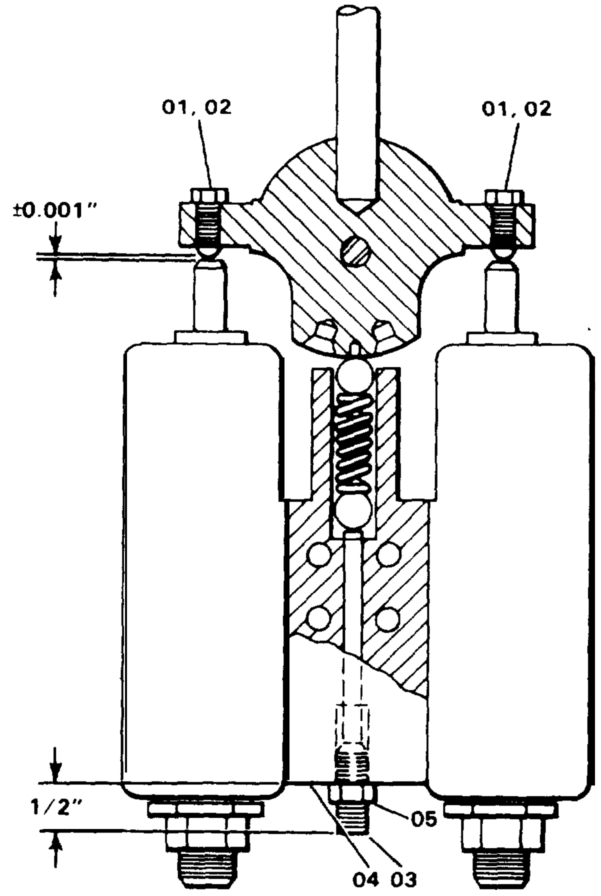


Figure 5C-3. Control Adjustments

REMOVAL. To remove this valve, proceed as follows:

1. See General Removal at the beginning of this section.

2. If attached, remove the flexible lines at this valve from the quick disconnects.

3. Loosen, but do not remove, the hydraulic lines to the valve to relieve any pressure. Tag and remove the lines. Cap the lines and plug the valve ports.

4. Remove the three capscrews and lockwashers securing the valve to the carbody.

DISASSEMBLY. During disassembly, particular attention should be given to the identification of parts for reassembly. Spools are selectively fitted to the valve bodies and must be returned to he same bodies from which they were removed. Valve sections must be reassembled in the same order. To disassemble this valve, proceed as follows (see Figure 5C-4):

1. Remove the “E” washers which retain the fulcrum rod and remove the rod, levers and pivot pins.

2. Remove the four screws and nuts. Separate the valve sections. Be careful not to destroy or lose spacers.

3. Slide the spool out of its bore and remove the O-rings from the groove in the spool and from the valve body around the spool bore. Do not remove the centering spring or retainer unless it is necessary to replace them.

4. Grip the stem of the check valve plug with pliers and pull it out of the valve body. Remove the O-ring and back-up ring. Remove the spring and ball from the valve body.

5. Remove the O-rings, back-up rings, seals, and retainers from the body sections.

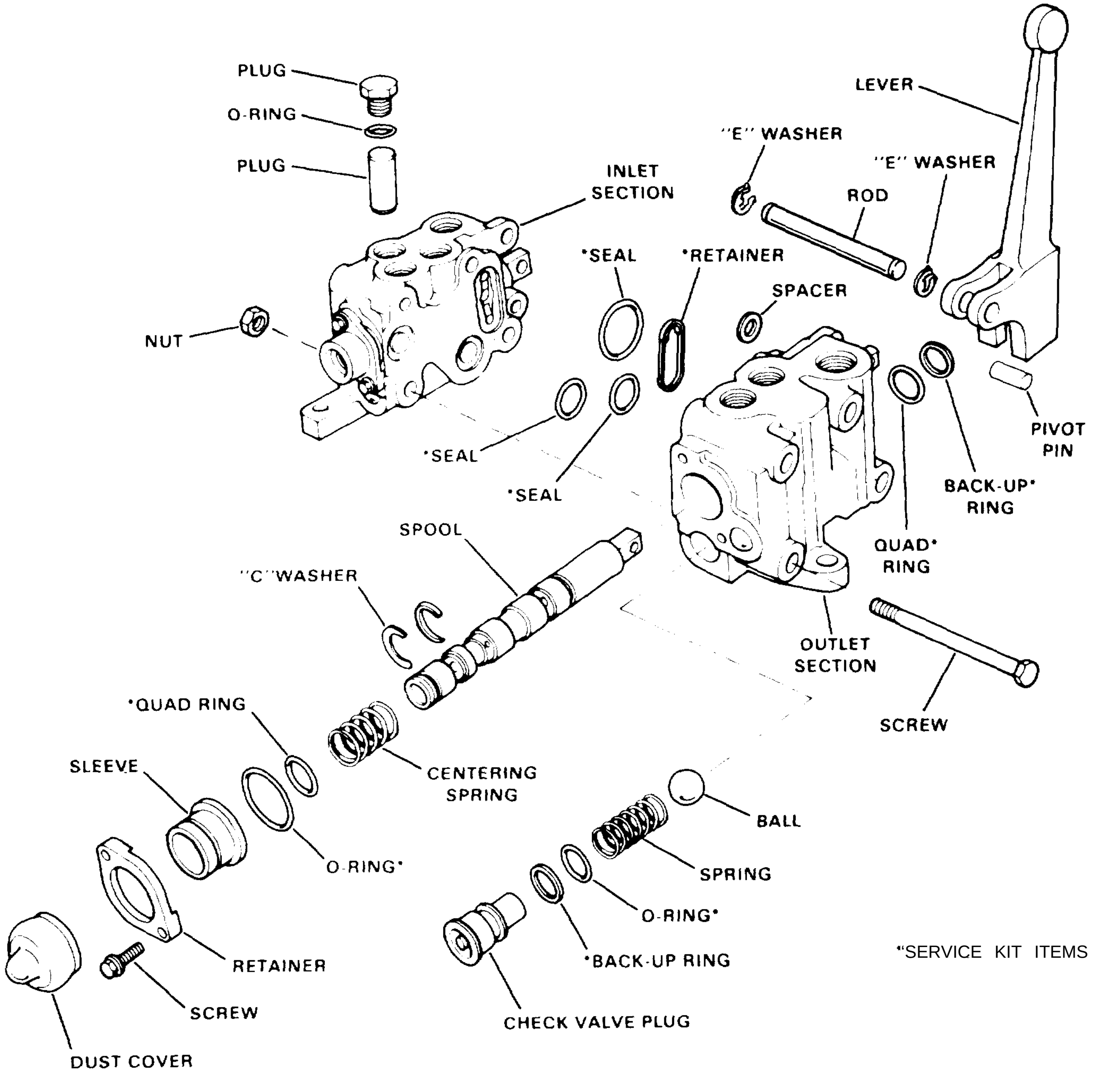


Figure 5C-4. Control Valve (36Z1077)

INSPECTION AND REPAIR. Discard all oil seals, O-rings and back-up rings. Wash the remaining parts in a clean mineral oil solvent and place them on a clean surface for inspection.

NOTE

A service kit is available. See the Replacement Parts Manual.

Carefully remove burrs by light stoning or lapping. *Be certain there is no paint or burring on mating surfaces of valve bodies.* Inspect the valve spools and bores for burrs and scoring. If scoring is not deep enough to cause objectionable leakage, the surfaces can be stoned or polished with crocus cloth. If scoring is excessive the entire valve must be replaced Check the valve spool for freedom of movement.

ASSEMBLY. To assemble the valve, proceed as follows (see Figure 5C-4):

1. Coat all parts with clean hydraulic oil to facilitate assembly and to provide initial lubrication. Petroleum jelly can be used to hold seal rings and O-rings in place on assembly.

2. Install a new back-up ring and O-ring on the check valve plug with the O-ring toward the spring and ball. Place the ball and spring in the body and install the plug. Be sure the hole in the plug lines up with the stud hole in the body.

3. If the centering spring was removed, install the spring and retainers on the spool. Place the O-ring in the groove around the spool bore and install the O-ring on the spool. Install the spool in the bore.

4. Install the seal rings and the seal ring retainer in the grooves in the body of the inlet and outlet section. Carefully place the sections together in the same order in which they were removed. Coat the screw threads with "Locktite" or similar sealant and install the screws and nuts. Tighten the nuts to 15 ft-lbs torque.

5. Install the pins in each spool and assemble the levers, fulcrum rod and "E" washers.

INSTALLATION. To install the valve, proceed as follows:

1. Position the valve on the carbody. Install the lockwashers and capscrews. Fully tighten the capscrews.

2. Reconnect the hydraulic lines.

3. Connect the flexible lines from the upper hydraulic tank and move the upper-lower diverting switch to the "lower" position. Connect the battery ground cable. Start the engine and operate this control to check the operation of the valve. Check all hydraulic lines for leakage.

SWING CONTROL VALVE (36Z1384)

DESCRIPTION. Mounted below the swing control console are two pressure reducing valves that control the swing clutch. As the swing control lever is moved forward or back, hydraulic pressure is metered from 30 to 600 psi through these valves to actuate the swing clutch cylinders.

The swing control valves are not repairable. If it is determined that the valves are defectiveor leak excessively, they must be replaced.

REMOVAL. To remove the swing control valve(s), proceed as follows (see Figure 5C-5):

1. Remove the sheet metal cover directly below the swing console.

2. Perform the GENERAL REMOVAL procedures as found in the beginning of this subsection.

3. Disconnect and tag the hydraulic lines to the valve.

4. Remove the capscrews holding the valve in place.

5. Remove the valve to a clean, dust free area for disassembly.

INSTALLATION AND ADJUSTMENT. To install and adjust the linkage to the swing control valves, proceed as follows:

1. Align the elbows and tees, if removed, and attach the valve(s) to the cabin wall with the capscrews.

2. Connect the hydraulic lines to the fittings.

3. Check and adjust the connecting rod to a length of 24-1/4 inches.

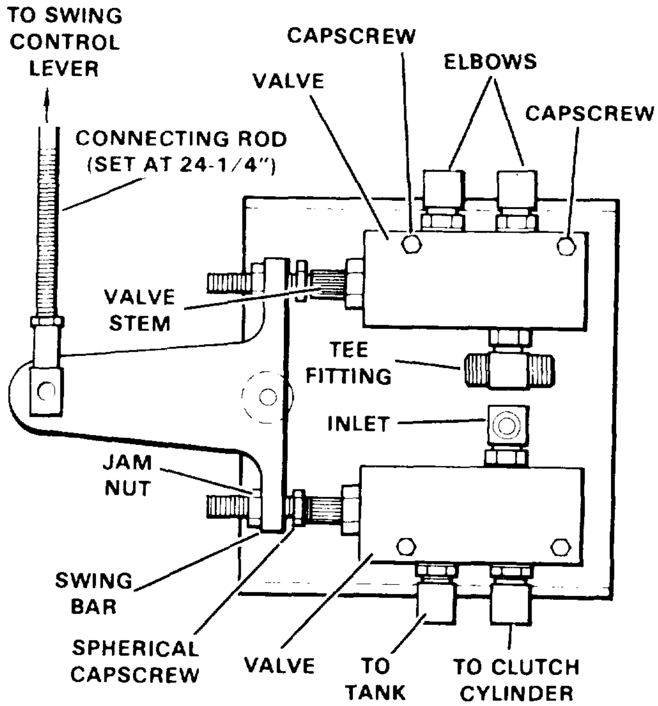


Figure 5C-5. Swing Control Valve (36Z1384)

4. Check and adjust for an air gap between the spherical capscrews and the valve stems. This distance must be at least 0.010 inch or slightly more.

5. Connect the battery ground cable and start the engine.

6. Operate the swing control lever to check for proper operation of the valves. Check the valve stem area and all hydraulic lines for leaks.

7. Install the sheet metal cover over the valves.

BRAKE VALVE (36U259)

DESCRIPTION. This valve is used to apply the front and rear drum brakes. Oil is supplied from the valve to the brake cylinder in direct proportion to the amount of pedal pressure applied by the operator. During heavy brake applications this valve is power assisted by pressure regulating valve (36U258).

REMOVAL. To remove the valve, proceed as follows (See Figure 5C-6)

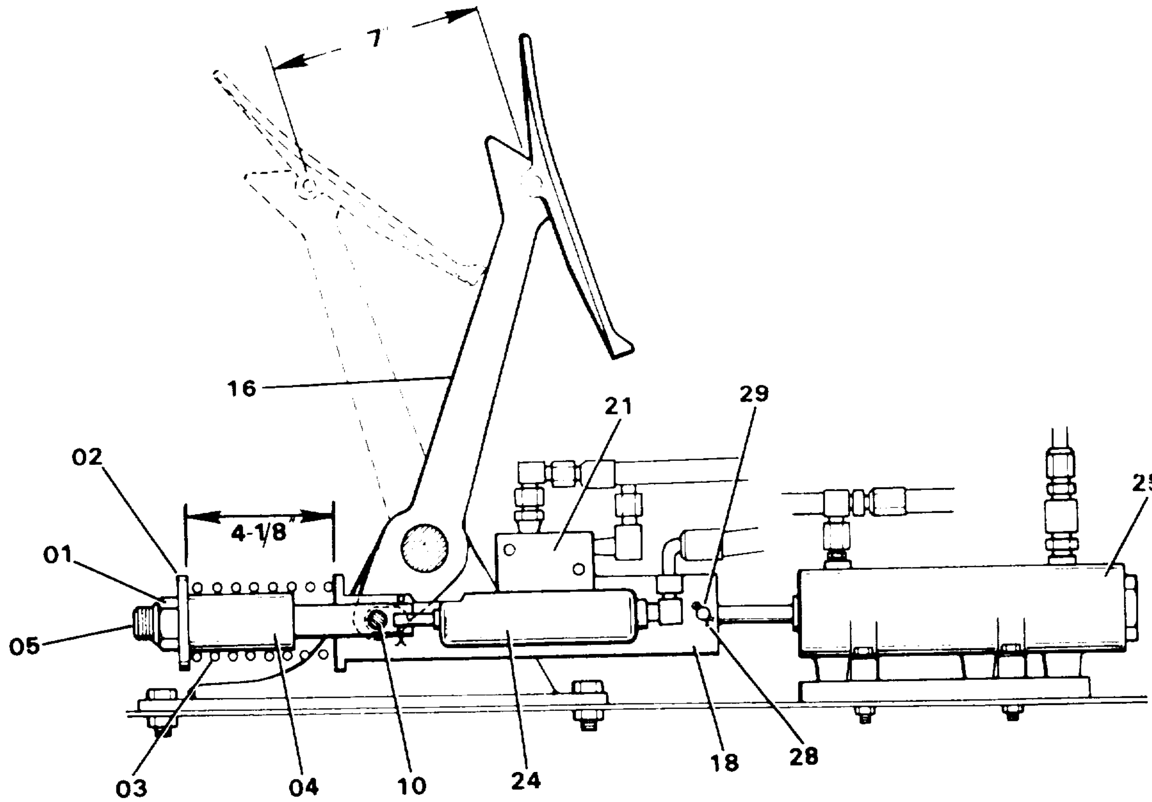
1. See General Removal at the beginning of this section.

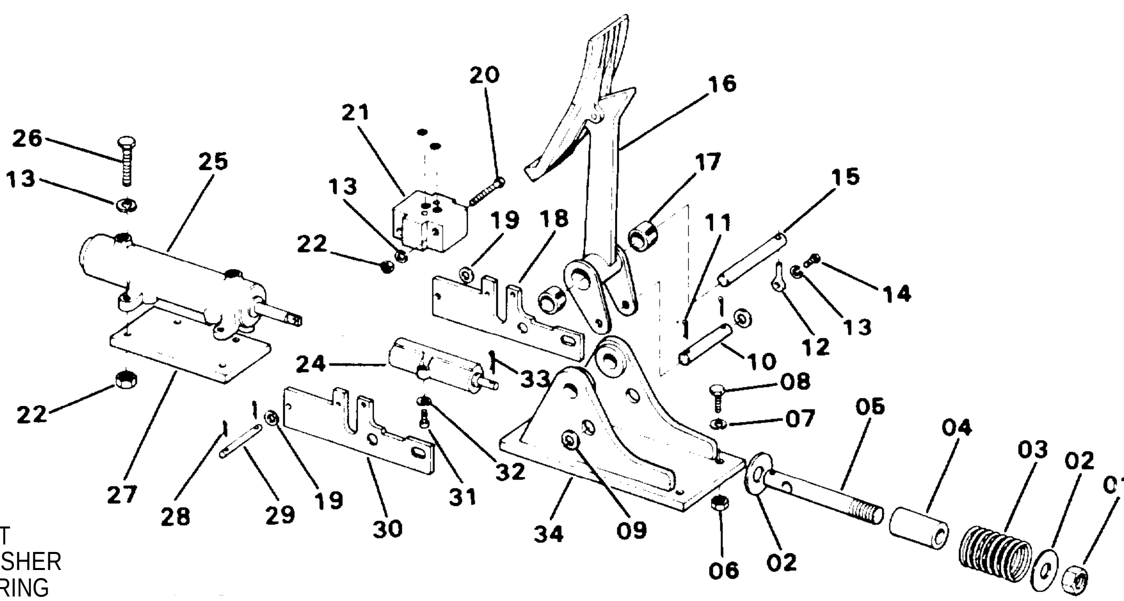
2. Remove the top cover from over the brake valve.

3. Disconnect the hydraulic lines at the brake valve. Cap the lines and plug the ports of the brake valve.

4. Remove cotter pin (28), washer (19) and pin (29) from support plates (30) and the valve stem.

5. Remove the hardware securing the valve to the bracket. Remove the valve from the machine.





01. NUT
02. WASHER
03. SPRING
04. SPACER
05. ROD
06. NUT
07. LOCKWASHER
08. CAPSCREW
09. WASHER
10. PIN
11. COTTER PIN
12. ROD END
13. LOCKWASHER
14. CAPSCREW
16. PIN
16. PEDAL
17. BEARING
18. SUPPORT PLATE
19. WASHER
20. CAPSCREW
21. VALVE BLOCK
22. NUT
23. O-RING
24. REGULATOR VALVE
26. BRAKE VALVE
26. CAPSCREW
27. BRACKET
28. COTTER PIN
29. PIN
30. SUPPORT PLATE
31. CAPSCREW
32. LOCKWASHER
33. COTTER PIN
34. BRACKET

Figure 5C-6. Brake Valve Installation (2100J1129)

DISASSEMBLY. Use the following procedure to disassemble the valve (see Figure 5C-7):

1. Rotate end plug (01) out of the valve body, O-ring (02), snap ring (03) and washer (04) will come out with the end plug.

2. Remove spring (05) and washer (06). Remove the stem and piston assembly (items 07 through 14) and sleeve (17) from the body. Press pin (12) out of piston (11A). This will release ball (11E), guide (11D), and spring (11C).

3. After removing retaining ring (24) from the stem end of the valve body, pry out plug (23).

INSPECTION AND REPAIR. Thoroughly clean all parts and dry with compressed air. Inspect the sleeve stem and piston for excessive wear, nicks or scratches. Check the piston assembly to make sure there is a good ball seat inside. Check the piston ball, guide and spring for excessive wear. Replace all seals and O-rings.

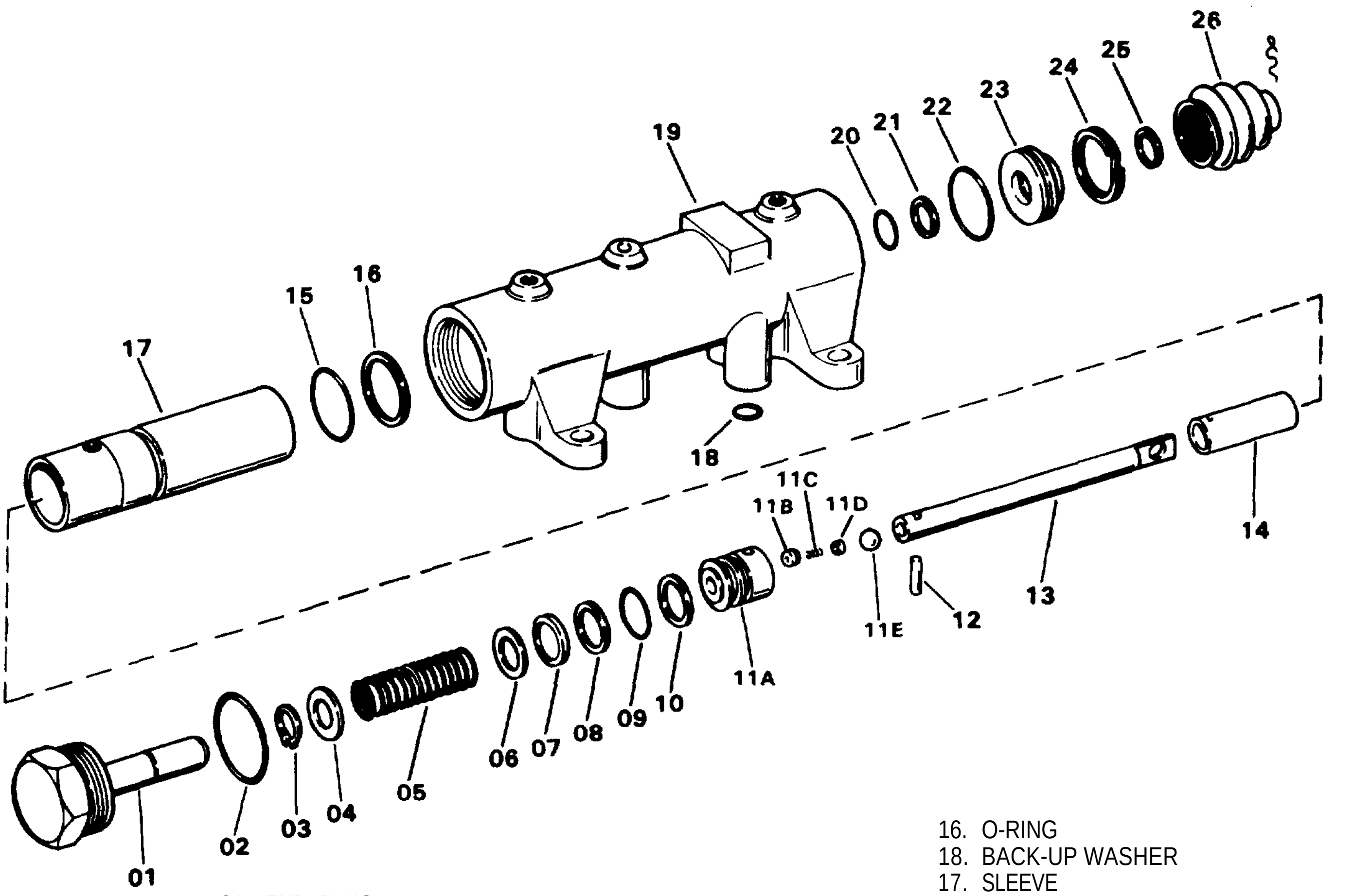
NOTE

Valve seal and repair kits are available. See the Replacement Parts Manual.

1. Generously coat all parts to be assembled with hydraulic oil.

2. Install new O-ring (15) and back-up washer (16) on sleeve (17). Place the sleeve in the valve body. The sleeve must enter smoothly with slight hand pressure.

3. Assemble the piston and stem assembly (items 07 through 14) as shown. install the seals and back-up washers on the piston.



01. END PLUG
02. O-RING
03. SNAP RING
04. WASHER
05. SPRING
06. WASHER
07. SEAL
08. BACK-UP WASHER
09. O-RING
10. BACK-UP WASHER
11 A. PISTON
11B. PLUG
11C. SPRING
11D. GUIDE
11E. BALL
12. PIN
13. STEM
14. SPACER
16. O-RING
18. BACK-UP WASHER
17. SLEEVE
18. O-RING
19. VALVE BODY
20. O-RING
21. BACK-UP WASHER
22. O-RING
23. END PLUG
24. RETAINING RING
26. SEAL
26. BOOT

Figure 5C-7. Brake Valve (36U259)

4. Insert the stem and piston assembly into sleeve (17) and push it all the way into place. Place washer (06) over the piston end and place spring (05) against the washer.

5. Install O-ring (02) on end plug (01), and place the plug with snap ring (03) and washer (04) installed, into the end of the valve. Rotate the end plug into the valve body until it is tight. *Do not overtighten the plug.*

6. Place O-rings (20 and 22), washer (21) and seal (25) on end plug (23). Place the end plug over stem (13) and work it on the stem and into place carefully so that O-ring (20) will not be cut. Install retaining ring (24). Place rubber boot (26) on the stem and wire it in place.

7. Just prior to installation of the valve, place an O-ring (18) in each of the five counterbores in the feet of the valve body.

INSTALLATION. To install the valve, proceed as follows (see Figure 5C-6).

1. Set the valve on the mounting bracket and secure with capscrews and lockwashers.

2. Connect the valve stem to support plates (18 and 30) with pin (29), washers (19) and cotter pin (28).

3. Attach the hydraulic lines to the brake valve.

4. Start the engine and operate the brake pedal. Observe the valve for leaks, binding or other problems.

ADJUSTMENT. After the valve has been installed, check linkage adjustment as follows (see Figure 5C-6):

1. Adjust the brake band linkage as explained in Subsection 7E.

2. Bleed air from the system as described in Subsection 5A.

3. With the pedal in the released position, adjust the spring length to 4-1/8” by turning adjusting nut (01).

NOTE

The 4-1/8” spring length is the recommended setting, however this length can be Increased (for softer pedal) or decreased (for harder pedal). Spring length must never exceed 4-1/4” for load handling.

4. Check brake pedal travel distance. This dimension should be approximately 7.0 inches If the travel exceeds 8.75 inches, check the brake band for proper adjustment and then bleed the brake as described in Subsection 5A.

NOTE

If the pedal “pumps up” or changes position, check that the brake cylinders are retracting fully when the brake pedal is fully released. Also check that the spring length adjusted in step 3 is 4-1/2” or less

5. Install the brake valve cover plates.

PRESSURE REGULATING VALVE (36U258)

DESCRIPTION. This valve is used in conjunction with brake valve (36U259) to apply the front and rear brakes The valve provides power assistance during hard brake pedal applications.

REMOVAL. To remove the valve, proceed as follows (see Figure 5C-6):

1. Perform the steps outined in the topic, General Removal, at the beginning of this section.

2. Remove the covers from over the brake valves.

3. Disconnect the hydraulic line at the back of the valve and the two lines attached to valve block (21).

4. Remove cotter pin (28) and pin (29) securing the brake valve stem to support plates (18 and 30).

5. Remove adjusting nut (01), washer (02), spacer (04) and spring (03) from adjusting rod (05).

6. Pull cotter pins (11), washers (09), and pin (10) from the pedal and support plates. Lift the valve assembly out of the machine.

7. Remove cotter pin (33) from rod (05) and valve (24). Separate valve (24) from valve block (21) by removing capscrews (31) and washers (32).

REPAIR. To repair the valve, proceed as follows (see Figure 5C-8):

1. Using a suitable tool, press in on gland (15) and remove retaining ring (11) from body (01).

2. Remove stem (14), gland (15), spring (09), and spool (08).

3. Remove O-ring (10), seal (12) and wiper (13) from gland (15) and replace with new parts from the seal kit.

4. Turn plug (04) out of body (01), remove O-ring (03) and replace with a new O-ring.

5. Clean and inspect the other parts for damage. Any defect to parts, other than the ones found in the seal kit, will require the replacement of the valve.

6. Lubricate the parts with clean hydraulic oil.

7. Install spool (08) into the body with the grooved end facing orifice plug (04).

8. Place spring guide (07), spring (D6), and new washer (05) into the body of the valve. Then install and tighten orifice plug (04).

9. Assemble spring guide (02), spring (09) and gland (15) on to stem (14) and place in the body. Carefully press gland (15) into the body to prevent damage to the wiper. Install retaining ring (11).

NOTE

The purpose of the wiper is to prevent dirt and water from entering the valve, therefore the lips face outward. The O-ring and seal prevent oil leakage from the valve.

INSTALLATION. To Install the valve, proceed as follows (see Figure 5C-6).

1. Place two new O-rings on valve (24) and attach the valve to valve block (21) with capscrews (31) and lockwashers (32).

2. Attach the valve stem to rod (05) with cotter pin (33).

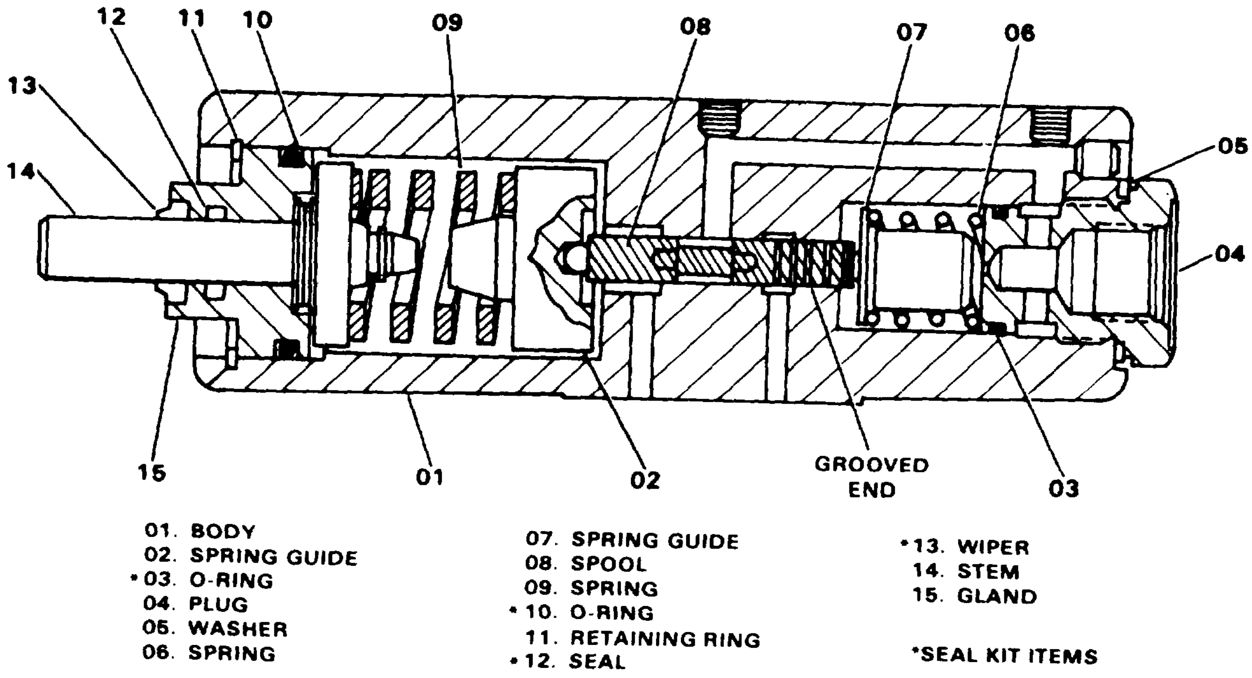


Figure 5C-8. Pressure Regulating Valve (36U258)

3. Place the valve assembly into the mounting bracket and attach support plates (18 and 30) to pedal (16) with pin (10), washers (09), and cotter pins (11).

4. Assemble washers (02), spacer (04), spring (03) and nut (01) to rod (05).

5. Connect the support plates to the brake valve stem with pin (29), washers (19) and cotter pins (28).

6. Attach the hydraulic lines to the valve and valve block.

7. Start the engine and operate the brake pedal. Observe the valve for leakage, binding or other problems.

8. Adjust the linkage as described in the Adjustment topic for brake valve (36U259).

THIRD DRUM CONTROL VALVE (36Q372)

DESCRIPTION. Mounted below the third drum control console are two pressure reducing valves that control the third drum circuit. As the third drum control lever is moved forward or back, hydraulic pressure is metered through these valves to actuate the third drum brake or clutch cylinders.

The third drum control valves are not repairable. If it is determined that the valves are defective or leak excessively, they must be replaced.

REMOVAL. To remove the third drum control valve(s), proceed as follows (see Figure 5C-9):

1. Remove the sheet metal cover directly below the console cover.

2. Perform the GENERAL REMOVAL procedures as found in the beginning of this subsection.

3. Disconnect and tag the hydraulic lines to the valve.

4. Remove the hardware holding the valve in place.

5. Remove the valve.

INSTALLATION AND ADJUSTMENT. To install and adjust the linkage to the third drum control valves, proceed as follows:

1. Attach the valve(s) with the capscrews, lockwashers and nuts.

2. Connect the hydraulic lines to the fittings.

3. Check and adjust the connecting rod to the 2-1/4" and 14" dimension shown in Figure 5C-9.

4. Check and adjust for an air gap between the spherical capscrews and the valve stems. This distance should be ±0.001". Secure the bolt with the jam nut.

5. Connect the battery ground cable and start the engine.

6. Operate the third drum control lever to check for proper operation of the valves. Check the valve stem area and all hydraulic lines for leaks.

7. Install the sheet metal cover over the valves.

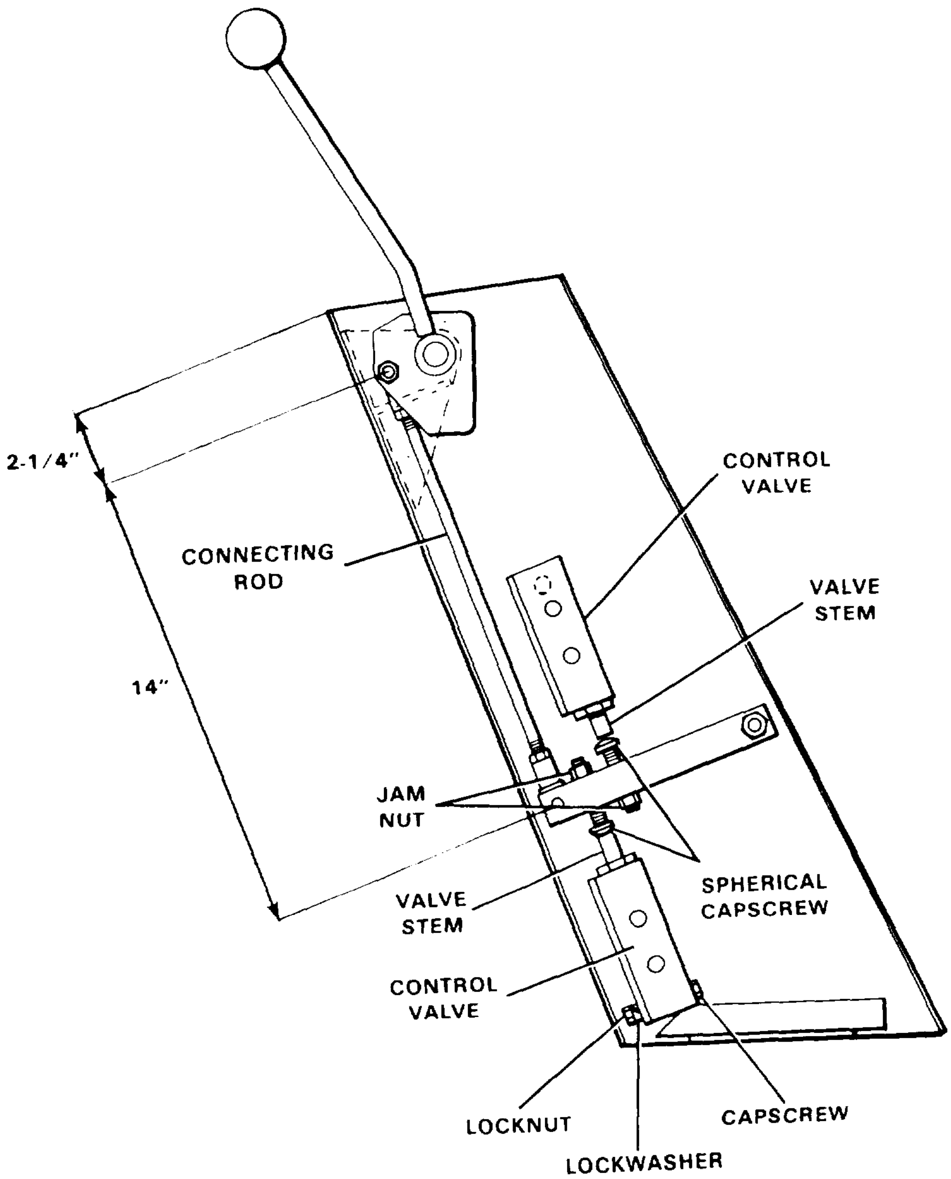


Figure 5C-9. Third Drum Control Valve (36Q372)

SUBSECTION 5D

HYDRAULIC COMPONENTS

GENERAL

This subsection contains the information necessary to repair the hydraulic components other than the control valves.

GENERAL REMOVAL

Prior to removing any of the components in this section shut down the engine and remove the battery ground cable to prevent operation of the machine while the item is being serviced. Operate the controls to relieve all pressure in the system and also clean the area around the item being removed to prevent the entry of contaminants.

COMBINATION CONTROL VALVE (36Q327)

DESCRIPTION. The combination control valve serves two functions (three if the machine is equipped with side frame extension). The primary function is to relieve system pressure and maintain it at a preset maximum. Hydraulic pump flow is diverted back to tank when the pressure setting is reached.

Secondly, it serves as an unloading valve to keep system pressure within preset limits. Pump pressure is used to charge up the accumulator, which acts as a pressure storage reservoir. When a preset upper pressure is reached the unloading valve directs the pump flow back to the reservoir at atmospheric pressure. Each time a hydraulic valve is operated, oil from the accumulator is used and system pressure begins to fall until a preset low limit is reached. At this point, the unloading valve will direct the flow of oil from the pump to the accumulator to recharge the system.

The third function of this valve is to act as a directional control device (diverter) to direct pump pressure to the side frame extension circuit. This is done through an electrically operated solenoid.

REMOVAL. Ordinarily there is no reason to remove this valve as all maintenance may be done by removing and replacing the individual components. If it becomes necessary to remove the valve, proceed as follows (see Figure 50-1):

1. See General Removal at the beginning of the section.

2. Disconnect the hydraulic lines and electrical connection at the valve and position the lines to avoid interference as the valve is removed. Cap the lines to prevent the entry of contaminants.

3. Remove the two capscrews and lockwashers attaching the valve to the hydraulic units panel.

4. The valve can now be removed.

REPAIR AND ADJUSTMENT. The valve may be repaired by replacing the individual components. All the subassembly valves are nonadjustable and non-repairable except the pressure unloading valve.

The relief valve has been adjusted at the factory and should retain its setting over extended periods of time, under normal conditions. The relief valve spring will eventually weaken with machine use, however, so periodic checking of the relief valve setting is recommended.

To check the setting on the relief valve, proceed as follows:

CAUTION

The pressure setting of 3000 psi must not be changed. Any attempt to change the setting will void any and all guarantees, expressed or implied.

1. Operate the machine until the hydraulic oil temperature is a minimum of 70°F. Shut the engine down and reduce hydraulic pressure to zero.

2. Obtain an accurate 0 to 5000 psi pressure gauge.

3. Connect the flexible hoses to the crawler extension and retraction controls.

4. Place the upper-lower diverter switch in the “lower” position.

5. Install a pressure gauge in the pressure gauge port of the tee fitting installed as shown in the insert of Figure 5D-1.

6. Increase engine speed to approximately 1400 rpm at no load.

7. Fully retract one crawler side frame and observe the pressure gauge to determine the point at which the relief valve opens. The relief should open at approximately 3000 psi. The pressure gauge will instantly show a drop of pressure at the point when the relief valve opens.

8. If the relief valve does not function as described in step 7, remove and replace the valve with a new one. Repeat steps 6 and 7 to test the new relief valve for proper operation.

The unloading valve section of the combination control valve is actually made up of two valves: The pressure unloading valve and the priority flow regulator valve. Only the former can be adjusted.

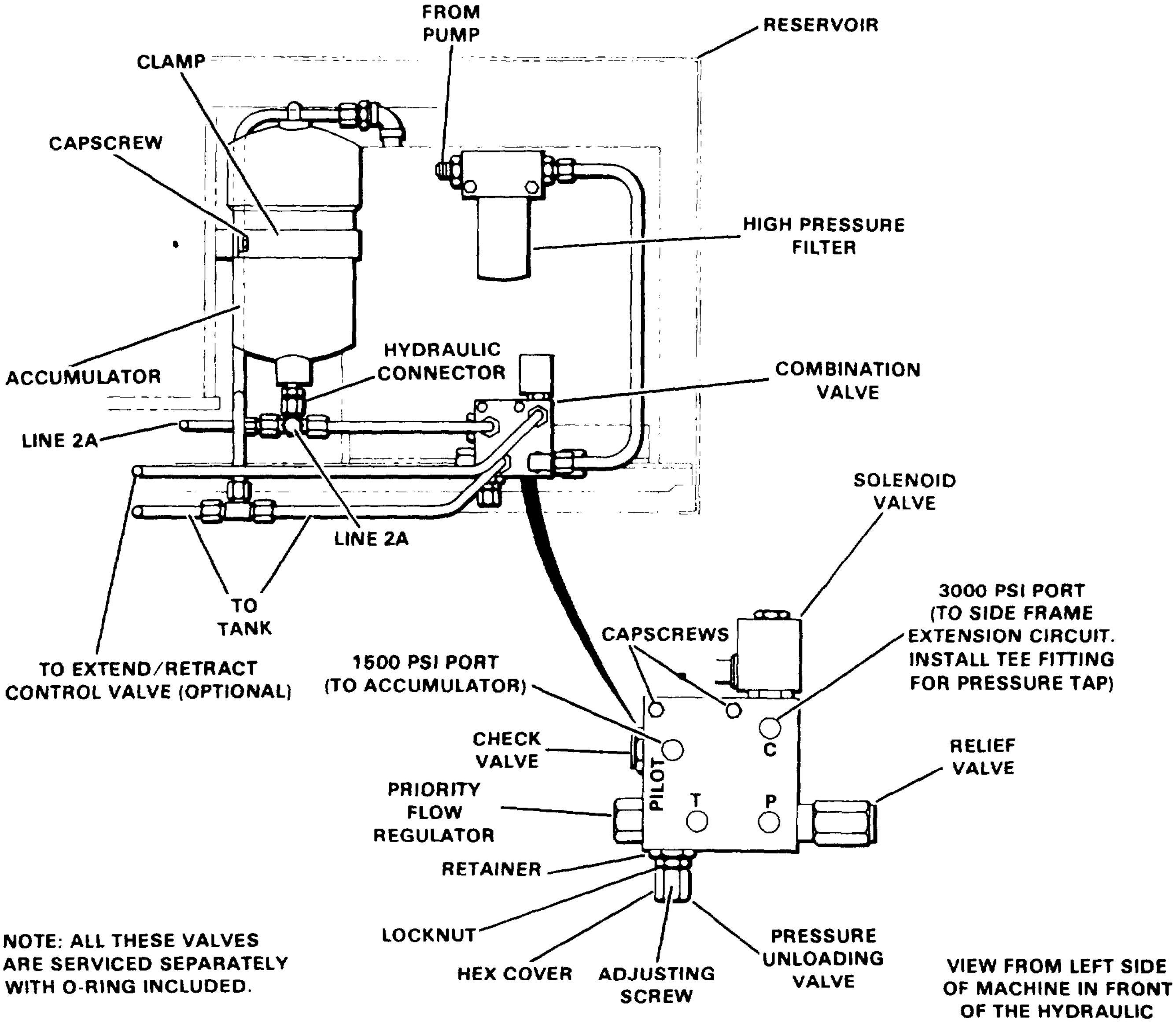


Figure 5D-1. Hydraulic Accumulator and Combination Valve Installation

To adjust the pressure unloading valve, proceed as follows:

1. Repeat steps 1 and 2 from the previous procedure for checking the relief valve.

2. Connect the pressure gauge to the port at line 2A. Plug the line to prevent loss of hydraulic oil.

3. Start the engine and allow the hydraulic pressure to build up to 1400 to 1710 psi.

4. Operate the controls until the pressure drops to 1400 psi. The unloading valve should close at this point and again recharge the system.

5. If the valve does not maintain the pressure as stated in step 4, remove the hex cover and adjust as follows (see Figure 5D-1 insert):

CAUTION

The following steps must be performed carefully or damage to the system components can result. In no case should a pressure adjusting screw be turned rapidly, always make adjustments slowly.

A. Loosen the locknut and turn the adjusting screw to obtain a maximum pressure to 1710 psi.

B. Repeat step 4 above.

C. If difficulty is encountered arriving at these settings, replace the priority flow regulator and repeat steps A and B.

D. Tighten the locknut and replace the hex cover.

INSTALLATION. In the event the valve was removed for bench testing or if a new valve is being installed, proceed as follows:

1. Line up the valve with the two holes on the mounting panel. Install and tighten the two capscrews.

2. Remove all protective caps and connect the hydraulic lines to the proper ports.

3. Connect the electrical adapters to the solenoid valve.

4. Start the engine, check for leaks, and test the valve for proper operation.

ACCUMULATOR (45U47D1)

DESCRIPTION. This is a one gallon, nitrogen charged, bladder type accumulator, which acts as a pressure storage reservoir (see Figure 5D-2). It helps eliminate rapid cycling of the unloading valve to prevent overheating of the oil and it smooths out pressure surges in the system.

Hydraulic oil from the pump is supplied to the accumulator until operating pressure is reached. This hydraulic oil in the accumulator is supplied to the control valves the instant a control valve is operated. When the accumulator is properly charged, the pressure gauge will show a gradual decrease in pressure when the control valves are actuated. When minimum pressure is reached, the pump will again charge the accumulator to operating pressure. The pressure gauge will also show a gradual decrease in pressure when the engine is turned off.

The most important function of the accumulator occurs in the event of malfunction of the pump or the unloading valve portion of the combination valve. If the pump or unloading valve malfunctions, the stored oil in the accumulator will enable the operator to make several clutch or brake engagements, thus allowing him to lower the load to the ground.

MAINTENANCE. This accumulator is considered non-repairable. If the accumulator is faulty, it may be due to loss of precharge pressure or it may be due to a defective bladder or housing. If the housing or bladder is faulty, the complete accumulator must be removed and replaced with a new accumulator.

REMOVAL. To remove the accumulator, proceed as follows (see Figure 5D-1):

1. See General Removal at the beginning of this section.

2. Disconnect the hydraulic line at the accumulator and position the line to avoid interference as the accumulator is removed. Cap the line to prevent the entry of contaminants.

3. Remove the two capscrews and lockwashers attaching the accumulator and clamp to the hydraulic units panel.

4. The accumulator can now be removed.

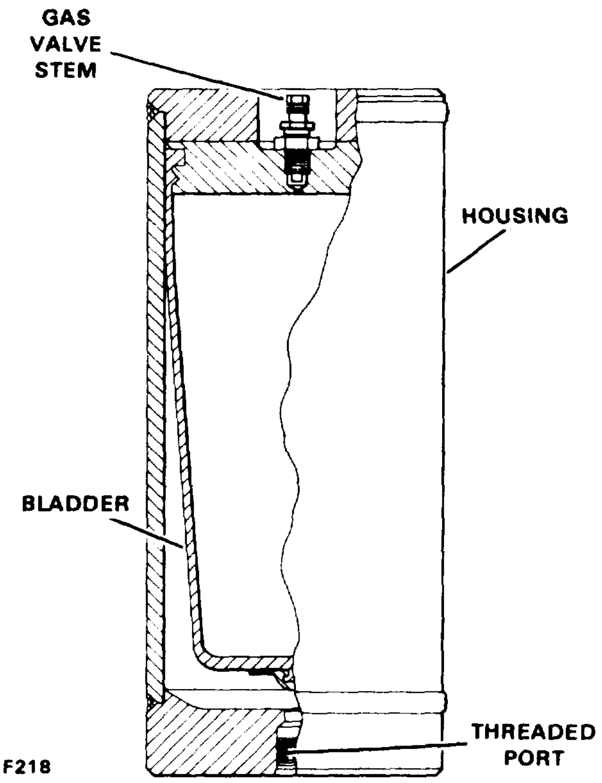


Figure 5D-2. Accumulator (45U47D1)

INSTALLATION. To install the accumulator, proceed as follows (see Figure 5D-1):

1. Line up the clamp and accumulator with the two holes in the hydraulic units panel. Install and fully tighten the two lockwashers and capscrews.

2. Remove the protective cap and connect the hydraulic line to the accumulator.

3. Connect the battery ground cable. Start the engine and observe the accumulator for leaks. Also, see that the accumulator charges to full operating pressure.

PRECHARGING PROCEDURE. There are two conditions under which the accumulator precharge pressure should be checked. *The first is when a new accumulator is installed and the second is when it is found thet the reason for a faulty accumulator is the toss of precharge pressure.* The accumulator is precharged with oil pumped nitrogen, preferably, to 700 +25 psi at room temperature, 70°F. A precharging kit (45Z232) is available from Harnischfeger for performing this operation.

CAUTION

When precharging the accumulator, use water pumped, oil pumped or dry nitrogen only.

Precharge the accumulator with the precharging kit as follows (see Figure 5D-3):

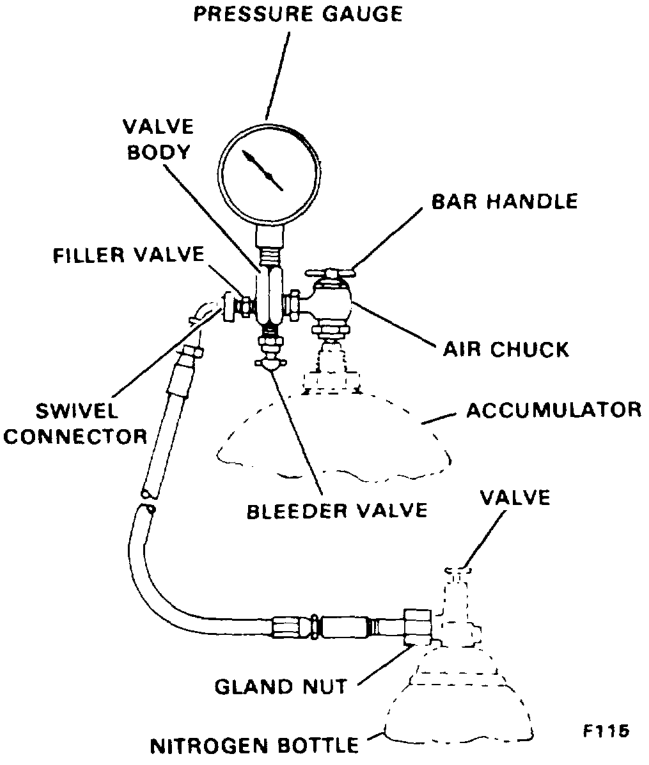


Figure 5D-3. Gauging Head Installation

1. Remove the valve guard and valve cap from the accumulator.

NOTE

To read or adjust the precharge pressure, hydraulic fluid must be completely drained from the fluid side of the accumulator.

2. To mount the gauging head, retract the shaft in the air chuck by turning the bar handle counterclockwise until it stops. Mount the swivel of the air chuck on the accumulator's gas valve stem, compressing the gasket in the swivel to prevent gas leakage. Turn the bar handle clockwise until the shaft depresses the valve core in the gas valve of the accumulator.

3. Mount the gland nut of the hose assembly on the nitrogen bottle.

4. Remove the cap from the filler valve and attach the swivel connector of the hose assembly. Hand tighten sufficiently to compress the gasket in the swivel connector in order to prevent gas leakage.

5. Proceed to inflate the accumulator to 700 + 25 psi by opening the valve on the nitrogen bottle slowly, closing it occasionally to allow the needle of the pressure gauge to settle in position, thus giving an accurate reading of the precharge pressure. When the correct precharge has been reached, close the valve in the nitrogen cylinder securely.

NOTE

Allow the accumulator to rest for about 30 minutes and then check the precharge pressure again. Due to the nitrogen expansion, additional precharging may be necessary to bring the precharge to the desired pressure.

6. The bleeder valve can be used to let out any gas pressure in excess of desired precharge.

7. Retract the shaft of the air chuck by turning the bar handle counterclockwise to the full stop position before disconnecting the swivel, thereby preventing excess leakage of gas from the accumulator. Remove the chuck from the accumulator gas valve stem.

8. The charging and gauging assembly may either be coiled around the nitrogen cylinder or the assembly may be removed from the cylinder and stored.

9. Check the accumulator gas valve assembly for leaks with a soapy water solution or oil. If the valve core is leaking, depress quickly once or twice to reseat the core. It may be necessary to replace the valve core if leakage continues.

10. Replace the accumulator gas valve cap and tighten one-half turn beyond hand tightness.

11. Replace the accumulator valve guard.

12. Check for precharge loss within one week after installation.

SOLENOID VALVE (36Z1349, 36Z1528 & 36Z1423)

DESCRIPTION. Each unit is a 4-way, 2 position, spring offset, solenoid operated valve. These valves are located on a panel directly behind the operator's module and below the upper deck panel. The valves are accessible from underneath.

In the energized position, oil flow is from the pressure port, through the valve and to the cylinder port to allow operation of the brake, clutch or the controls system.

In the de-energized position (spring offset), the pressure port is blocked. Oil flow is from the cylinder port to the exhaust port and then to the reservoir.

A manual plunger is provided at the end of the solenoid coil so the valve can be shifted manually in the event of an electrical malfunction.

One valve mounted on a separate subplate functions the 360° swing lock. This valve controls the 360° swing lock cylinder.

One valve mounted on a separate subplate functions the dapper trip valve. This valve controls the dipper trip drum.

The two valves, mounted on separate subplates, function as the boom hoist interlock and the boom hoist limit Valve. These valves control the boom hoist brakes, clutch and pawls.

There are four valves mounted on one manifold which function as the swing brake lock valve, propel brake valve, left drum brake valve, and right drum brake valve. These valves control the swing brake, the left and right drum brake and clutch, and the propel brakes.

There are also two valves mounted on one manifold which function as left and right drum pawl valves. These valves control the left and right drum pawls.

TROUBLESHOOTING. The table and maintenance hints that follow are of a general nature, but should provide helpful information when combined with the schematic in Subsection 5A.

Table 5D-1 lists the common difficulties experienced with directional valves and systems. It also indicates the probable causes and remedies for each of the troubles listed.

It should always be remembered that many apparent valve failures are actually the failure of other parts of the system. The cause of improper operation is best diagnosed with adequate testing equipment and a thorough understanding of the complete hydraulic system.

SOLENOID REPLACEMENT. It is not necessary to remove the valve to replace the solenoid coil. After determining the solenoid coil is defective, proceed as follows (see Figure 5D-4):

CAUTION

Before breaking an electrical circuit, be sure the power is OFF. To do this, disconnect the battery ground cable.

1. Remove plate (01), gasket (02) and disconnect the wires from the coil to the terminal strip. Make tags to identify the wires for proper assembly.

2. Remove snap ring (29) and pull coil (30) from solenoid (27). Remove the manual plunger and install in the new coil.

NOTE

Attach a piece of wire or cord to the wire ends of coil (30). This will make assembly easier.

3. Attach the wires to the new coil to the cord (wire) and pull the wires into body (05). Push the coil into the solenoid.

4. Install the snap ring and connect the coil wires to the terminal strip.

5. If removed on disassembly, connect wire on gasket (02) to *ground* and install plate (01).

REMOVAL. The removal of any of these valves does not require the disconnection of hydraulic lines. Each valve is held to a subplate or a manifold by four socket head screws. To remove a valve, proceed as follows (see Figure 5D-4):

CAUTION

Before breaking any circuit, be sure all pawl locks are engaged and block or lower any load whose movement could generate pressure.

1. Complete the General Removal instructions at the beginning of this subsection.

2. Remove plate (01), move gasket (02) aside and disconnect the solenoid wiring. Mark or tag the wires to ensure proper assembly. Set aside terminal block (32) and plate and gaskets (33) until installation.

3. Remove the four socket head screws from the wiring cavity inside the valve body. The valve can now be removed from the machine. Be ready to catch the oil that is retained in the lines and the valve.

4. Cap all the system openings to prevent the entrance of contaminants.

DISASSEMBLY. To disassemble the valve, proceed as follows (see Figure 5D-4):

1. Loosen screws (28) and remove solenoid (27) from the valve.

2. Loosen screws (06) and remove cover (07) from the other end of the valve body.

3. Remove snap ring (09) then remove guide (11), O-rings (10 and 12), limiters (13 and 15) and spring (14). Apply force to push pin (16) as this will aid in removing guide (11) from the valve body.

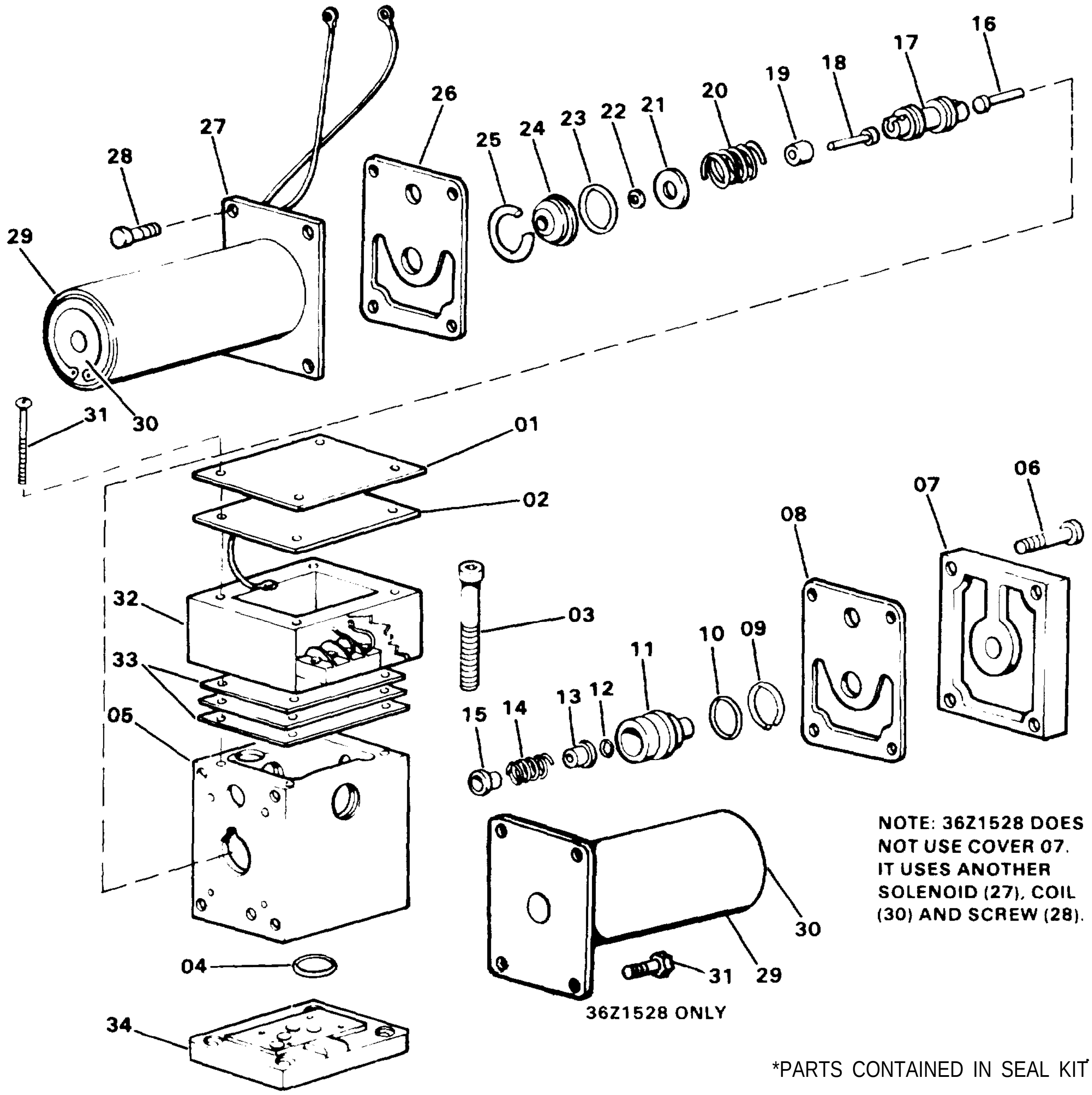
4. Remove snap ring (25), now remove guide (24), O-rings (22 and 23) and washer (21).

NOTE

Discard and replace all O-rings and gaskets removed in disassembly except gasket (02) unless it is damaged. Refer to the Parts Manual for the applicable seal kit number.

Table 5D-1. Troubleshooting Chart

TROUBLE	PROBABLE CAUSE	REMEDY
Valve spool fails to move.	Dirt in system.	Disassemble, clean and flush.
	Solenoids inoperative.	Check electrical source and solenoids.
	Improper assembly after overhaul.	See Figure 5D-4 to check proper assembly of unit.
	Improper installation connection.	Check installation.
Valve produces undesirable response in work unit.	Improper assembly of valve or improper installation connections.	Check Figure 5D-4 for assembly and the schematic diagram in Subsection 5A for installation.



*PARTS CONTAINED IN SEAL KIT

01. PLATE
02. GASKET
03. SCREWS
* 04. O-RINGS
05. BODY
06. SCREW
07. COVER
* 08. GASKET
09. SNAP RING
* 10. O-RING
11. GUIDE
* 12. O-RING
13. LIMITER
14. SPRING
15. LIMITER
16. PUSH PIN
17. SPOOL
18. PUSH PIN
19. SPACER
20. SPRING
21. WASHER
* 22. O-RING
* 23. O-RING
24. GUIDE
25. SNAP RING
* 26. GASKET
27. SOLENOID
28. SCREW
29. SNAP RING
30. COIL
31. SCREWS
32. TERMINAL BLOCK
33. PLATE AND GASKETS
34. SUB PLATE AND/OR MANIFOLD (NOT SHOWN)

Figure 5D-4. Solenoid Valves (3621349, 36Z1528 and 36Z1423)

5. Remove spring (20) and spacer (19).

6. Slide spool (17) from the valve body with push pins (16 and 18). Remove the push pins from the spool, then mark the spool as noted below.

NOTE

Certain spool types are not symmetrical. To provide correct assembly, it is recommended that the spool and body be marked with a metal scribe. The spool should be marked on the minor diameter, not across the sealing lands.

CLEANING. The importance of cleaning the valve and all its parts can not be overemphasized. All parts must be thoroughly cleaned and kept clean during inspection and assembly. The close tolerance of the valve body and spool makes this requirement more stringent than usual. Clean all removed parts, using commercial solvent that is compatible with the system fluid. Compressed air may be used in cleaning the valve, but it must be filtered to remove water and contamination. Clean compressed air is particularly useful in cleaning the spool orifices and body passages.

INSPECTION AND REPAIR. Inspect, repair, and replace the valve and all its parts as follows:

1. Visually inspect the internal bore of valve body (05) for scratches or erosion across the spool land sealing areas. If scratches or erosion are found, replace the complete valve.

CAUTION

Do not stone the edges of the sealing lands on the valve spool. Rather, use a 500 grit abrasive paper to remove any burrs found on the spool. Use the paper very lightly on the outer diameter of the spool only.

2. Inspect the spool for burrs or small scratches. If any are found, remove them with 500 grit abrasive paper. Then insert the spool into the bore, rotate it while moving it back and forth to check for binding. If any binding or side movement exists, the spool must be replaced.

3. If a new spool (17) is required, use a very fine grit stone to break the feathered edges of the balancing grooves. Use 500 grit paper to lightly polish the outside diameter of the spool.

4. Inspect all the other parts for wear or damage and replace as necessary.

5. Check the grooves where any seals are placed; grooves and detents should be free of any rough edges to prevent damage to the new seals on assembly.

6. Perform a continuity check on the solenoid coil. The coil should have a resistance value of 24 ohms.

ASSEMBLY. To assemble the valve, proceed as follows:

1. Lubricate all the parts and O-rings with clean hydraulic oil to aid in assembly and provide initial lubrication.

2. The assembly of the valve is basically the reverse of the disassembly procedure. The following items require special attention:

A. Check the special marks on the spool and valve bore to ensure correct assembly.

B. Insert the heads of push pins (16 and 18) into the spool before installing the spool into the valve body.

C. Check for secure installation of snap rings (09 and 25).

D. Complete the wiring connection of the solenoid at installation.

INSTALLATION. To install the solenoid valve, proceed as follows:

1. Place O-rings (04) in the ports at the bottom of the valve body if not already done. Now set the valve on the subplate or manifold in its correct position and secure with the four socket head screws.

2. Install the terminal block and gaskets (33) in position and complete the wiring of the solenoid. Then attach the ground wire of gasket (02) and install plate (01) and fasten with the screws (31).

3. Bleed the system of air as described in Subsection 5A.

4. Connect the battery cable, start the engine, and check for leaks. If none, test the valve for proper operation.

SHUTTLE VALVE (36Z1171)

DESCRIPTION. Shuttle valves are used in several places in the system to direct the flow of hydraulic fluid into a common line from either of two other lines. When pressurized oil is available at either of the side ports, the floating piston (shuttle) moves to the opposite side of the valve to close the opposite side port. Oil is allowed to flow out the top port to a common line.

REPAIRS. The shuttle valve is considered non-repairable. If the valve is faulty, the complete valve should be removed and replaced with a new valve.

REMOVAL. To remove the valve, proceed as follows.

1. See General Removal at the beginning of this section.

2. Disconnect the hydraulic lines at the valve and position the lines to avoid interference as the valve is removed. Cap the lanes to prevent the entry of contaminants.

3. Remove the two capscrews which secure the valve. The valve can now be removed.

INSTALLATION. To Install the valve, proceed as follows.

1. Position the valve and install the two capscrews. Fully tighten the capscrews to secure the valve.

2. Remove the protective caps and connect the hydraulic lines to the valve.

3. Connect the battery cable. Start the engine and operate the controls. Observe the valve for leaks, binding or other defects.

SWIVELS (44Z2058)

DESCRIPTION. Swivels are provided at the input end of the hydraulic lines to clutches and brakes wherever required. A swivel is also provided on the rotary joint for the propel brake. The swivel allows hydraulic fluid to flow into a rotating member to apply a clutch or brake.

REPAIRS. The swivel is considered non-repairable. If the swivel is faulty the complete swivel should be removed and replaced.

REMOVAL. To remove the swivel, proceed as follows:

1. See General Removal at the beginning of this section.

2. Disconnect the hydraulic line at the swivel and position the line to avoid interference as the swivel is removed. Cap the line to prevent the entry of contaminants.

3. Remove the swivel by backing it out of the shaft.

INSTALLATION. To install the swivel, proceed as follows:

1. Install the O-ring on the swivel. Thread and tighten the swivel into the shaft.

2 Remove the protective cap and connect the hydraulic line to the swivel.

3. Connect the battery cable. Start the engine and operate the controls. Observe the swivel for leaks or other defects.

BRAKE, CLUTCH, AND PAWL CYLINDERS (38U34, 38U39, 38U45, 38U104 & 38U112)

REMOVAL. To remove the actuating cylinder, proceed as follows:

1. See General Removal at the beginning of this section.

2. Disconnect the hydraulic line to the cylinder. Cap the line and install a dust cap in the cylinder to prevent the entry of contaminants.

3. Relieve any tension on the brake, clutch or pawl operating mechanism springs. Remove the linkage from the yoke or eyebolt end of the cylinder.

NOTE

See the particular brake, clutch or pawl instructions on how to relieve spring tension in the operating mechanism and how to remove the linkage from the yoke or eyebolt.

4. Remove the capscrew and lockwasher securing the cylinder to the operating mechanism.

DISASSEMBLY. Use the following procedure to disassemble the cylinder (see Figure 5D-5):

1. Remove the piston and spring from the cylinder body.

2. Remove the seals, back-up rings, and the O-ring from the cylinder body. Note the position of the seals when removing them.

INSPECTION AND REPAIRS. Inspect the piston and cylinder bore for excessive wear, nicks or scratches. If either of these parts are damaged, the entire cylinder must be repaired.

NOTE

A service kit is available. See the Replacement Parts Manual.

ASSEMBLY. To assemble the cylinder, proceed as follows (see Figure 5D-5):

1. Generously coat all parts to be assembled with hydraulic oil.

2. Install the inner seal, larger diameter back-up ring, O-ring, small diameter back-up ring, and outer seal.

NOTE

Cylinders (38U34 & 38U104) have a metal and rubber outer seal. Cylinders (38U39, 38U45 and 38U112) have a rubber outer seal.

3. Install the spring and piston in the cylinder body.

INSTALLATION. To install the actuating cylinder, proceed as follows:

1. Secure the cylinder to the operating mechanism with the lockwasher and capscrew.

2. Attach the linkage to the yoke or eyebolt end of the cylinder.

3. Remove the dust cap from the cylinder and remove the cap from the hydraulic line. Connect the hydraulic line to the cylinder.

4. Bleed the hydraulic cylinder to remove any air trapped in the hydraulic line. See Bleeding Procedure in this section to bleed the cylinder.

5. Connect the battery cable. Start the engine and operate the controls. Observe the cylinder for leaks, binding or other defects.

CRAWLER EXTENSION/RETRACTION CYLINDER (38U113)

DESCRIPTION. This cylinder is a double acting hydraulic device for extending and retracting the crawler side frame. It has a 4 inch bore, 27 inch stroke and extends to a total length of 67 inches. Although this cylinder gets moderate use, it may in time develope leaks or function erratically calling for special maintenance to be done. A special seal kit is available and must be installed if the cylinder is overhauled.

REMOVAL. To remove the crawler extension cylinder, proceed as follows:

1. Perform the GENERAL REMOVAL procedures, as they apply to this function, found in the beginning of this subsection.

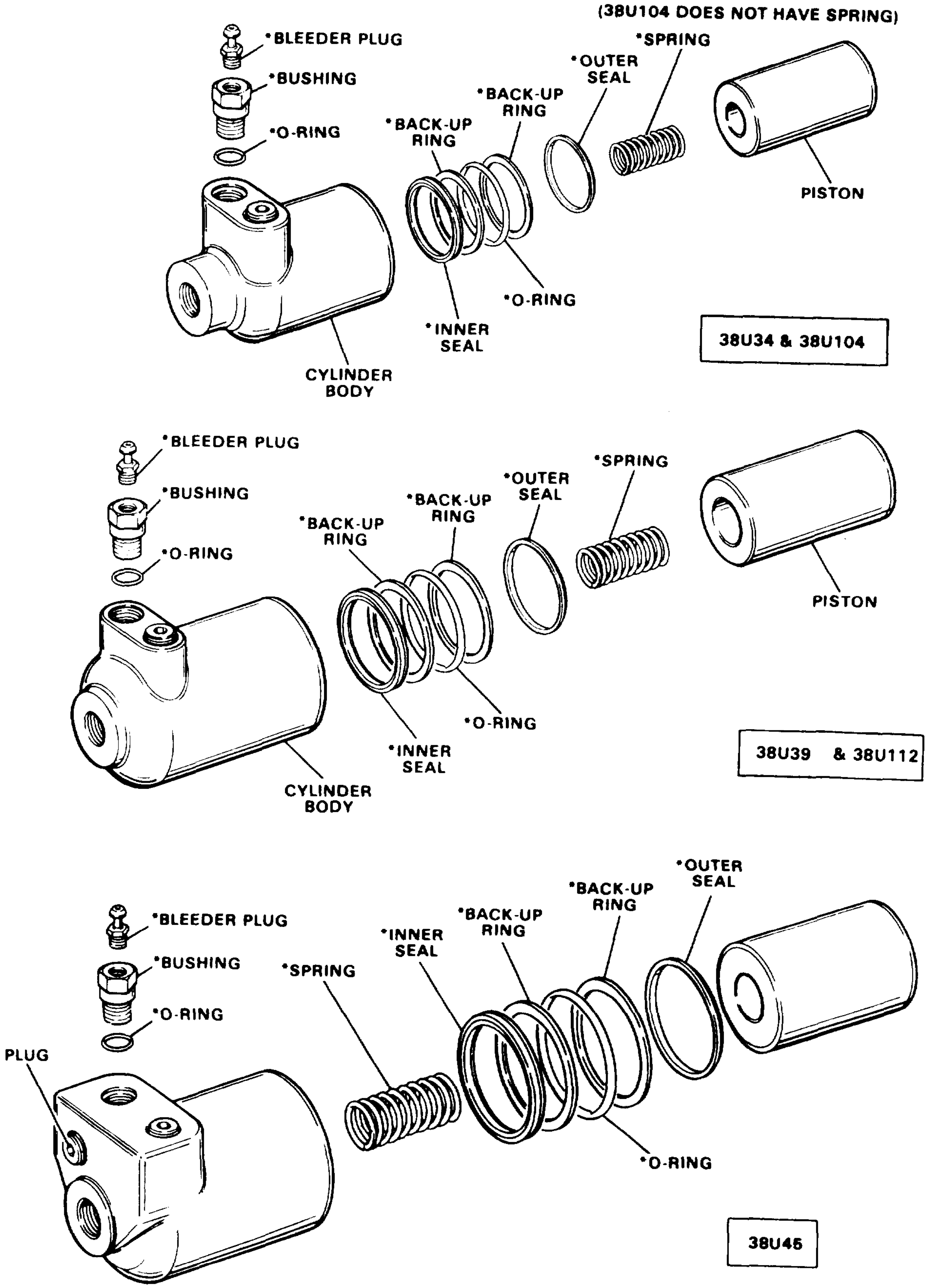
2. Remove hydraulic lines at quick disconnect and pull the pins at either end of the cylinder. Connect the quick disconnects to keep them clean.

3. Move the cylinder to a clean, dust free work area for disassembly.

DISASSEMBLY. To disassemble the cylinder, proceed as follows (see Figure 5D-6):

1. Remove the two capscrews holding head gland (06) against lock wire (03).

2. Push the head gland into the body approximately 1 inch and remove the lock wire from the groove.



*SERVICE KIT ITEMS

Figure 5D-5. Actuating Cylinders

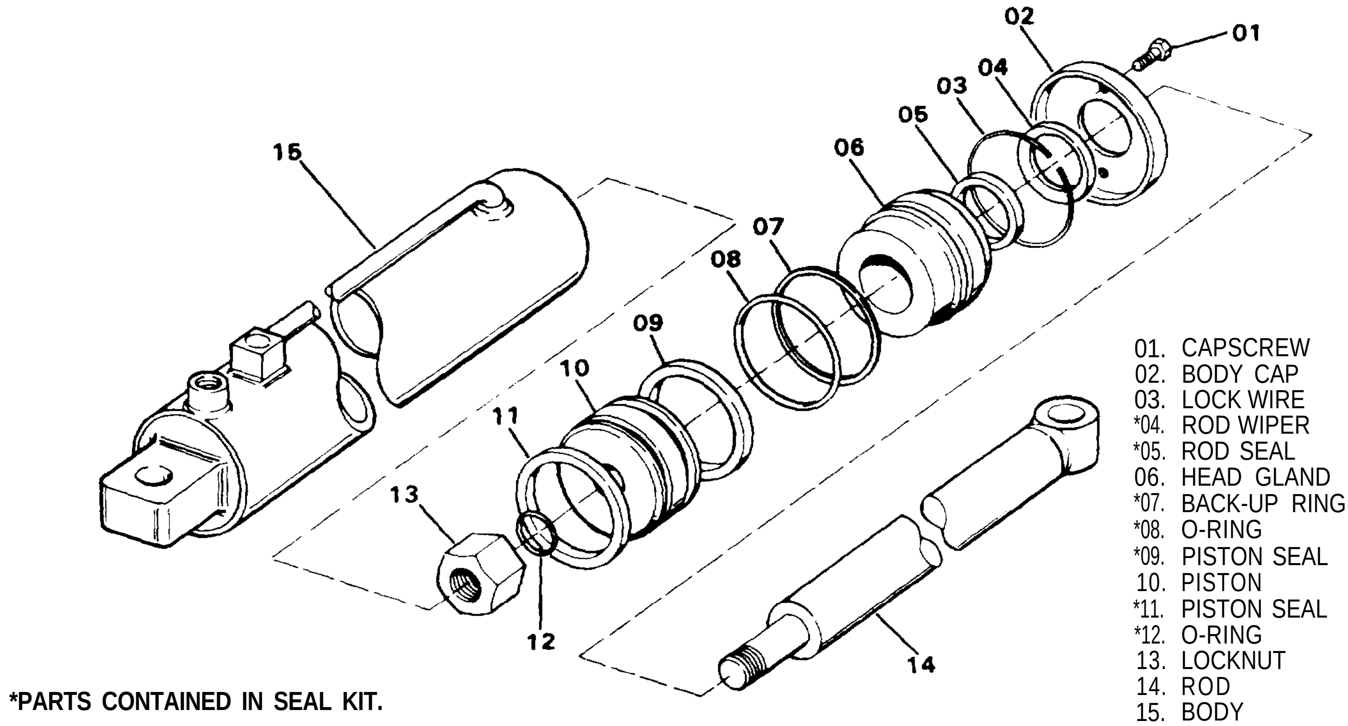


Figure 5D-6. Crawler Extension Cylinder (38U113)

3. Pull the complete rod, head gland and piston from the body of the cylinde.

4. Remove locknut (13) from rod (14) and slide off piston (10) and head gland (06).

5. Remove all the seals from piston (10) and head gland (06) and discard.

INSPECTION AND REPAIR Clean all the parts with a suitable solvent and inspect the rod, piston, head gland and cylinder bore for excessive wear, nicks, or scratches. If any of these parts are damaged, the part(s) may be replaced as indicated in the Parts Manual.

ASSEMBLY. To assemble the cylinder, proceed as follows (see Figure 5D-6):

1. Coat all parts with clean hydraulic oil.

2. Install O-ring (08) and back-up ring (07) in the groove of head gland (06). The back-up ring is located nearest lock ring (03).

3. Place rod seal (05) into the inside head gland groove with the lips of the seal facing O-ring (08) groove.

4. Seal (04) is placed in the outside groove of the grooves of piston (10) with the lips facing the rod end of the cylinder.

5. Assemble piston seals (09 and 11) into the grooves of piston (10) with the lips of both seals facing the outside of the piston.

6. Slide body cap (02), lock wire (03) and head gland (06) onto rod (14).

7. Install O-ring (12) in the groove of rod (14) and insert piston (10) to the shoulder of the rod. Then, tighten locknut (13) securely.

8. Carefully insert the assembled unit into the bore of the cylinder. Compress the seals as necessary to prevent them from being damaged.

9. Push the head gland into the bore and install the lock wire.

10. Pull out on the rod to move the head gland into position, then install the capscrews and tighten securely.

INSTALLATION. To Install the crawler extension cylinder, proceed as follows:

1. Place the head end of the cylinder in the bracket on the carbody and insert the pin. Mount the rod end on a support to provide free movement in and out.

2. Connect the hydraulic line for extending the cylinder first.

NOTE

The extend port is the one nearest the head end of the cylinder.

3. Connect the battery ground and start the engine. Gradually operate the control valve to fill the head end of the cylinder with hydraulic oil.

4. With the rod fully extended, connect the other hydraulic line and operate the control valve to fully retract the rod. Cycle the cylinder several times to remove any air trapped.

5. Swing the cylinder to either of the side frame brackets and install the pin.

6. Repeat steps 1 through 5 for the other cylinder.

7. Check the hydraulic reservoir level and add oil to bring it to the proper level in the glass.

SWIVEL (45Z453)

DESCRIPTION. Thus swivel is the means by which hydraulic oil is delivered from the upper of the machine to the lower. With the swivel it is possible to rotate the upper a full 360 degrees without interfering with pipe or hose connections.

The swivel consists of a swivel body which engages with the pivot bracket on the bottom of the revolving frame and a spool which is fixed to the carbody. All of the hydraulic lines from the upper, required for the propel circuits, are connected to the swivel body. The ports of the swivel body are connected to the corresponding parts of the spool. Hydraulic lines connected to the bottom of the spool direct oil to the propel motors and brakes.

REMOVAL. If leakage between the swivel body and the spool is detected, the swivel must be removed from the machine for repair. To remove the swivel for seal replacement or other maintenance, proceed as follows (see Figure 5D-7):

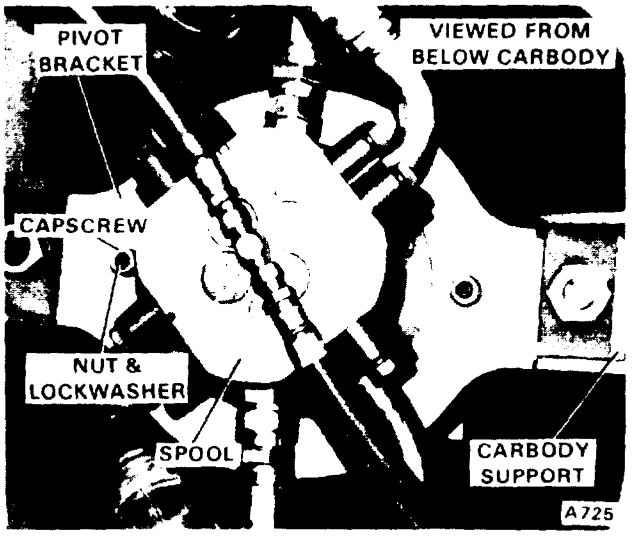


Figure 5D-7. Swivel Removal

1. Swing the upper so that the attachment is over the front of the lower, lower the boom, set the swing brake, and stop the engine. Disconnect the battery ground cable.

2. Tag and disconnect all the hydraulic lanes attached to the spool. The spool is numbered to correspond with numbers stamped on the swivel body. Cap the lines to prevent the entry of contaminants.

NOTE

Access to the spool and swivel body can be gained from below the carbody.

3. Tag and disconnect all the hydraulic lanes attached to the swivel body.

4. Using a suitable lacking arrangement support the swivel spool from below. Remove the two attaching capscrews, lockwashers, and nuts securing the swivel support to the carbody.

5. Swing the pivot bracket 90 degrees and slowly lower the swivel out of the carbody. Set the swivel aside for disassembly.

DISASSEMBLY. Disassemble the swivel as follows (See Figure 5D-8):

1. Remove the capscrews securing the retainer to the spool. Remove the retainer and O-ring.

2. Slide the spool out of the swivel body. Remove the bearings, slipper seals, and O-rings from the spool. Discard the seals and O-rings.

INSPECTION AND REPAIR. After the swivel has been disassembled, proceed as follows:

1. Thoroughly wash the swivel body and spool with a suitable cleaning solvent or diesel fuel.

2. Inspect all parts for wear or damage. Carefully inspect the swivel body and spool for excessive scoring or deep scratches. Replace worn or damaged parts.

NOTE

Excessive scoring or deep scratches are usually caused by foreign material in the hydraulic system. If these defects are found, the hydraulic system should be checked for foreign material.

ASSEMBLY. To assemble the swivel, proceed as follows (see Figure 5D-8):

1. Generously lubricate the swivel body, spool, and all O-rings and seals with clean hydraulic oil.

2. Install the lower O-ring and bearing.

3. Starting at one end of the spool carefully install the O-ring in the first groove in the swivel stem. Carefully install the slipper seal over the O-ring. Knead the slipper seal by hand to squeeze it into the O-ring groove.

4. Repeat step 3-above until a new O-ring and slipper seal have been installed in each O-ring groove of the spool.

5. Place the swivel body in a vertical position with the bottom of the body facing up. Insert the top of the spool into the bore of the swivel body, and while the spool is being lowered into the body compress the slaiper seals by hand as they enter the body.

6. When the spool is installed, install the upper bearing. Install the upper O-ring on the retainer and set the retainer on the spool. Fasten the retainer with the capscrews.

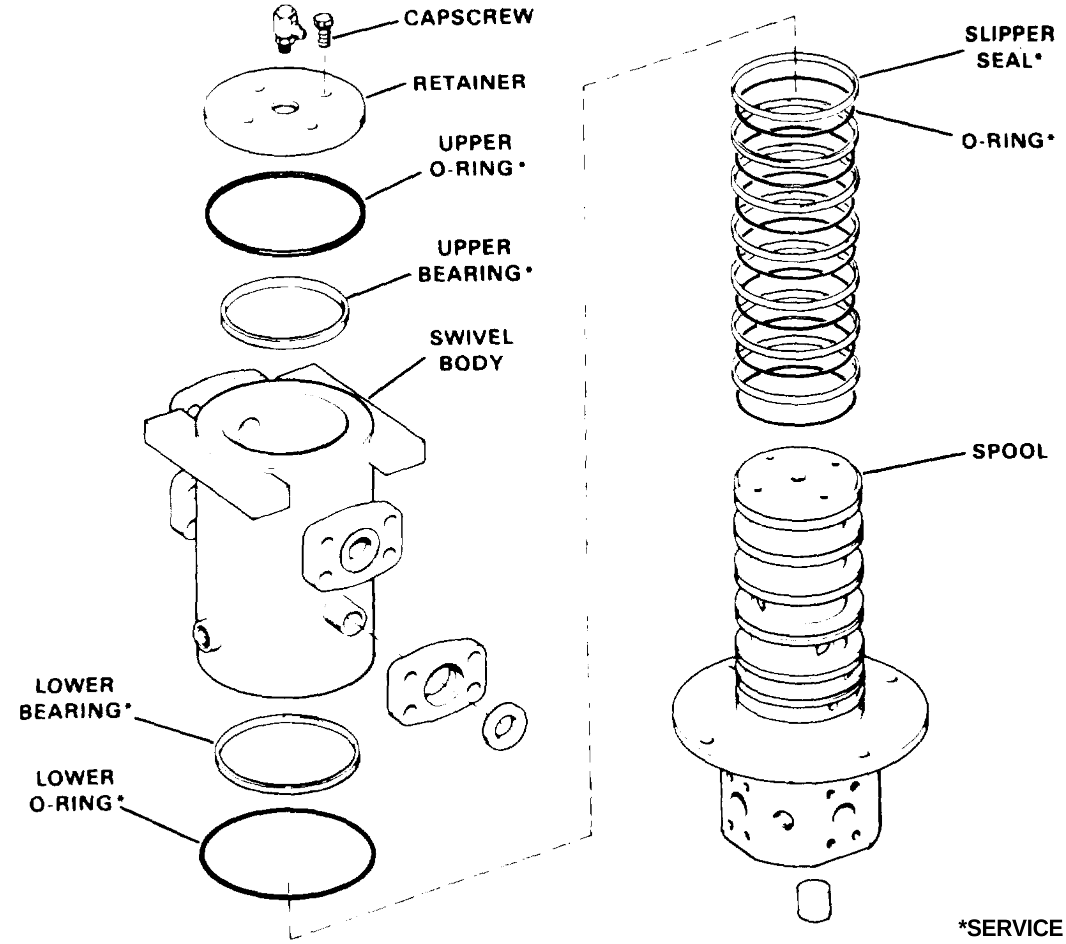


Figure 5D-8. Swivel (45Z453)

INSTALLATION. To install a new or repaired swivel, proceed as follows (see Figure 5D-7):

1. Position the swivel support such that it will fit through the opening of the carbody and slowly lift or jack the swivel up until the pivot bracket can be turned and rested on the carbody support.

2. When the swivel is in position, install the capscrews, lockwashers, and nuts. Tighten securely.

NOTE

Position the swivel so that the numbers stamped on the body and spool face the respective hoses tagged earlier.

3. Reconnect the hydraulic lines from the upper to the appropriate ports in the swivel body.

4. Reconnect the hydraulic lines from the lower to the appropriate ports on the spool.

5. Connect the battery ground cable. Start the engine and check for leaks while operating the propel functions. Add clean hydraulic oil, as necessary, to the hydraulic propel and/or controls reservoirs.

DRUM PAWL CYLINDER (38Q123)

DESCRIPTION. The drum pawl cylinder releases the drum pawl from the left or right drums. When hydraulic pressure is applied to the cylinder the pawl is released from drum.

REPAIRS. The drum pawl cylinder is a non-repairable item. If the cylinder leaks or has not been operating properly, replace it.

REPLACEMENT. To replace cylinder, see Subsection 7E.

SWING LOCK CYLINDER (36Z434)

DESCRIPTION. The swing lock cylinder engages and disengages the 360° swing lock. Hydraulic pressure engages and disengages the stop block into the slewing ring bull gear.

REPAIRS. The swing lock cylinder is a non-repairable item. If the cylinder leaks or has not been operating properly, replace it.

REPLACEMENT. To replace the swing lock cylinder, proceed as follows (see Figure 5D-9):

1. Shutdown the engine and make sure all hydraulic pressure is released from the system.

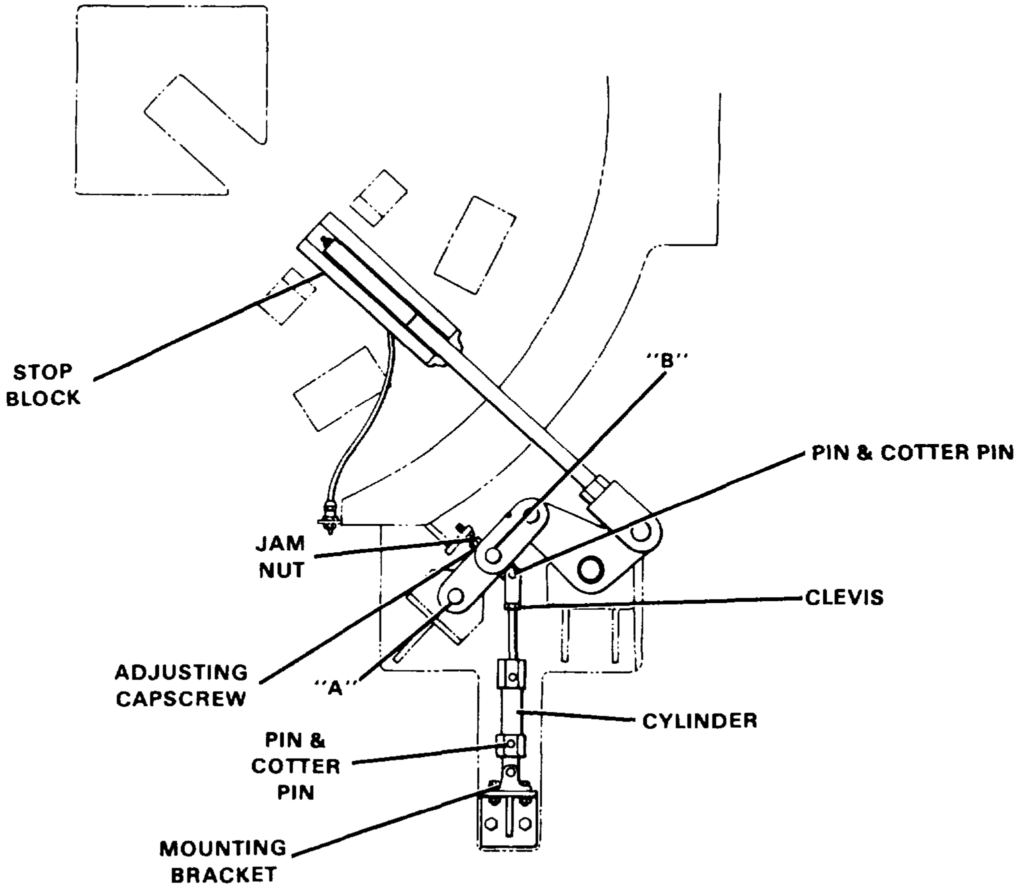


Figure 5D-9. Swing Lock Cylinder (36Z434)

2. Tag the hydraulic lines at the cylinder. Remove the lines and plug them to prevent the entry of dirt.

3. At each end of the cylinder, remove the cotter pin and pin from the clevis and mounting bracket.

4. Remove the cylinder. If the cylinder is to be replaced by a new one, note the positioning of the clevis threaded on the cylinder rod. Loosen jam nut and remove clevis and jam nut. Transfer clevis and jam nut to new cylinder. Install clevis as noted on old cylinder. Tighten jam nut.

5. Set cylinder up to link and mounting bracket. Install pins and cotter pins.

6. Install and tighten hydraulic lines.

7. Operate cylinder to make sure it is operating correctly.

8. With the stop block fully engaged in the slewing ring gear, pins "A", "B" and "C" are to be inline. Adjust using jam nut and adjusting capscrew. Tighten jam nut after adjusting.

SECTION VI

SWING SYSTEM AND COMPONENTS

SUBSECTION PAGE

SUBSECTION 6A

SWING SYSTEM

GENERAL

This section describes the components required to transmit swing torque from the horizontal swing shafts to the swing gear.

The swing system consists of the horizontal swing shafts, swing clutches, intermediate swing shaft, vertical swing shaft and slewing ring as shown in Figure 6A-1.

DESCRIPTION

The swing system is powered by the upper engine through the chain driven horizontal swing shafts. The horizontal swing shaft sprocket hubs and clutch housings turn continuously while the engine is running and the torque converter is engaged. However, the operator must engage either the left or right swing clutch to swing the upper.

When a swing clutch is engaged a horizontal swing shaft bevel gear transmits torque to the vertical swing shaft. The pinion on the vertical swing shaft meshes with the swing gear, which rotates the upper.

The swing brake is a hydraulically released-spring set device. When the control switch is in the OFF position, hydraulic pressure causes the cylinder to release the brake. The upper is now free to swing. When the control switch is in the ON position, hydraulic pressure is diverted back to tank and the springs set the brake.

A 360° swing lock is provided to secure the upper in any position in relation to the lower. The stop block engages the slewing ring bull gear and is hydraulically actuated.

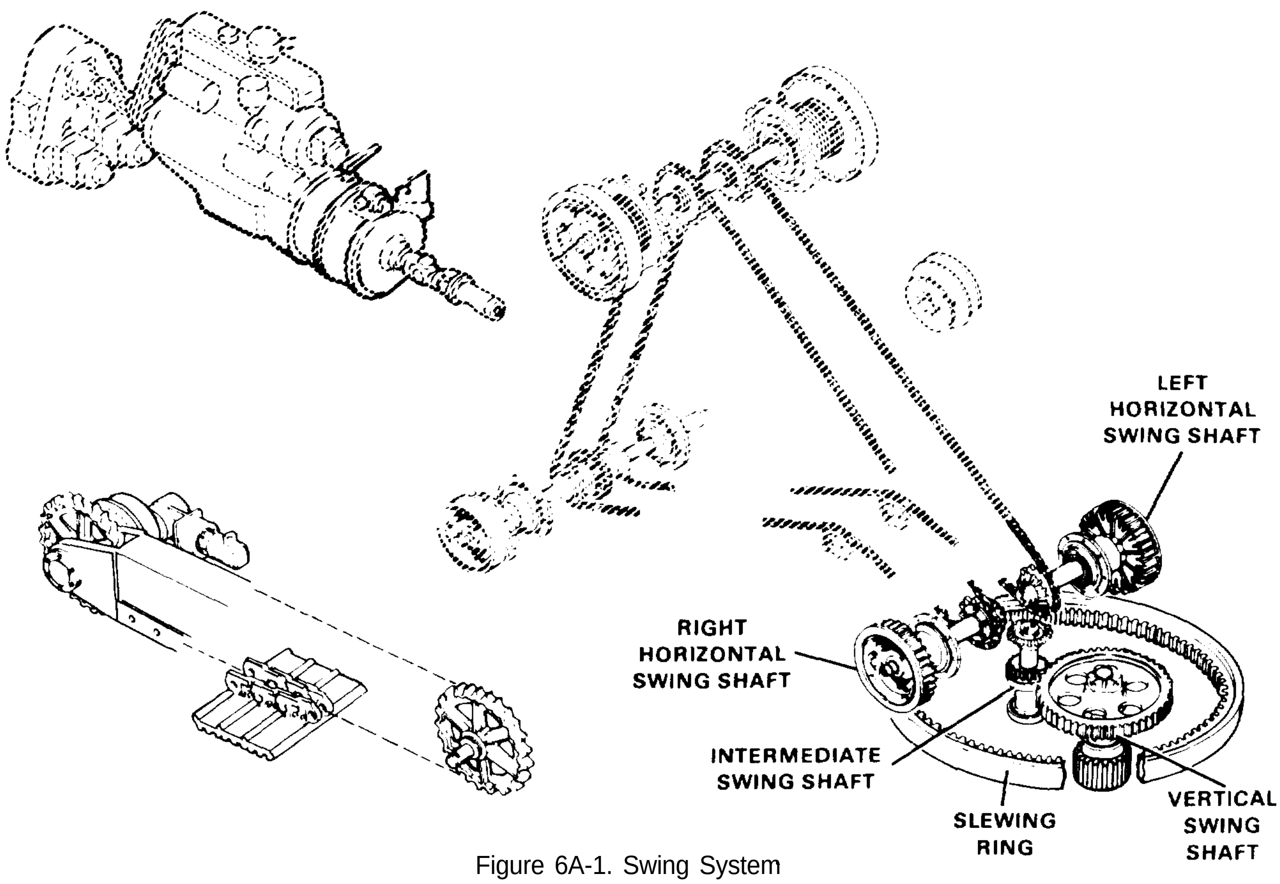


Figure 6A-1. Swing System

SUBSECTION 6B

HORIZONTAL SWING SHAFTS

GENERAL

This subsection contains the information necessary to remove, disassemble, assemble and install the horizontal swing shafts.

HORIZONTAL SWING SHAFT (2910J30-6)

GENERAL. The left and right horizontal swing shafts are mounted in the side wall of the chain case. The bevel on the horizontal swing shafts are in constant contact with the bevel gear of the intermediate swing shaft.

REMOVAL. To remove either horizontal swing shaft, proceed as follows (see Figure 6B-3):

1. Remove the swing clutch assembly from the swing shaft. See the topic, Removal, in Subsection 6F.
2. Remove the chain case cover, loosen the drive chains, and lift the chain off the sprocket of the shaft assembly to be removed (see Subsection 4E).
3. Support hub (20) and remove nuts (18) and lockwashers (19). Remove the horizontal shaft assembly from the machine and place it on a clean bench. This assembly weighs approximately 420 Ibs.

DISASSEMBLY. To disassemble either horizontal swing shaft assembly, proceed as follows (see Figure 6B-1):

1. Remove washer (03) and pinion (04) from shaft (05).
2. With sprocket (22) on blocking, press shaft (05) out of the assembly from the clutch end. Bearing (23) will come out with the shaft.
3. Remove spacer (30), O-ring (29) and oil seal (28).
4. Pull bearing (27) from drum (24) Ring (26) may now be removed.
5. Remove drum (24), seal (17) and shims (14, 15 and 16).
6. Block housing (20) and press sprocket (22) out of the housing, pressing on the end of the sprocket hub which is tapped for capscrews (25). The cone of bearing (21) will come out with the sprocket.
7. Remove all remaining items from the housing and sprocket hub.

INSPECTION AND REPAIR. Prior to assembly, all swing clutch parts should be inspected as follows:

1. Replace all oil seals and O-rings. Any bearing which shows signs of wear or damage should be replaced.
2. Inspect pinion (04) and sprocket (22) for excessive wear or damage. If they are scored, pitted, ridged or worn they should be replaced.
3. Grease all seals and O-rings prior to installation.

ASSEMBLY. To assemble the horizontal swing shaft, proceed as follows (see Figure 6B-3):

1. Press seal (10) into housing (20).

NOTE

All seals in this assembly should be installed with the sealing lip and spring facing inward, toward the chain case.

2. Heat the cone of bearing (21) and install it on the hub of sprocket (22). Install the outer cup of the bearing in housing (20).
3. Install the outer cup of bearing (13) into housing (20).
4. Place sprocket (22) on end, with the sprocket end down. Carefully place housing (20) over the sprocket hub. Pack the area between seal (10) and bearing (13) with multipurpose grease.
5. Install the inner cone of bearing (13) over the hub of sprocket (22).
6. Assemble drum (24) on the hub of sprocket (22) with three capscrews (25). Do not install shims (14, 15 and 16) at this time. Tighten the capscrews to 20 to 25 ft-lbs.
7. Hold housing (20) stationary and check the end play at the sprocket with a dial indicator. After noting the end play, remove the drum and install sufficient shams (14, 15 and 16) to provide from 0.003 to 0.005 inch end play.
8. Press seal (17) into the bore of the clutch housing.
9. Reinstall the clutch drum with the measured amount of shims (14, 15 and 16) in place. Tighten capscrews (25) to 120 ft-lbs (dry).
10. Install ring (26) with the hole in the ring aligned with grease fitting (12). If the ring is incorrectly installed, bearing (27) may not receive adequate lubrication.
11. Press bearing (27) firmly against ring (26).
12. If bearing (23) was removed from shaft (05), heat and replace it at this time.

13. Slide shaft (05) and bearing (23) into sprocket and hub (22). Be sure bearing (23) fits firmly against the shoulder in the sprocket.

14. Install pinion (04), washer (03), capscrews (02) and lockwire (01) on shaft (05).

15. Press seal (28) into drum (24). Be sure the seal seating surface on spacer (30) is clean and free from nicks and burrs, since minor shaft imperfections can wear seal lips rapidly.

16. Install O-ring (29) in spacer (30) and slide the spacer into position on shaft (05), being careful to avoid damage to seal (28).

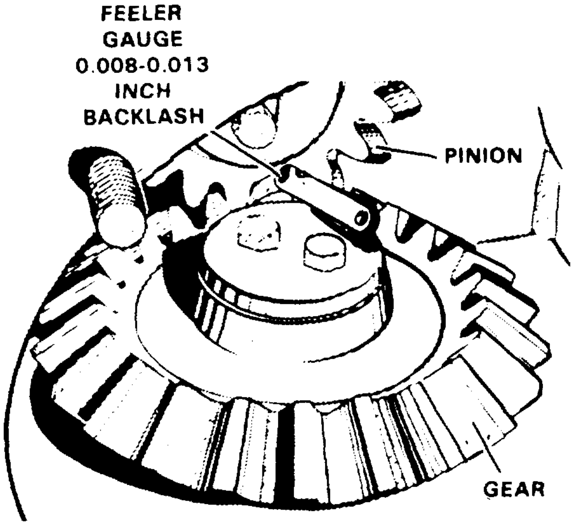


Figure 6B-1. Checking Backlash

INSTALLATION. To install the horizontal swing shaft, proceed as follows:

1. Replace O-ring in the clutch housing. Place shims (08 and 09) on the studs extending from the chain case. Apply a coat of number two Permatex to the threads of the studs.

2. Attach the swing shaft assembly to the chain case Install and tighten washers (19) and nuts (18).

3. Install the clutch assembly on shaft (05) and secure in position with washers (06 and 31) and locknut (07).

4. Install and adjust the drive chain, chain case cover and gasket (see Subsection 4E).

5. Connect the hydraulic line to the clutch and open the petcock at the hydraulic reservoir. Bleed the line from the reservoir to the clutch (see Subsection 5A).

6. Check the backlash between pinion (04) and the vertical swing bevel gear as shown in Figure 6B-1 Adjustment is made by means of the shims located beneath the vertical swing shaft bearing retainers (see Subsection 6D).

7. Check the bevel pinion gear contact, using a thin coating of Prussian blue or white lead on one gear. Rotate the gears together under no load to determine contact on the gear teeth as shown in Figure 6B-2. Correct any poor contact condition as shown.

8. Lubricate the assembly with multipurpose grease through fitting (12).

NOTE

Fitting (11) is a relief fitting. When grease backs up through the relief fitting, stop adding lubricant. Be careful not to overlubricate fittings (12) since damage to seals could result.

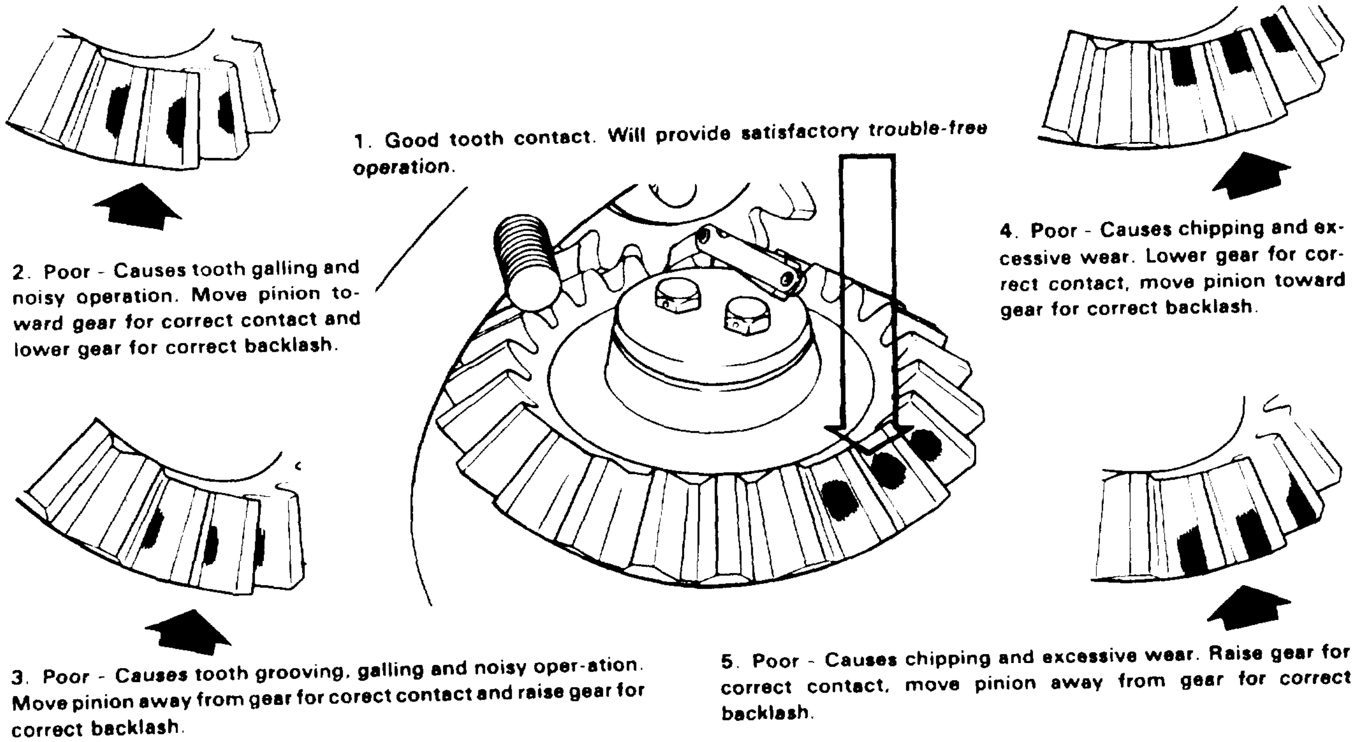
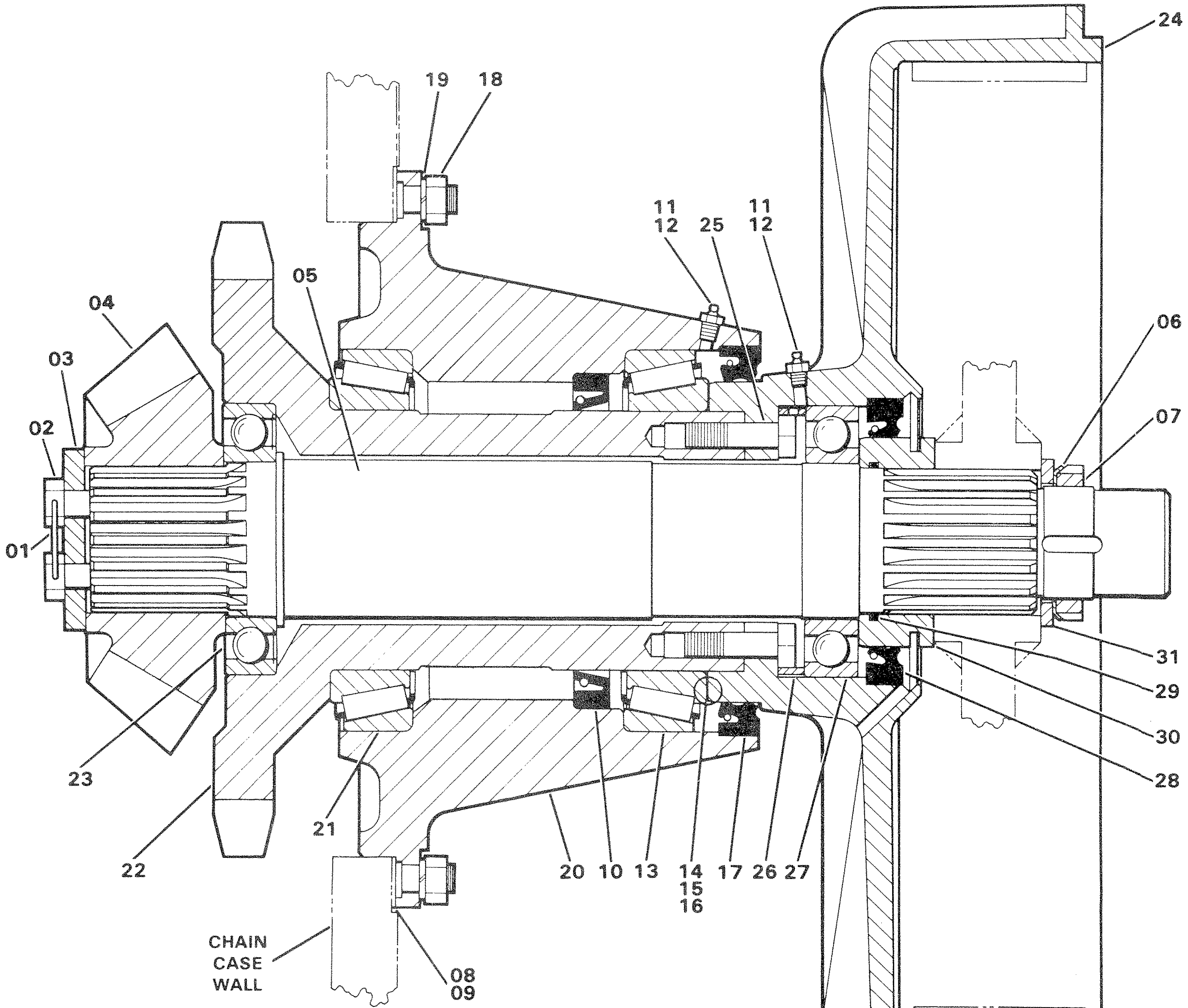
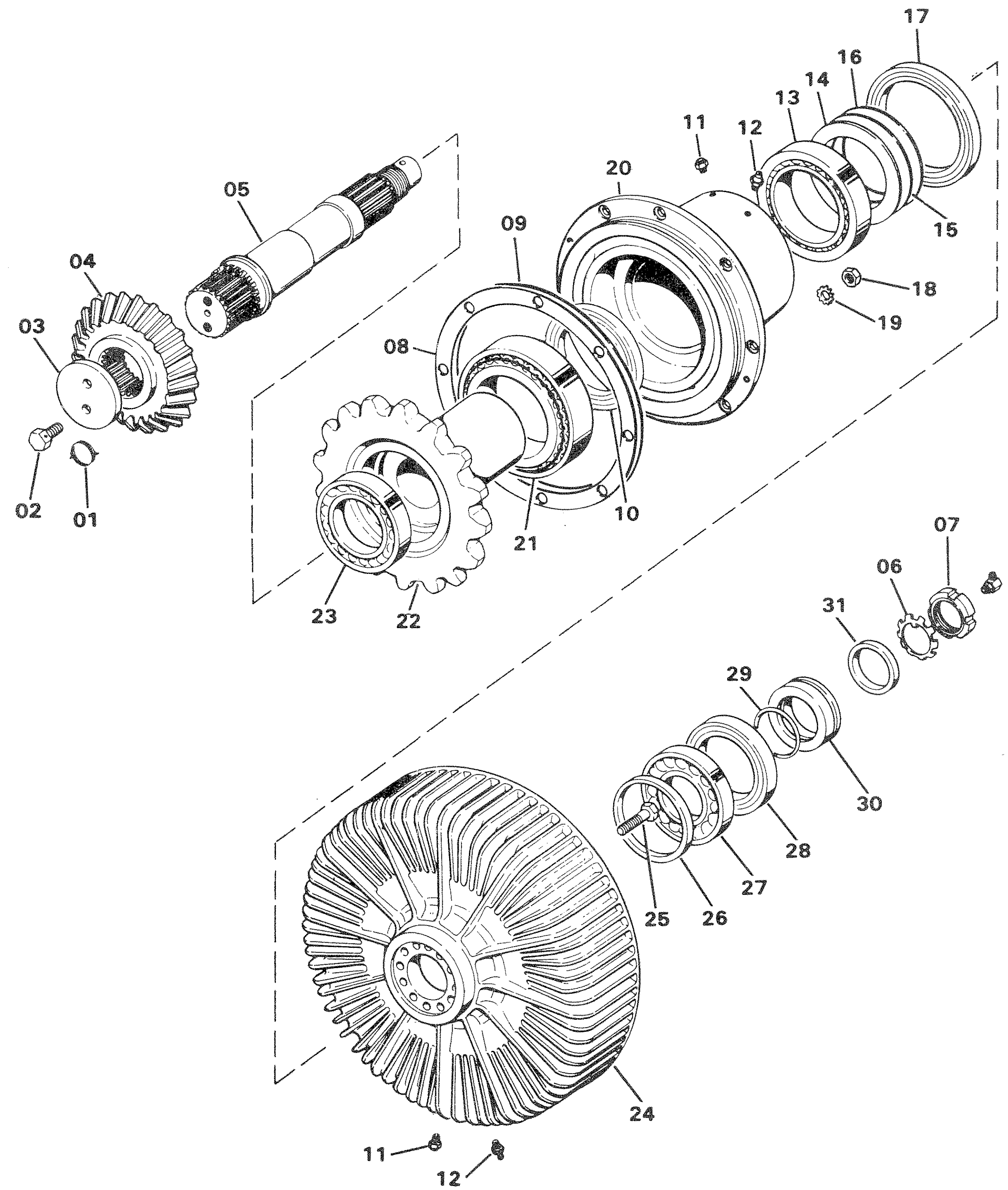


Figure 6B-2. Checking Tooth Contact





01. LOCKWIRE
02. CAPSCREW
03. WASHER
04. PINION
05. SHAFT
06. WASHER
07. LOCKNUT
08. GASKET
09. SHIM
10. OIL SEAL
11. RELIEF FITTING
12. GREASE FITTING
13. BEARING
14. SHIM
15. SHIM
16. SHIM
17. OIL SEAL
18. NUT
19. WASHER
20. HOUSING
21. BEARING
22. SPROCKET
23. BEARING
24. DRUM
25. CAPSCREW
26. LOCK RING
27. BEARING
28. OIL SEAL
29. O-RING
30. SPACER
31. WASHER

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Figure 6B-3. Horizontal Swing Shaft (2910J30-5)

SUBSECTION 6C

INTERMEDIATE SWING SHAFTS

GENERAL

This subsection covers the removal, disassembly, inspection, repair, assembly and installation of the intermediate swing shaft. It is important to note that during assembly and installation shims are used to adjust the bevel gear backlash with the swing clutch shaft bevel pinions.

INTERMEDIATE SWING SHAFT (9210JS0-3)

GENERAL. The intermediate swing shaft is mounted in the revolving frame with the bevel gear in contact with the swing clutch shaft pinions. The bevel gear, on the intermediate swing shaft and the pinions on the swing clutch shaft, are immersed in oil and continually lubricated.

REMOVAL AND DISASSEMBLY. Disassembly is accomplished during removal. To remove the intermediate swing shaft, proceed as follows (see Figure 6C-1):

1. Drain the chain case and remove the chain case covers on the front of the revolving frame.
2. Remove the horizontal swing shafts (see Subsection 6B).
3. Remove the end plate, then pull the bevel gear and pinion from the shaft.
4. Attach an eyebolt to the shaft and lift the shaft and bearings from the chain case bore.

NOTE

It is not necessary to remove the bottom spacer or spacer retainer at this time.

5. Remove the cover plate by cutting the tie wire and removing the capscrews.
6. Remove the bearing spacer and press the bearings off the shaft.

INSPECTION AND REPAIR. Prior to assembly, all intermediate swing shaft parts should be inspected as follows:

1. If the bevel gear or either of the swing pinions on the swing clutch shaft are defective, replace all three gears. The three gears tend to wear uniformly and the use of a combination of old and new gears, particularly bevel gears, will make backlash adjustments all but impossible.
2. Any bearing which shows any sign of wear or damage should be replaced.
3 Replace all capscrews which have rounded corners and all other damaged or worn parts.

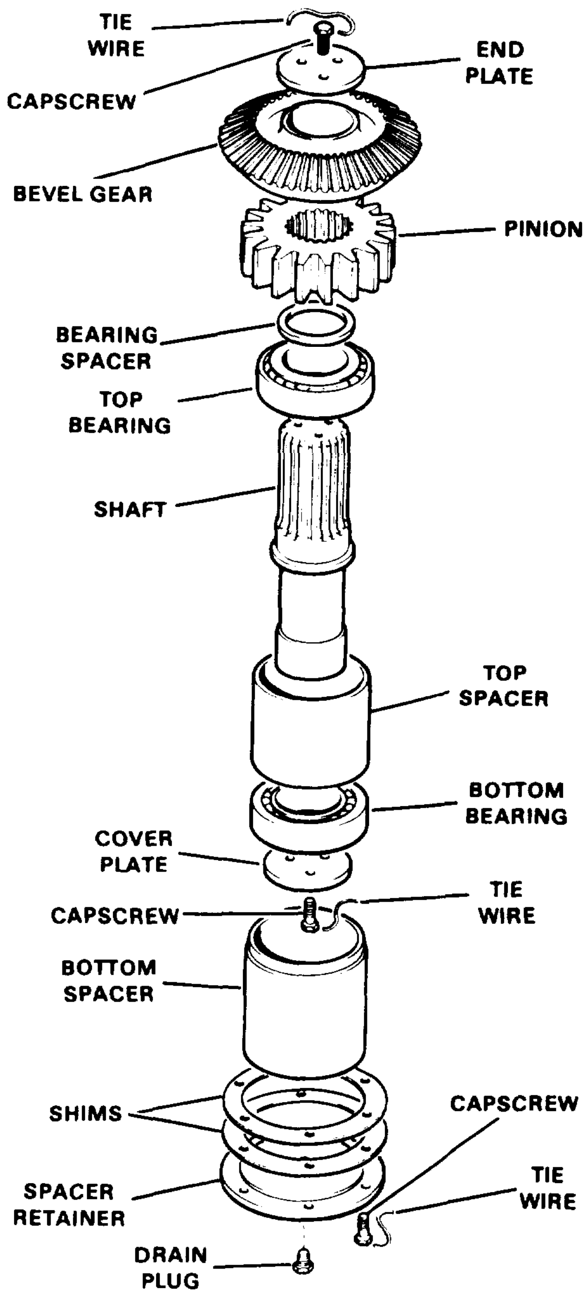


Figure 6C-1. Intermediate Swing Shaft (9210J60-3)

4. If inspection reveals nicks, mars or burrs on machined or ground surfaces, use a fine mill file or stone for removal. Be sure all threaded items are clean and that threads are not damaged.

ASSEMBLY AND INSTALLATION. To assemble and install the intermediate swing shaft, proceed as follows (see Figure 6C-1):

1. Press the cone of the top bearing on the shaft until it is snug against the shoulder. Pack the bearing with grease and install the outer race. Install the top spacer against the top bearing.

2. Install the outer race of the bottom bearing against the top spacer. Pack the cone of the bottom bearing with grease and press the bearing on the shaft until it is seated with the outer race. Turn the outer races to be sure the bearings have seated properly and turn freely.

3. Install the cover plate to the end of the shaft with the capscrews. Bench set the bearing end play by rotating the shaft while adjusting the bearings. Tighten the cover plate capscrews with the shaft rotating freely and no appreciable end play. Secure the cover plate capscrews with the tie wire.

4. Install the shaft assembly into the chain case bore.

5. Install the bearing spacer, the pinion, and the bevel gear.

6. Attach the end plate with the capscrews and secure with the tie wire.

7. Install the swing shafts as described in Subsection 6B and check the bevel gear contact as described and illustrated. Each swing shaft bevel gear and intermediate bevel gear has a backlash dimension stamped on its face. Backlash measurements must be taken at the pitch diameter of a bevel gear tooth, preferably with a 0.001 inch dial indicator, while the mating bevel gear is held in a locked position.

8. If backlash adjustment is required, proceed as follows:

A. Remove the hardware holding the swivel to the bracket on one side only. Move the swivel to one side and block it in place.

8. Drain the intermediate swing shaft bore by removing the pipe plug in the spacer retainer. Remove the tie wire, the capscrews and the spacer retainer. Be ready to catch any additional gear oil trapped in the chain case bore.

C. Add or remove shims between the bottom spacer and spacer retainer to bring the bevel gears into proper contact with the required backlash.

NOTE

The measured backlash, at each bevel gear set, should equal the sum of the backlash values stamped on the bevel gear and the mating bevel pinion. Backlash can be corrected by adding or removing the backlash shims. Adding shims will drop the intermediate swing shaft down, thereby increasing backlash. Removing shims will move the shaft up and decrease backlash. When checking bevel gear contact, use only three capscrews to hold the spacer retainer in place.

D. When proper backlash has been set, install the other capscrews and secure them with the tie wire.

E. Center the swivel and secure it in placewith the mounting hardware.

9. Install the chain case covers and any other sheet metal removed during disassembly.

10. Fill the chain case with the gear oil specified in Section Ill.

TABLE OF CONTENTS

SUBSECTION 6D

VERTICAL SWING SHAFTS

GENERAL

This subsection covers the removal, disassembly, inspection and repair and the assembly and installation of the vertical swing shaft.

VERTICAL SWING SHAFT (2100J1334-1)

GENERAL. The vertical swing shaft is driven from the intermediate swing shaft pinion. It transmits swing torque to the swing pinion, which mates with the teeth of the ring gear.

REMOVAL. To remove the vertical swing shaft, proceed as follows (see Figure 6D-1 on page 6D-2):

1. Swing the machine to a position where the shaft can be reached through an opening in the carbody. Set the swing brake.

2. Drain the chain case and remove the chain case covers.

3. Remove the intermediate swing shaft as described in Subsection 6C.

4. Block the swing shaft to prevent it from dropping when the attaching material is removed.

5. Remove locknut (01), lockwasher (02) and spacer (03) from the shaft. Remove gear (04) from the shaft.

6. Loosen bearing retainer (07) by removing tie wire (06) and capscrews (05). Remove retainer (04) and shims (08).

7. Install an eyebolt in the end of the shaft and attach a suitable lifting device to it (the swing shaft weighs approximately 175 lbs).

8. Loosen bearing retainer (16) by removing tie wire (18) and loosening capscrews (17).

9. Raise the shaft and the bearings out of the bore.

DISASSEMBLY. To disassembly the remaining parts of the vertical swing shaft, proceed follows (see Figure 6D-1 on page 6D-2):

1. Remove upper bearing (09) from the shaft if it was not removed during removal of the shaft.

2. Remove spacer (10) and then remove lower bearing (11).

3. Remove capscrews (17), retainer (16), gasket (13) and O-ring (15).

4. Remove inner retainer (14) and seal (19).

INSPECTION AND REPAIR. Prior to assembly, all vertical swing shaft parts should be inspected as follows:

1. Replace new oil seal (19) in bearing retainer (14). Install new O-ring (15) in retainer (16).

2. Bearings that show any signs of wear or damage should be replaced.

3. Replace all capscrews which have rounded corners and all other damaged or worn parts.

4. If inspection reveals nicks, mars or burrs on machined or ground surfaces, use a fine mill file or stone for removal. Be sure all threaded items are clean and that threads are not damaged.

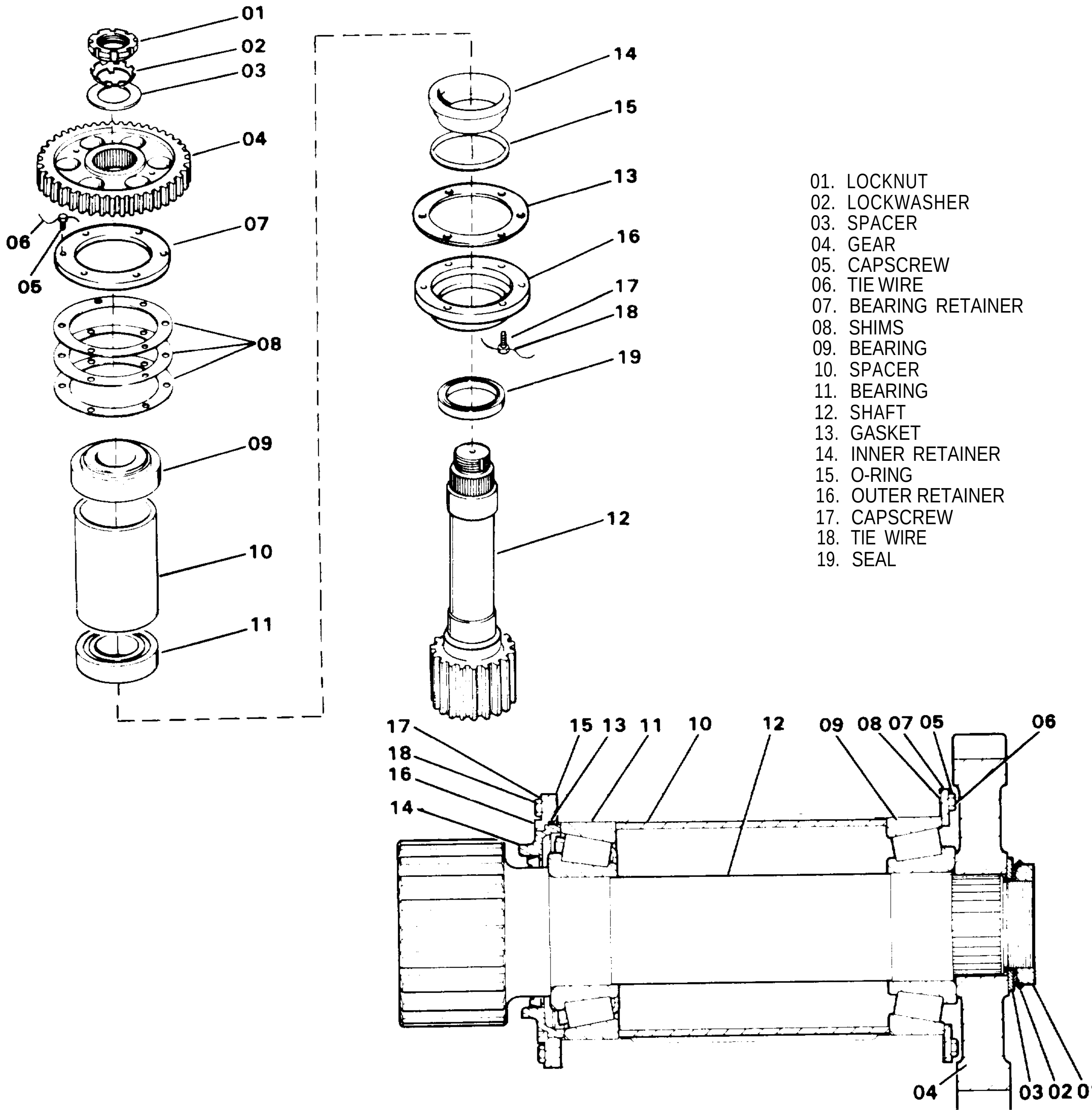


Figure 6D-1. Vertical Swing Shaft (2100J1334-1)

5. Check the vertical swing gear, the pinions, and the bevel gear on the intermediate swing shaft for wear, cracks, or damage. If any of these are defective, replace them.

ASSEMBLY AND INSTALLATION. To assemble and install the vertical swing shaft, proceed as follows (see Figure 6D-1):

1. Set retainer (14) with new seal (19) on shaft (12).

2. Press the inner race of lower bearing (11) on shaft (12) until it is snug against the shoulder. Pack the bearing with grease and install the outer race.

3. Slide space (10) on shaft (12).

4. Place the outer race of upper bearing (09) against spacer (10). Pack the inner race with grease and press onto shaft (12) until it is seated with the outer race. Turn the outer race of bearings (09 and 11) to make sure the bearings have seated properly and turn freely.

5. Install retainer (16) with new O-ring (15) and gasket (13) on the machine with capscrews (17). Do not tighten the capscrews at this time.

6. Install the eyebolt in the vertical swing shaft if it was removed during inspection. Attach a suitable lifting device to the eyebolt (the shaft and bearings weigh approximately 175 lbs).

7. Install the shaft into the machine by CAREFULLY lowering the shaft until inner bearing (14) seats in bearing retainer (16).

CAUTION

Slowly lower the shaft so that O-ring (15) and seal (19) are not damaged.

8. Tighten capscrews (17) and install tie wire (18).

9. Place bearing retainer (07) on the top bearing, install and snug down capscrews (05). Measure the clearance between the bearing retainer and the top of the chain case bore.

10. Remove capscrews (05) from bearing retainer (07) and add an amount of shims greater than the clearance measured in Step 9. Reinstall the capscrews, tighten, and secure with tie wire (06).

11. Place gear (04) on the shaft splines and install spacer (03), lockwasher (02) and nut (01).

12. Rotate the shaft while tightening nut (01). Bearings must be free to rotate with no appreciable end play. Secure the nut with the locking tab on lockwasher (02).

13. Replace the intermediate shaft as described in Subsection 6C.

14. Replace the chain and adjust according to the procedure in Subsection 4E.

15. Fill the chain case to the proper level with the lubricant specified in Section III.

16. Replace the chain case covers.

SUBSECTION 6E

SWING BRAKES AND LOCKS

GENERAL

This subsection contains the information necessary to remove, repair, install and adjust the swing brake.

SWING BRAKE (2100J992-4)

GENERAL. The swing brake is located at the left side of the upper. The pinion of the swing brake shaft is engaged in the ring gear. The brake is of the spring set-hydraulically released type. The purpose of the swing brake is to lock the upper in position in relation to the carrier, while traveling, working, or moving to a new location. It is not intended or designed to stop the upper from swinging at the end of each swing cycle or as a control regularly used in operating the machine. It is more accurately described as a "locking" brake.

When the operator moves the swing brake control switch to release the swing brake, hydraulic pressure is applied to the cylinder which extends a piston to release the brake. When the operator moves the swing brake control switch to engage the swing brake, hydraulic pressure is released from the cylinder, retracting the piston which allows a spring to set the brake.

The length of the operating springs with the brakes applied (hydraulic pressure released to the cylinder) should be 4-1/4 inches when in proper adjustment (see Figure 6E-1).

The swing brake shoes should be replaced if the shoes become cracked, warped, scored or otherwise unserviceable. Proper swing brake use results in very little shoe wear, thus shoes seldom "wear" out.

REMOVAL AND DISASSEMBLY. To remove and disassemble the swing brake, proceed as follows (see Figure 6E-2):

1. Swing the upper so that shaft (34) is over the access opening provided in the carrier deck. Place blocking at the bottom of the shaft.
2. Remove shield (07), spacers (08) and retainer (09).
3. Remove the blocking and lower the shaft from the machine.
4. Disconnect lines (32) and remove pins (14). Remove the brake mechanism from the machine and pull bearing (39) from the shaft bore.
5. Remove bearing (37) from shaft (34).

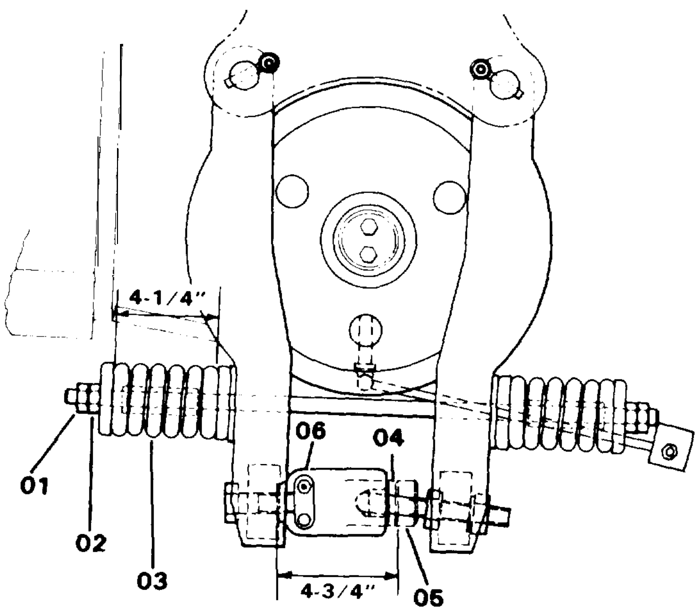


Figure 6E-1. Swing Brake Adjustment

INSPECTION AND REPAIR. Prior to assembly, all swing brake parts should be inspected as follows (see Figure 6E-2):

1. Replace springs (04) and shoe linings (22).
2. If either bearing shows signs of wear or damage it should be replaced.
3. Inspect shaft (34) for defects. Replace the shaft if it is worn, cracked or otherwise damaged.
4. Inspect sheave (10) for excessive wear and replace if necessary.
5. If cylinder (44) leaks or has been performing erratically, overhaul it (see Subsection 5D).

INSTALLATION. To install the swing brake, proceed as follows (see Figure 6E-2):

1. Heat bearing (37) and install the bearing firmly against the shoulder of shaft (34). Slide spacer (38) over shaft (34).

2. Press bearing (39) into the shaft bore of the revolving frame, pressing on the outer cup only.

3. Pack the cavity below bearrng (39) with multipurpose grease.

4. Install shaft (34) from beneath the upper until spacer (38) is pressed firmly against bearing (39).

5. Place the brake shoe assembly over shaft (34). Install and fasten pins (14) in place.

6. Connect lines (32) and lubricate the bearings thoroughly through the grease fittings.

7. Install retainer (09). spacer (08) and shield (07) and fasten securely with capscrews (05).

ADJUSTMENT. To adjust the swing brake, proceed as follows (see Figure 6E-1):

1. With the brake *applied* (hydraulic pressure *released)* loosen jam nuts (01) and turn adjusting nuts (02) so that the length of springs (03) is 4-1/4 inches.

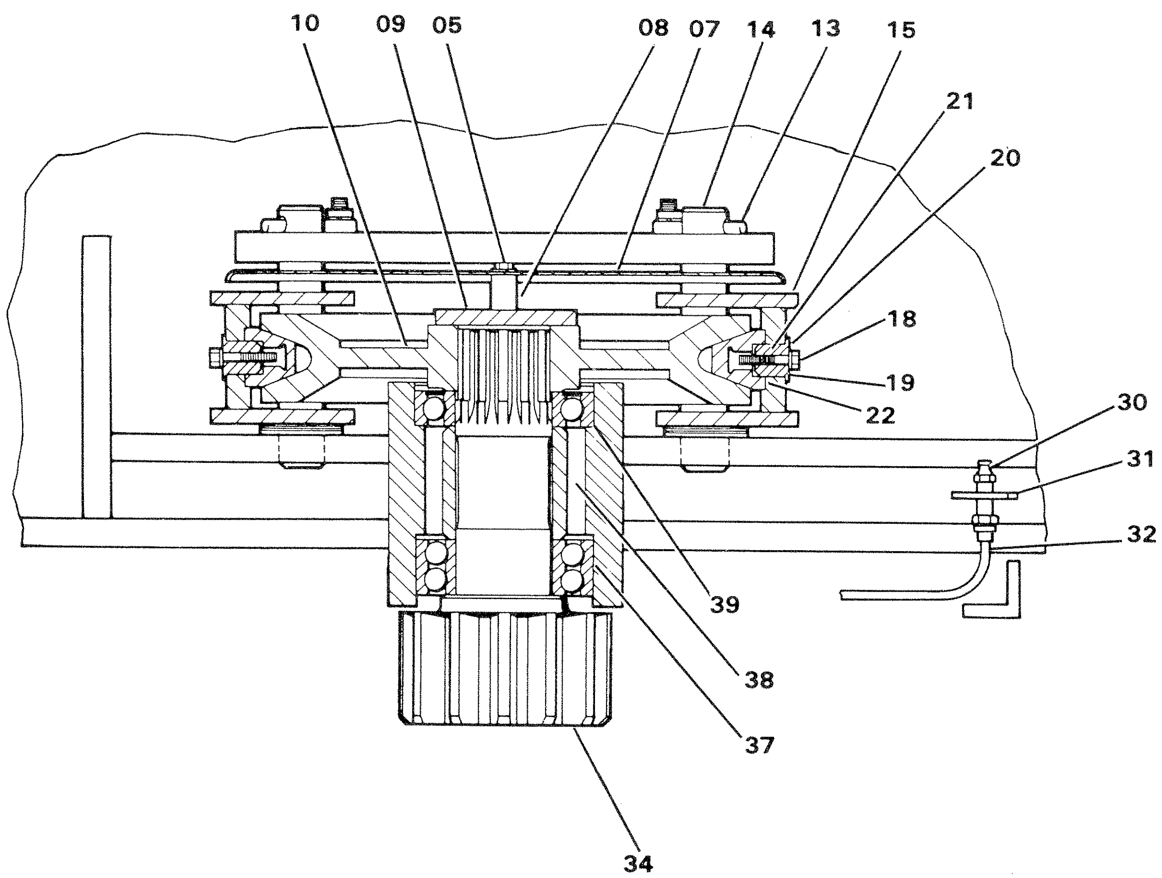
2. Loosen jam nut (04) and adjust nut (05) so that the piston of cylinder (06) has one inch of stroke travel when the brake is *released* (hydraulic pressure *applied).*

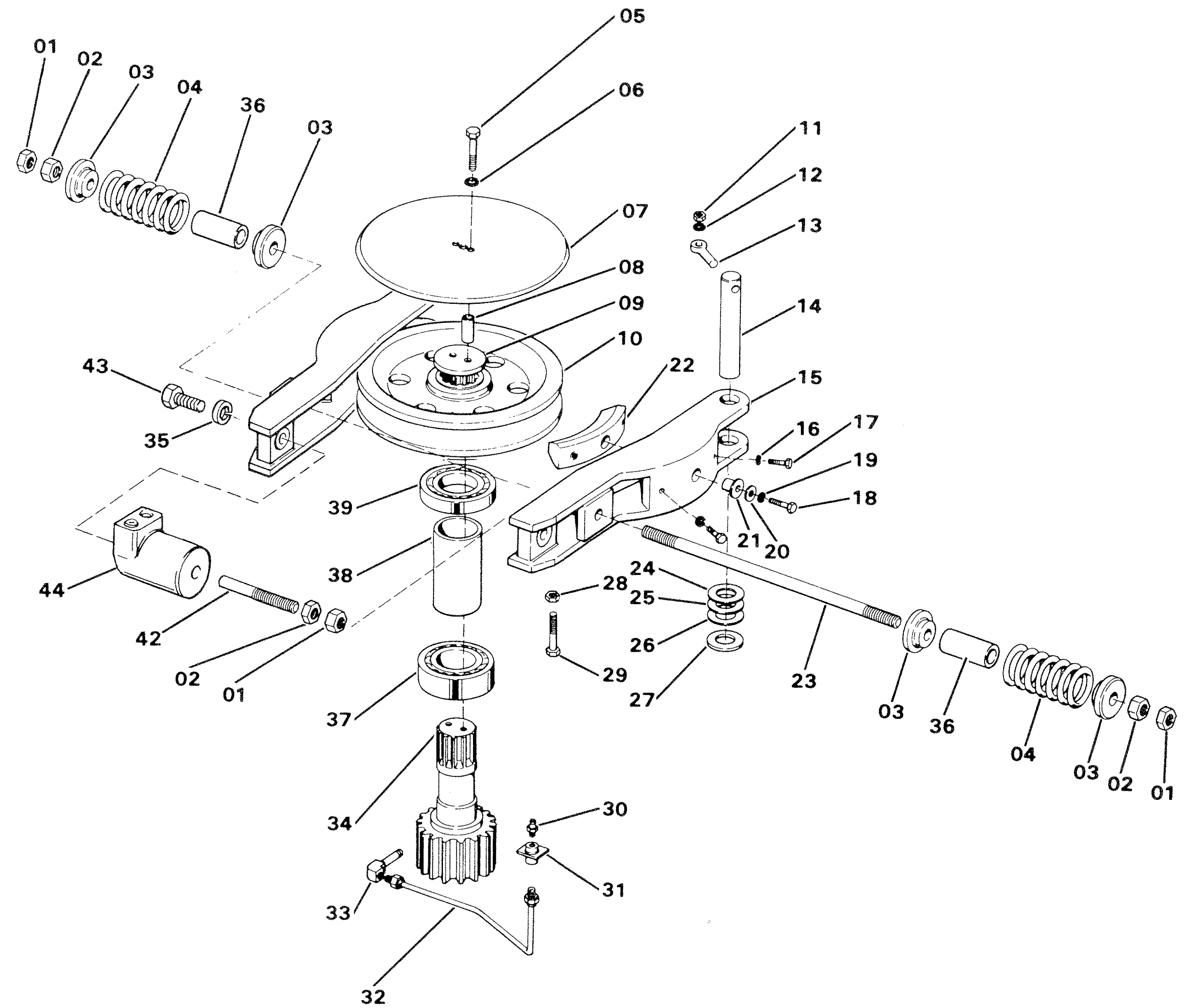
360° SWING LOCK (2100J1405)

GENERAL. The 360° swing lock is used to lock the machine upper in any position in relation to the lower. Moving the switch to the disengaged position moves the stop block out of slewing ring bull gear. Moving the switch to the engaged position moves the stop block into the slewing ring bull gear. See Figure 6E-3.

REPAIRS. The only repair item is the hydraulic cylinder. See Subsection 5D for replacement of the hydraulic cylinder.

ADJUSTMENT. The swing lock must be adjusted so that pins “A”, “B” and “C” are in line when the stop block is fully engaged in the slewing ring bull gear (see Figure 6E-3). Adjust as needed using adjusting capscrew and jam nut. Tighten jam nut after adjusting.





01. NUT
02. NUT
03. SEAT
04. SPRING
05. BOLT
06. WASHER
07. SHIELD
08. SPACER
09. RETAINER
10. SHEAVE
11. NUT
12. WASHER
13. ROD END
14. PIN
15. BRAKE SHOES
16. WASHER
17. CAPSCREW
18. CAPSCREW
19. WASHER
20. WASHER
21. PLUG
22. SHOE LINING
23. SPRING BOLT
24. SHIM
25. SHIM
26. SHIM
27. WASHER
28. JAM NUT
29. BOLT
30. GREASE FITTING
31. BRACKET
32. LINE
33. ELBOW
34. SHAFT
35. LOCKWASHER
36. SPACER
37. BEARING
38. SPACER
39. BEARING
40. ROD
41. JAM NUT
42. PUSH ROD
43. CAPSCREW
44. CYLINDER
45. LOCKWASHER

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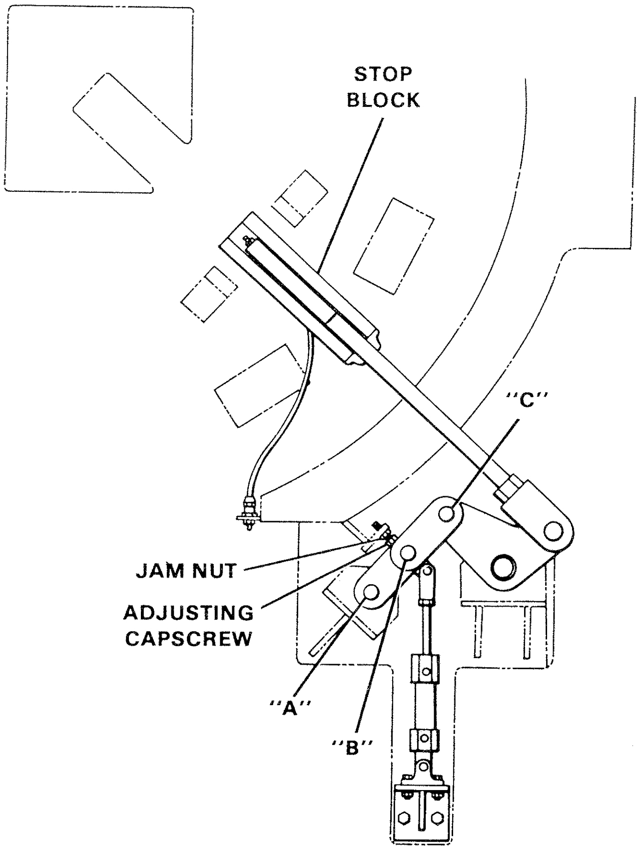
Figure 6E-2. Swing Brake (2100J992-3)



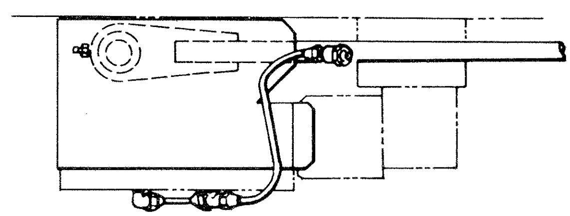


Figure 6E-3. 360° Swing Lock (2100J1405)

TABLE OF CONTENTS

SUBSECTION 6F

SWING CLUTCHES

GENERAL

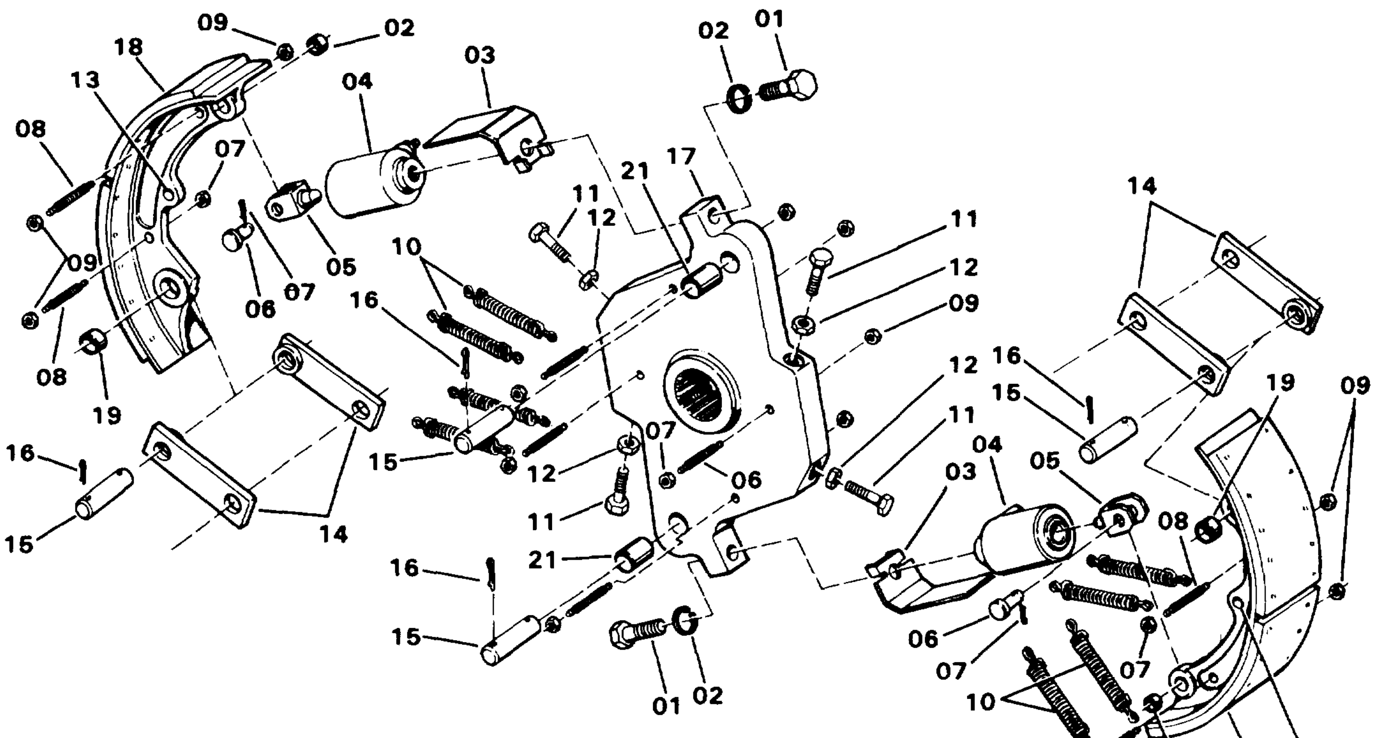
This subsection contains the information necessary to remove, repair, install and adjust the swing clutch assembly.

SWING CLUTCH (2100J1346-1)

REMOVAL AND DISASSEMBLY. The clutch assembly shown in Figure 6F-1 is the left swing clutch. The right swing clutch is the same as the left, except that it is rotated 180°. To remove and disassemble the swing clutch, proceed as follows (see Figure 6F-1):

1. Place the swing lever in the neutral position.

2. Disconnect and cap the hydraulic line to the clutch swivel. Unscrew the swivel from the swing shaft.



01. CAPSCREW
02. LOCKWASHER
03. SHIELD
04. CYLINDER
05. PUSH ROD
06. PIN
07. COTTER PIN
08. SPRING ANCHOR
09. NUT
10. DRAW SPRING
11. ADJUSTING SCREW
12. JAM NUT
13. SHOE
14. LINK
15. PIN
16. COTTER PIN
17. SPIDER
18. CLUTCH LINING
19. BUSHING
20. BUSHING
21. BUSHING

Figure 6F-1. Swing Clutch (2100J1346-1)

3. Disconnect the hydraulic line attached to the swing shaft. Remove the nut, lockwasher and flat washer from the end of the swing shaft.

4. Carefully slide the clutch assembly off of the swing shaft and place it on a clean bench.

5. Loosen jam nuts (12). Back off adjusting screws (11) and remove return spring (10).

6. Disconnect shoes (13) from push rods (06) and links (14).

INSPECTION AND REPAIR. Prior to reinstalling the clutch assembly on the shaft, inspect the following items (see Figure 6F-1 on page 6F-1):

1. Replace return spring (10).

2. Remove bushing (21) from spider (24) and replace. Also remove bushings (19) and (20) and replace them.

3. If cylinder (04) leaks or has been performing erratically, remove it from the spider and overhaul or replace it. See Subsection 5D.

4. Check clutch lining (18) for excessive wear. The linings should be replaced when wear has reduced the thickness of the lining to within 1/16 inch of the rivets. Check the clutch shoes for cracks or distortion.

NOTE

A lining kit is available. See the Replacement Parts Manual.

5. Check links (14) and push rods (05) for wear. Replace if necessary.

6. Inspect the clutch drum for cracks, scores or other damage.

ASSEMBLY AND INSTALLATION. To assembly and install the swing clutch, proceed as follows (see Figure 6F-1 on page 6F-1):

1. Assemble the clutch in the reverse order of disassembly.

2. Attach the clutch assembly to the swing shaft.

3. Connect the hydraulic line from the cylinder to the shaft.

4. Attach the swivel to the shaft and connect the hydraulic line to the swivel.

5. Bleed the hydraulic cylinder to remove any air trapped in the hydraulic lines (see Subsection 5A).

ADJUSTMENT. To adjust the swing clutch when the clutch has been removed, proceed as follows (see Figure 6F-2 on page 6F-3):

CAUTION

Make sure that the swing clutch shoes do not drag. Dragging shoes will cause the upper to swing with the swing control lever in neutral.

1. Engage the clutch, using the swing clutch lever, then release.

2. Loosen the jam nuts and turn the adjusting screws until there is 0.093 (3/32) inch between the drum and the clutch shoe. Tighten the jam nuts and recheck the gap.

3. Repeat Step 3 for the other shoe.

4. Check the swing clutch operation by making several applications and releases. Readjust the clutch if necessary.

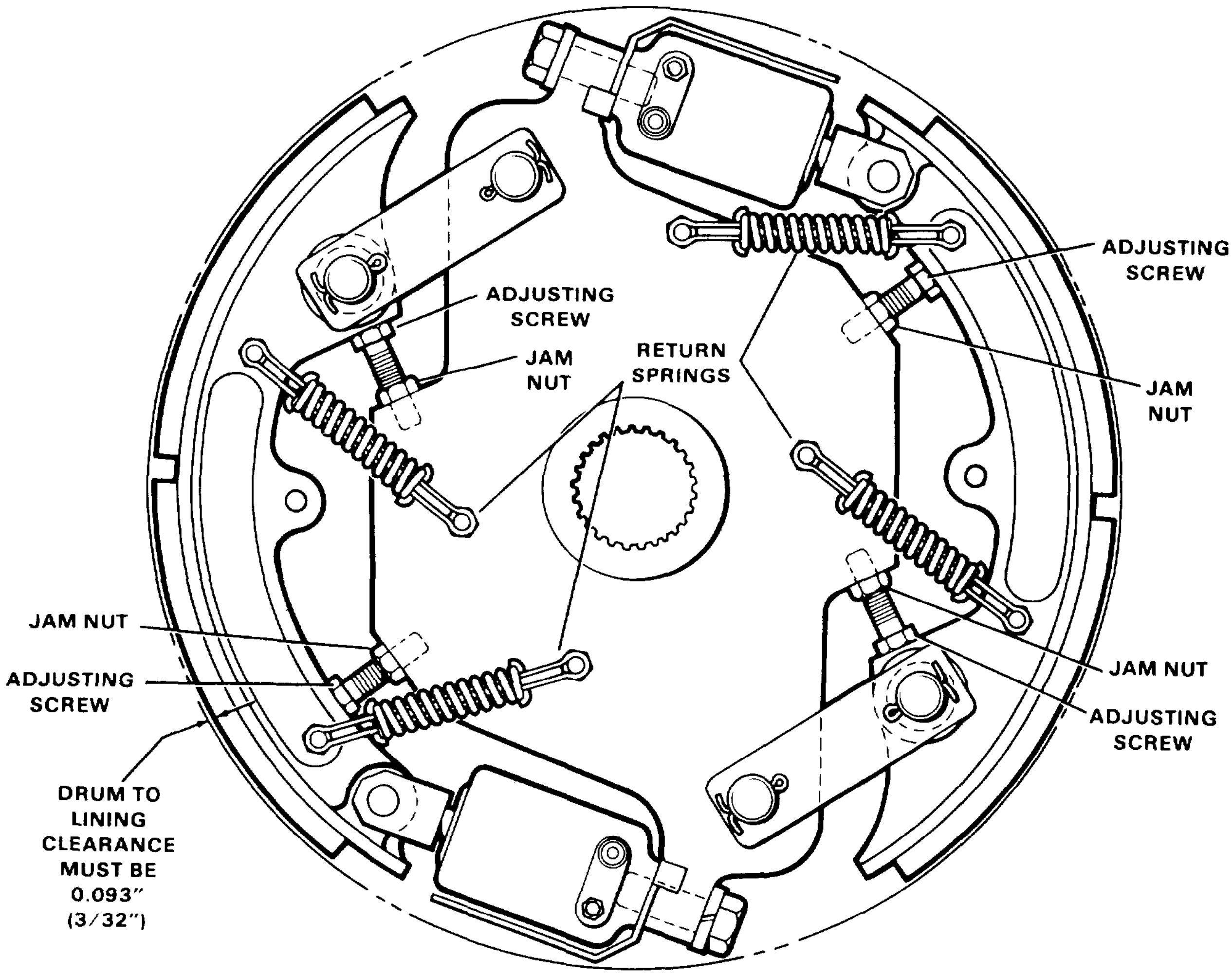


Figure 6F-2. Swing Clutch Adjustment

SUBSECTION 6G

SLEWING RINGS

GENERAL

The slewing ring is basically large bearing upon which the upper is mounted. The outer race of the slewing ring is bolted to the upper, and the inner race is bolted to the carbody. An internal ring gear, machined into the inner race, mates with the swing pinion which projects downward from the vertical swing shaft. This arrangement allows the upper to rotate in a full circle, when the upper is driven by the mechanic drive from the swing clutch to the vertical swing shaft.

SLEWING RING (901J22)

REMOVAL. To remove the stewing ring, proceed as follows (see Figure 6G-1):

WARNING

Extreme caution must be exercised when removing the slewing ring, as it is necessary to completely remove the upper from the carbody. Every precaution must be taken to prevent the upper from falling or shifting while lifting the upper and when the upper is off the carbody.

1. Move the machine onto firm, level ground, and block the crawlers so that it will not move while the upper is being removed. Shutdown the engine and relieve all pressure in the propel hydraulic system. Turn the propel brake “on”.

2. Tag and disconnect the hydraulic tubing, at the points where the tubing is connected to the top of the swivel joint. Cap the tubing to prevent dirt from entering the system.

3. Block or support the upper using a suitable lifting device. Be sure the upper is blocked or supported adequately, because the next step of these instructions is to remove the bolts which secure the upper to the slewing ring.

4. Loosen the 36 bolts which secure the upper to the slewing ring from below the outer race and allow them to drop onto the carbody.

5. Lift the upper until the revolving frame is above the top of the hydraulic swivel. Place the upper on suitable blocking away from the carbody.

6. Remove the 40 bolts which secure the inner race of the slewing ring to the carbody.

7. Install a suitable eyebolt in two holes, in the slewing ring, which are 180 degrees apart. Attach a suitable lifting sling to these eyebolts, and lift the slewing ring from the carbody. The slewing rim weighs approximately 1800 Ibs.

REPAIRS. The slewing ring is not a repairable item. If the slewing ring is no longer serviceable, it must be replaced with a new unit.

CAUTION

Any attempt to disassemble or repair the slewing ring will void any warranty, expressed or implied.

INSTALLATION. To install a new slewing ring, proceed as follows (see Figure 6G-1):

1. Inspect and clean the tapped holes in both the carbody ring and the revolving frame with a suitable cleaning solvent, and blow the surface and holes dry with compressed air. Clean the mating surfaces of the slewing ring, carbody, and revolving frame with an oily rag.

2. Install eyebolts in the new slewing ring in the same manner as they were installed in the old slewing ring for removal, and lift the new slewing ring onto the carbody. The slewing ring weighs approximately 1800 Ibs.

3. Position the slewing ring so that the word FRONT, stamped on the inner race, faces the front of the carbody when the slewing ring is bolted to the carbody.

4. Position the slewing ring on the carbody ring so that the mounting holes line up.

5. Lubricate all 40 lower bolts with light oil (SAE 30) and apply a never-seize type lubricant to the threads and undersides of bolt heads.

6. Check for possible gaps between the ring and the carbody. No gaps should exceed 0.005 inch.

7. Tighten two bolts, which are 180 degrees apart on the center line of the carrier, to 150 ft-lbs. Tighten two other bolts which are 180 degrees apart and 90 degrees from the first two bolts, to 150 ft-lbs. Continue this cross-bolting procedure until all of the bolts have been torqued to 150 ft-lbs.

8. Repeat the cross tightening procedure but increase the torque to 1130 ft-lbs.

9. Press the two dowels 2 inches deep into the upper if they were removed. The dowel holes in the ring are indicated in Figure 6G-1 and Section A-A.

10. Double deck the machine making sure that the bolt holes and dowel pins are in alignment.

11. Lubricate and install the bolts in the upper. Hand tighten all bolts.

12. Use the same tightening procedure on the upper as on the lower and the same final torque as in step 8.

13. Connect all hydraulic lines that were disconnected during removal.

14. Check the torque of the bolts after first 200 hours of operation.

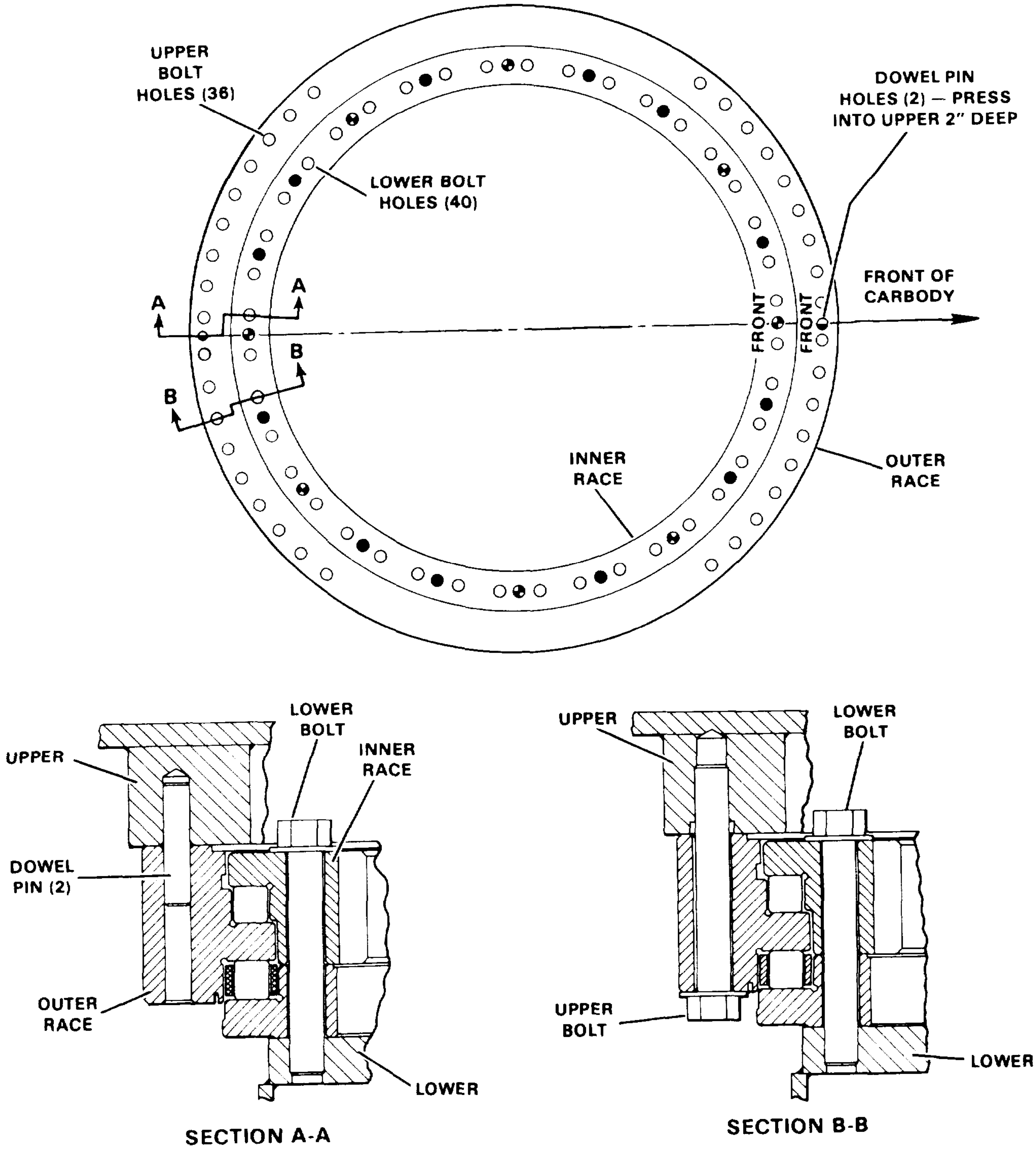


Figure 6G-1. Slewing Ring (2100J950)

SECTION VII

HOIST SYSTEM AND COMPONENTS

SUBSECTION 7A

HOIST SYSTEM

GENERAL

This section describes the components required to transmit hoist torque from the drumshaft to the hoist drums.

The hoist system consists of the drumshaft, drum brakes, drum cltuches and drum pawls as shown in Figure 7A-1.

DESCRIPTION

The hoist system is powered by the upper engine through the chain driven drumshaft. The drumshaft and drum clutches turn continuously while the engine is running and torque converter is engaged. However, the operator must engage one of the hoist clutches to rotate a hoist drum.

Hydraulically operated pawls engage the ratchets of the drums to prevent the rotation of the drums when the operator so desires. The pawls should be adjusted as described in Subsection 7E.

Left and right drum planetary systems are included on these drums. The planetary assemblies are identical on the left and right drumswith a planetary brake band around the planetary drum. To raise a load, the drum clutch is engaged and shaft rotation is transmitted through the clutch to the drum spool and lagging. The lagging rotates in the same direction as the drumshaft to take up on the hoist line and raise the load.

When lowering a load with power lowering, power is transmitted through the planetary system which reverses the direction of the shaft rotation.

The third drum is installed on the left end of the boom hoist shaft. The third drum rotates only when the third drum clutch is engaged.

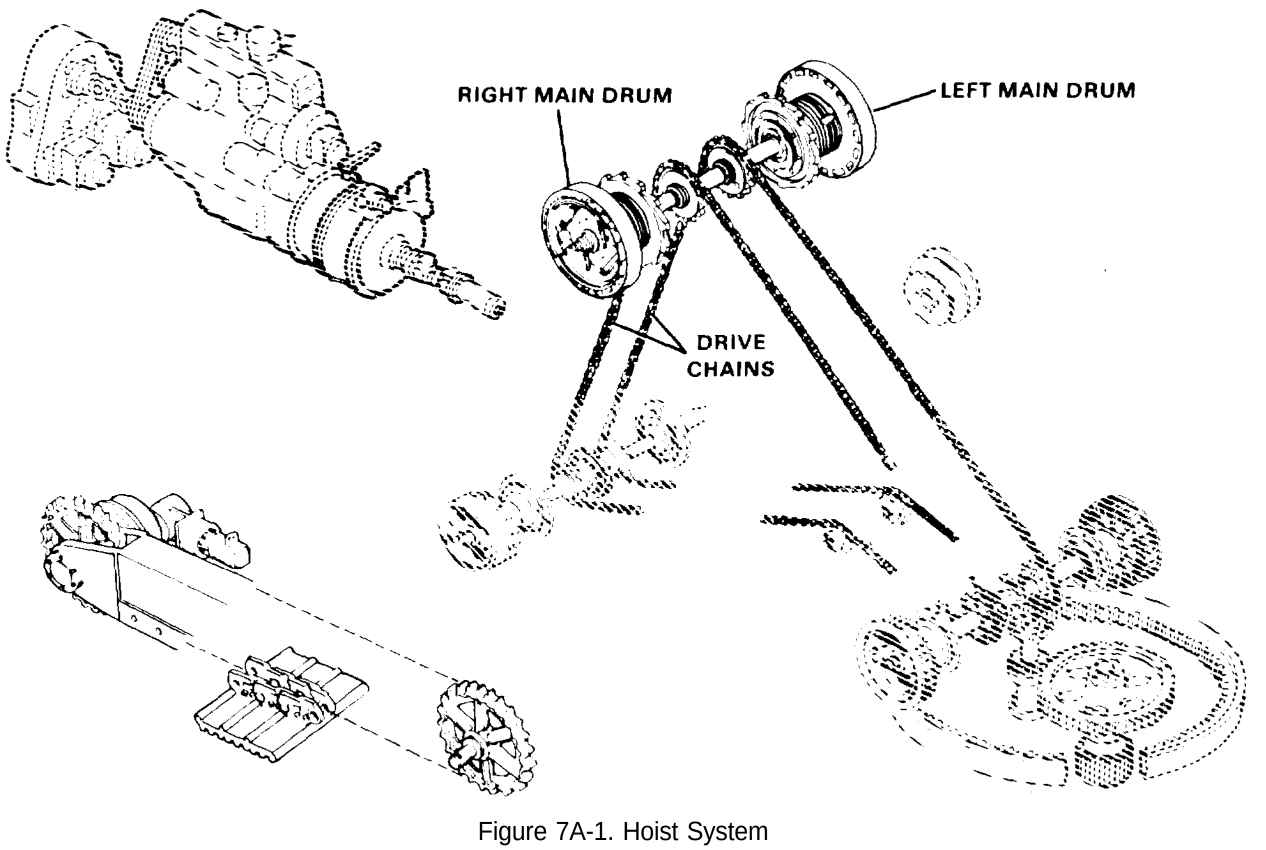


Figure 7A-1. Hoist System

SUBSECTION 7B

DRUMSHAFTS

GENERAL

This subsection contains the information necessary to remove, disassemble, repair, assemble, and install the main drumshaft and third drumshaft.

DRUMSHAFT (2100J974)

REMOVAL. To remove the main drumshaft, proceed as follows (see Figure 7B-1):

1. Disconnect and cap all hydraulic lines to the drumshaft assembly. Plug all connections where hydraulic lines were removed. Also remove any other hydraulic lines which might interfere with the drumshaft removal.

2. Remove the chain case cover, loosen the drive chains. and lift the chain off the sprocket of the shaft assembly to be removed (see Subsection 4E).

3. Disconnect and remove all brake bands on the drumshaft assembly. See Subsection 7C.

4. Remove hydraulic swivels (01 and 53) from the ends of the shaft.

5. Remove locknut (52), lockwasher (51) and washer (50) from shaft (22).

6. Remove the clutch assembly and place it in a clean area.

7. Support the drum assembly with a hoist and slide it off the shaft. Keep clutch drum (39) facing up.

8. Place blocking under shaft (22).

9. Remove nuts (30). washers (29) and retainers (27). Also, remove shims (28).

10. Remove bearings (23) from shaft (22). Remove spacers (21).

11. Repeat steps 5 through 10, as applicable, and remove the left main drum.

12. Remove the blocking and push the shaft out of the chain case. Support sprockets (20) and remove through the chain case cover.

DISASSEMBLY. To disassemble the hoist drum, proceedas follows (see Figure 7B-1):

1. Place the hoist drum assembly on a work bench with clutch drum (39) facing up.

2. Remove capscrews and washers (42), then retainer (41).

3. Pull clutch drum (39) from brake drum (37), taking care not to damage seal (38).

4. Remove pins (35) and pinions (36) from drum (39).

5. Separate sun gear (34) from drum (39).

6. Remove seal (46), bearings (47 and 49) and spacer (48) from drum (39). Do not remove seal (38) unless condition indicates replacement is required.

INSPECTION AND REPAIR. Prior to assembly, all drumshaft parts should be inspected as follows:

1. Replace all oil seals and O-rings. Any bearing which shows signs of wear or damage should be replaced.

NOTE

Replacement of seal (38) is necessary only if the seal has been damaged.

2. Inspect the bushings (54) for wear or damage. Replace if necessary.

3. Clean out all lube lines and grease passages to insure free flow of lubricant.

4. Inspect all the pinions and gears for wear or damage. If they are scored, pitted, ridged or worn, they should be replaced.

5. Repair or replace any damaged or broken parts, Be sure all threaded items are clean and that threads are not damaged. Studs must be tight before reinstalling parts that are mounted to them.

6. Inspect all clutch and brake linings at this time. Replace the innings, if necessary, before reinstalling them on the drumshaft.

7. Inspect the drum cooling fins for cracks or broken fins. Repair or replace if necessary.

8. Inspect the brake and clutch rims for cracks, scratches, or discoloration. Repair or replace if necessary.

ASSEMBLY. To assemble the hoist drumshaft, proceed as follows (see Figure 7B-1):

1. Lubricate all the O-rings and seals prior to assembly.

2. Place the drum with ratchet end down and pack the cavity between bearings (26 and 31) with multipurpose grease.

NOTE

All ball bearings, new or used, should be packed with multipurpose grease before assembly.

3. Tap bearings (26 and 31) into the bore of the drum until it is firmly seated against the drum shoulders.

4. Install grease seal (38) on the upturned face of the drum, if the seal was removed. Pack the seal with multipurpose grease and be sure the sealing lips face inward.

5. Place pinions (36) on drum (39). Install pins (35) in pinions (36) with the pins turned so flats on the outer end allow retainer (41) to be installed. Secure with capscrews and lockwasher (42).

6. Install bearing (47) and spacer (48) on the elongated hub of gear (34). Install the other bearing (49) and grease seal (46) on the opposite end of the drum.

7. Install the gear, with bearing, spacer, and seal assembled, into the bore of the drum. Check bearing (49) for proper seating against the flange of drum (39).

8. Generously apply a multipurpose grease to all fittings (40 and 45). Wipe off any excess grease from seal (46).

9. If the machine is equipped with planetary lowering, repeat steps 1 through 8.

10. If the machine does not have planetary lowering, then proceed to steps 11 through 13.

11. Pack cavity between bearings (10 and 12) with grease, then press bearing (12) into the drum. Be sure shielded side of the bearing is towards the ratchet side of the drum.

12. Slide bearing (10) onto spacer (11), then press the bearing and spacer onto the drum.

13. Carefully press seal (07) into the drum.

INSTALLATION. To install the hoist drumshaft, proceed as follows (see Figure 7B-1):

1. Place either end of drumshaft (22) into the chain case bore. Let the shaft extend only part way through the chain case, while sprockets (20) are placed on the shaft.Be sure the larger inner diameters of the sprockets, which fit over split spacers (21), face each other.

2. Install spacers (21) and slide the sprockets tightly over the ends of the spacers.

NOTE

Sprockets (21) are match marked during manufacture, and must be installed in matched pairs. Be sure that both sprockets have the same number stamped at the outer edge. The marked spline on each sprocket will line up with the match marks on the shaft when the sprockets are installed properly.

3. Center the shaft in the chain case bore, and block the shaft to prevent movement in any direction until bearings (19 and 23) and bearing retainers (16 and 27) have been installed.

4. Pack seals (18 and 24) with grease and install the seals into retainers (16 and 27). The spring side of each seal face the center of the chain case.

5. Install bearings (19 and 23) on the shaft, tight against sprockets (21).

6. Install the shims located beneath retainer (16), and install both retainers. Apply a coat of No. 2 Permatex to the stud threads before installing nuts (14 and 30) and lockwashers (15 and 29).

NOTE

Before proceeding with installation of the drums, check the shaft end play. End play should be between 0.003 to 0.005 inches. If end play is not within these limits, add or remove shims beneath retainer (27) as necessary.

7. Using a suitable hoist, install the assembled drum(s) on the end of shaft (22).

8. Insert O-rings in the clutch assemblies. Then install spacer (06) against bearing (10).

9. Secure drum and clutch assemblies to the shaft wit washers (04 and 50). lockwashers (03 and 51) and locknuts (02 and 52).

10. Connect hydraulic swivels (01 and 53) to the ends of the shaft. Remove the caps and plugs from all hydraulic lines.

11. Install and adjust all brake bands on the drumshaft assembly (see Subsection 7C). Also adjust the clutch as described in Subsection 7D.

12. Install or connect any other items removed during disassembly.

13. Bleed the hydraulic cylinders to remove any air trapped in the hydraulic lines (see Subection 5A).

THIRD DRUMSHAFT (2100J1132-9)

REMOVAL. To remove the third drumshaft, proceed as follows (see Figure 7B-2):

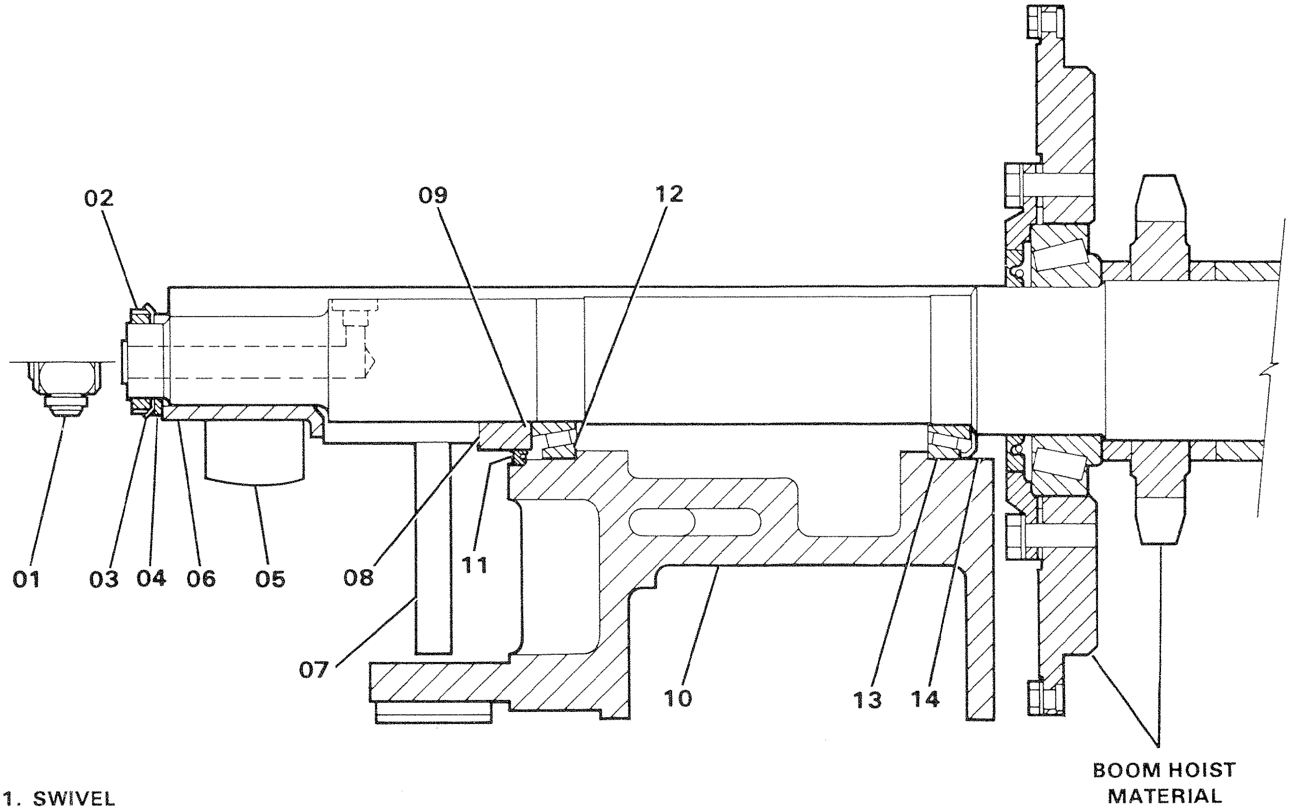
1. Disconnect and cap all hydraulic lines to the drumshaft assembly. Plug all connections where hydraulic lines were removed.

2. Disconnect and remove the third drum brake (15). See Subsection 7C.

3. Remove hydraulic swivel (01).

4. Remove nut (02), lockwasher (03) and spacer (04).

5. Support the drumshaft and remove bearing retainer, bearing support (16), bearing (05) and sleeve (06).



01. SWIVEL
02. NUT
03. LOCKWASHER
04. SPACER
05. BEARING
06. SLEEVE
07. CLUTCH ASSEMBLY
08. SPACER
09. O-RING
10. THIRD DRUM
11. SEAL
12. BEARING
13. BEARING
14. SEAL
15. BRAKE ASSEMBLY
16. BEARING SUPPORT
17. CAPSCREW
18. WASHER
19. NUT

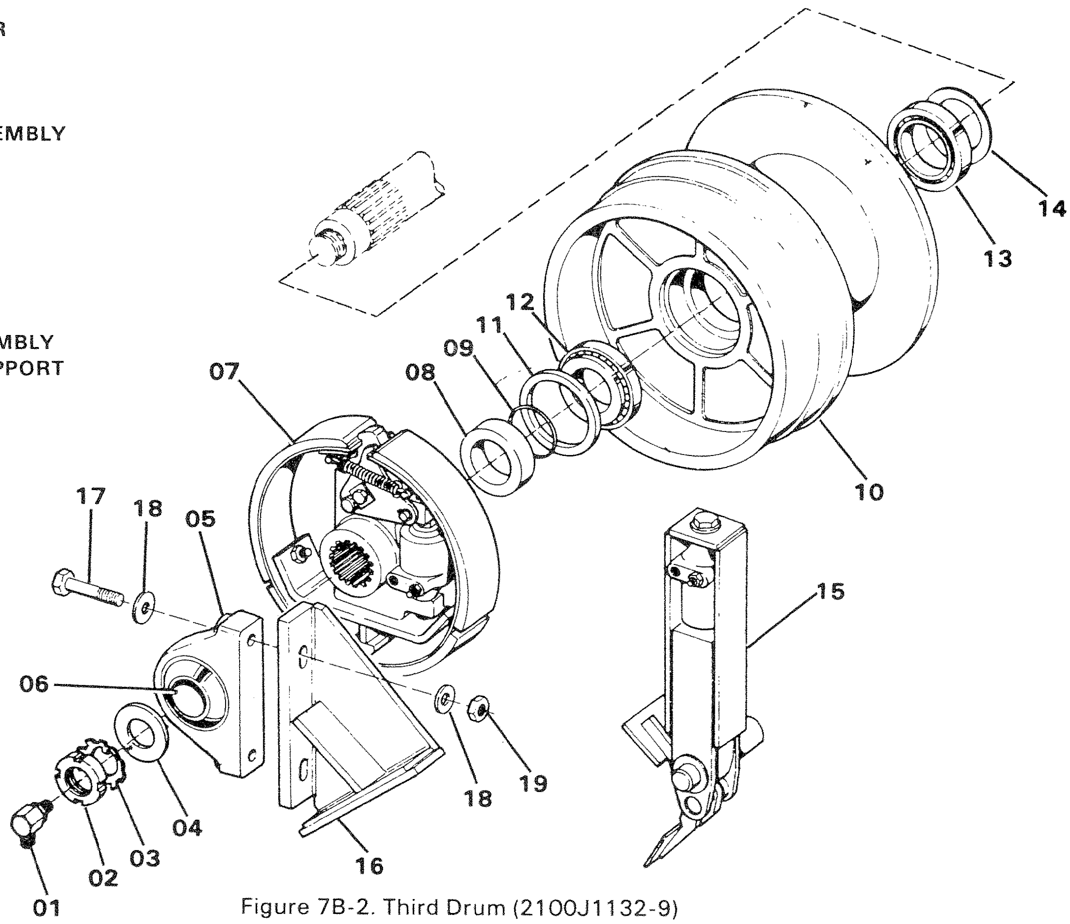
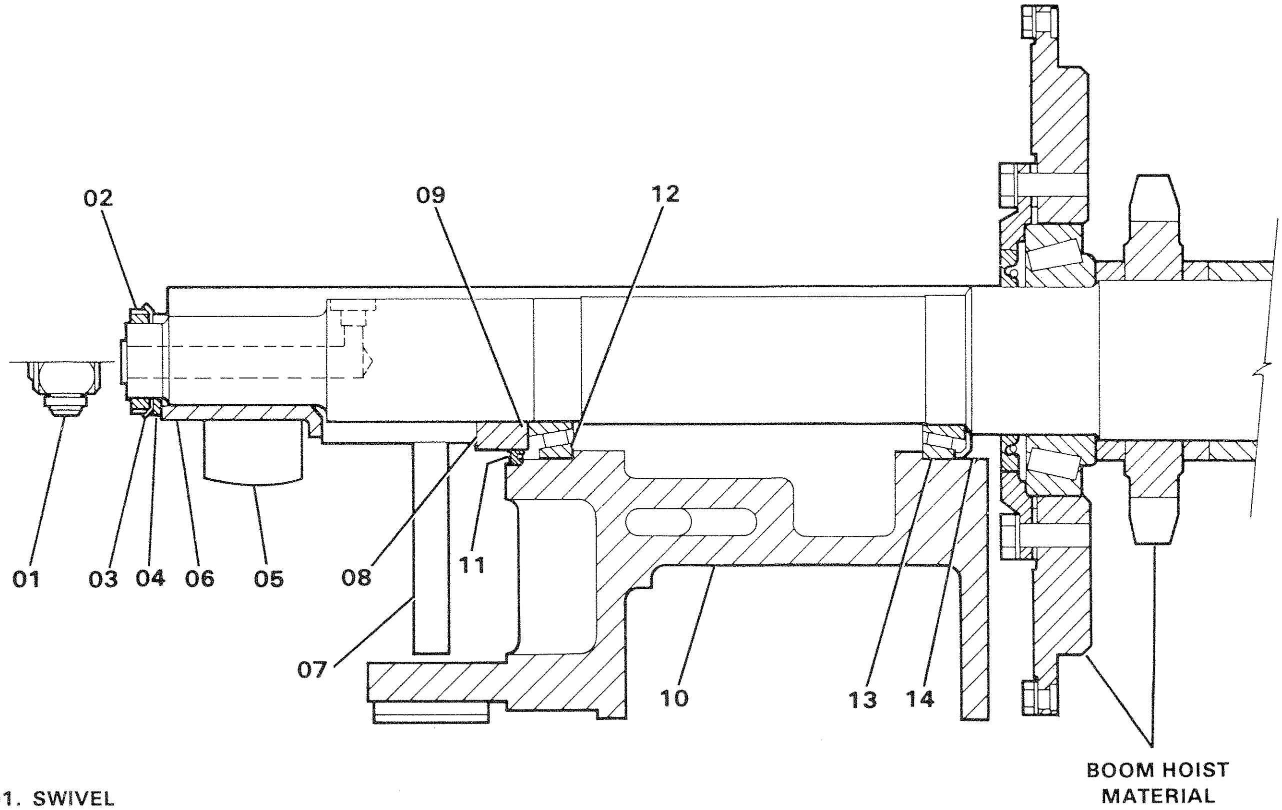


Figure 7B-2. Third Drum (2100J1132-9)



01. SWIVEL
02. NUT
03. LOCKWASHER
04. SPACER
05. BEARING
06. SLEEVE
07. CLUTCH ASSEMBLY
08. SPACER
09. O-RING
10. THIRD DRUM
11. SEAL
12. BEARING
13. BEARING
14. SEAL
15. BRAKE ASSEMBLY
16. BEARING SUPPORT
17. CAPSCREW
18. WASHER
19. NUT

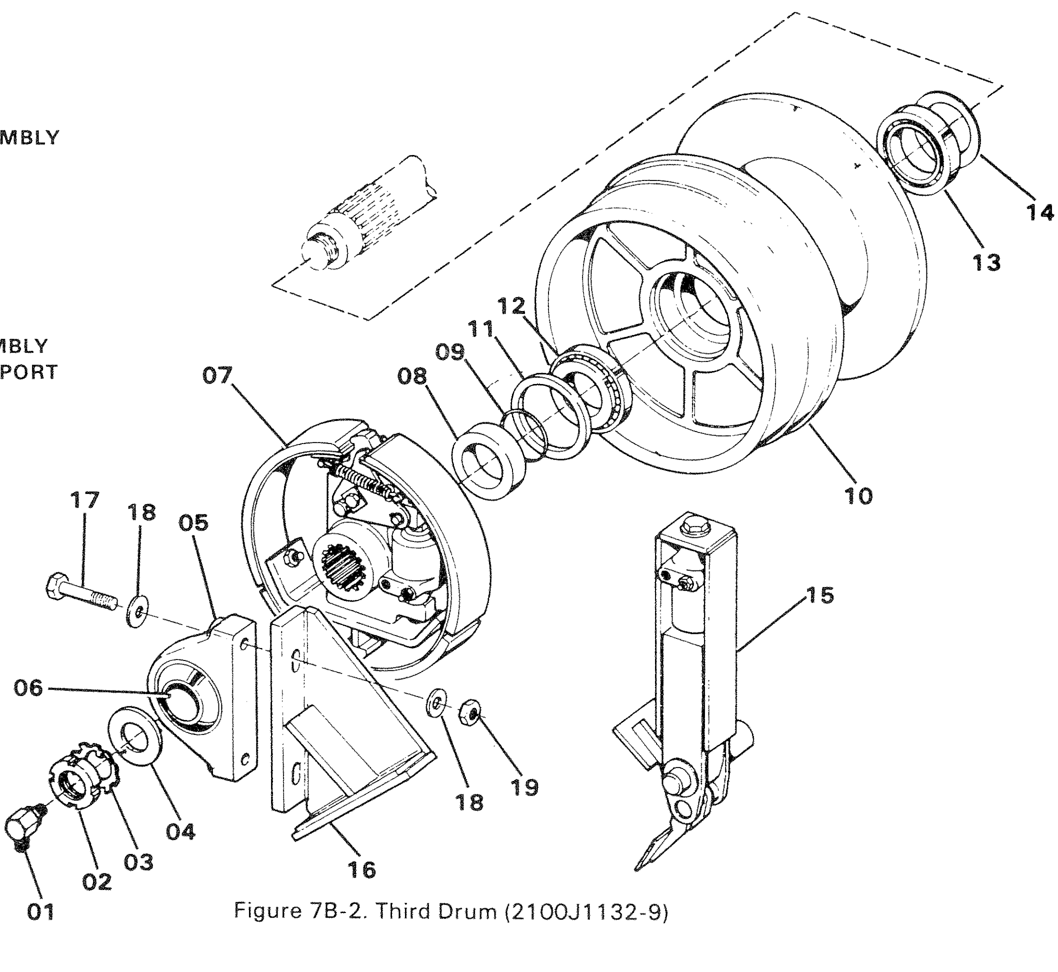


Figure 7B-2. Third Drum (2100J1132-9)

6. Remove clutch assembly (07) and place in a clean area.

7. Remove spacer (08) with O-ring (09).

8. Support the drum assembly with a hoist and slide drum (10) off of shaft.

9. Remove seal (11) and bearing (12) from the drum.

10. Remove bearing (13) and oil seal (14) from the drumshaft.

INSPECTION AND REPAIR. Prior to assembly, all drumshaft parts should be inspected as follows:

1. Replace all oil seals and O-rings. Any bearing which shows signs of wear or damage should be replaced.

2. Inspect the clutch and brake linings at this time. Replace the linings, if necessary, before reinstalling them on the drumshaft.

3. Repair or replace any damaged or broken parts. Be sure all threaded items are clean and that threads are not damaged. Studs must be tight before installing perts that are mounted to them.

4. Clean out all lube lines and grease passages to insure free flow of lubricant.

5. Inspect the drum cooling fins for cracks or broken fins. Repair or replace if necessary.

6. Inspect the brake and clutch rims forcracks, scratches or discoloration. Repair or replace if necessary.

INSTALLATION. To install the third drum, proceed as follows (see Figure 78-2):

1. Pack bearings (12 and 13) and drum (10) cavity with 472 grease.

2. Install seal (14), then bearing (13) on drumshaft.

3. Using a hoist, install drum (10) on drumshaft and over bearing (13).

4. Keep drum (10) supported and install bearing (12). Remove hoist.

5. Install seal (11) in drum (10).

6. Install spacer (08) and O-ring (09).

7. Install clutch assembly (07).

8. Install bearing retainer, bearing support (16), bearing (05) and sleeve (06). Tighten bearing retainer using capscrews (17), lockwashers (18) and nuts (19).

9. Install spacer (04), lockwasher (03) and nut (02). Tighten nut (02) until drum (10) does not rotate by hand. Loosen up on nut (02) until drum (10) just rotates freely by hand. Stake nut (02) with lockwasher (03).

10. Install swivel (01). Remove the caps and plugs from all hydraulic lines.

11. Install and adjust the third drum brake (15) (see Subsection 7C).

12. Install all hydraulic lines. Adjust the third drum clutch. See Subsection 7D.

13. Install or connect any other items removed during removal.

14. Bleed the hydraulic lines to remove any air trapped in the hydraulic lines (see Subsection 5A).

SUBSECTION 7C

DRUM BRAKES

GENERAL

This subsection contains the information necessary to remove, repair, install and adjust the main brakes and planetary brakes.

Several terms are often misunderstood when used in reference to brake bands on this machine. The following definitions, as used in this manual, are as follows:

1. Brake Set. This means the brake band is tightened around a rotating member to stop or prevent the rotation of that member.

2. Live End. This is the end of a brake band to which force is applied.

3. Dead End. This is the anchor end of a brake band. Typically, most lining wear will occur at this end of the band.

MAIN BRAKE (9215J107)

DESCRIPTION. Both the left and right main brake bands are connected to two hydraulic cylinders with opposing springs (see Figure 7C-1). When there is no pressure in the lock cylinder, each brake is set by the lock spring which opposes the lock cylinder. When the operator moves a brake lock switch to the OFF position, hydraulic pressure is applied to the lock cylinder, extending the piston and compressing the lock spring. This releases the brake so that it may be operated by the foot brake.

When the operator depresses the foot brake pedal, hydraulic pressure is applied to the brake cylinder, extending the piston and setting the brake. When the operator releases the brake pedal, hydraulic pressure is released from the brake cylinder, retracting the piston and releasing the brake. A return spring is used to assist in releasing the brake and retracting the piston.

When the brake linings are new and the brakes are in proper adjustment, two dimensions should be noted. With the brake set and hydraulic pressure released from the cylinders, the length of the lock spring should be 7-3/4 inches and the piston extension of the brake cylinder should be 1/8 inch.

When the brake linings start to wear, two things happen. With the brake set and hydraulic pressure released from the cylinders the length of the lock spring and the piston extension of the brake cylinder should increase.

As the lining wears, increasing the length of the lockspring and the piston extension of the brake cylinder, the brakes will need adjusting. See the Operator's Manual for the method of adjusting the brakes for normal lining wear.

The main brakes should be relined when brake lining thickness reaches 3/16 inch as measured at the dead end of the band.

REMOVAL. To remove the main brake bands, proceed as follows {see Figure 7C-2):

1. Shut down the engine and operate a control lever until all hydraulic pressure is exhausted from the system.

2. If any rope remains on the drum to be worked on, set the drum pawl to prevent the rotation of the drum.

3. Remove the sheet metal from around the brake band to be worked on.

4. Release the tension on the hanger springs by loosening the turnbuckles. Remove the hanger springs from the band.

5. Remove the brake band adjusting bolt and spring by removing the nut and spacer.

6. Remove the dead end link pin to free the dead end of the band from the dead end links. Remove the live end pin to free the live end of the band from the actuating levers.

7. Remove the brake band halves from the machine and reline them.

NOTE

A lining kit is available. See the Replacement Parts Manual.

8. After replacing the lining on the brake bands, file the linings with a half round file, or sandpaper, to take out the high spots. This will assure total contact with the drum.

9. Bevel the edges between each segment of the lining. This will reduce drag on the drum. Be sure to remove all filing dust from the rivet holes prior to installation.

INSPECTION AND REPAIR. Before reinstalling the band halves on the drum, inspect the following items:

1. Check all the springs for sufficient compression. Replace any weak springs.

2. Inspect all pins, bushings and linkages for wear. Replace any worn parts. Also, check that links, levers, and pins are not bent.

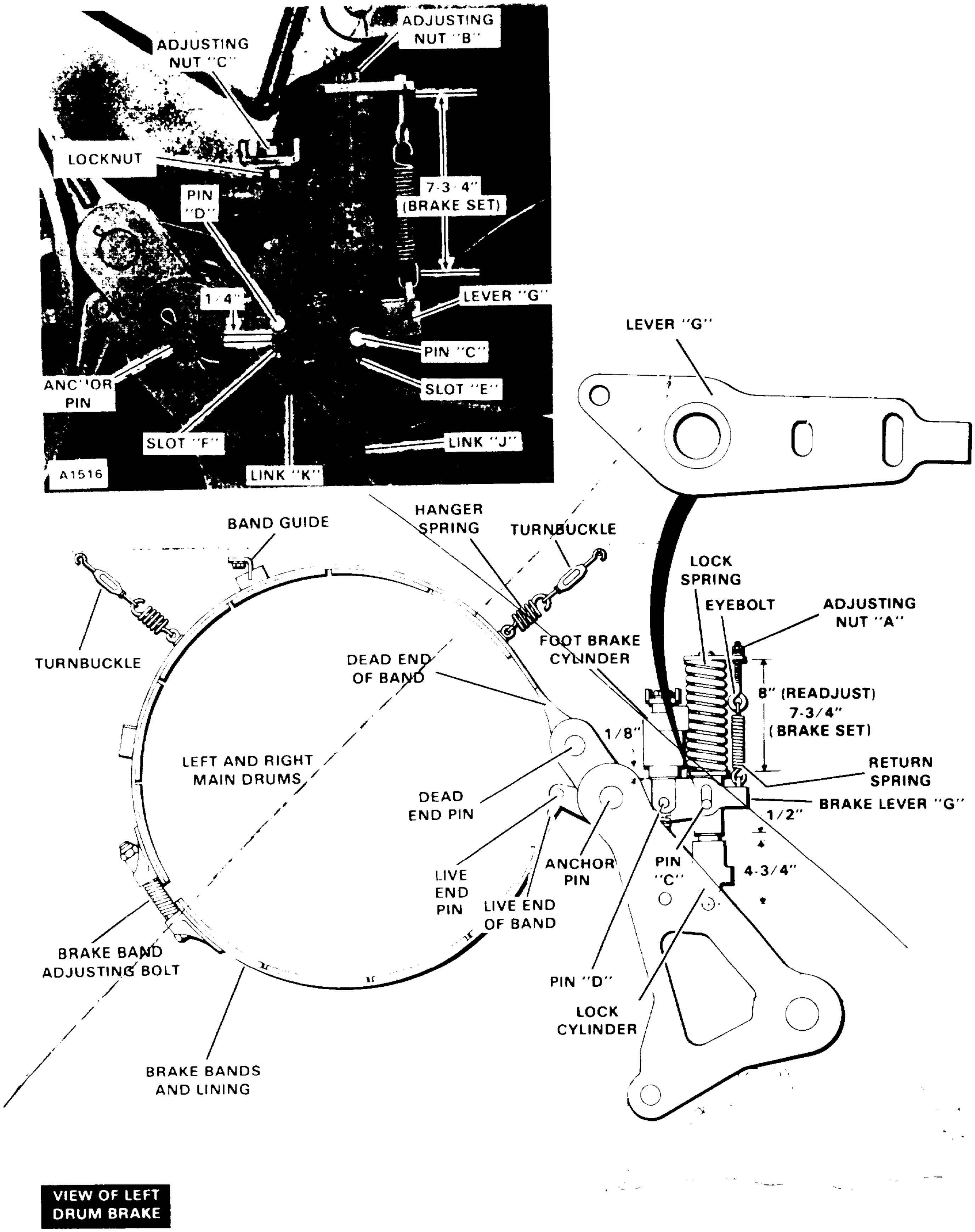


Figure 7C-1. Left and Right Drum Brakes (9215J107)

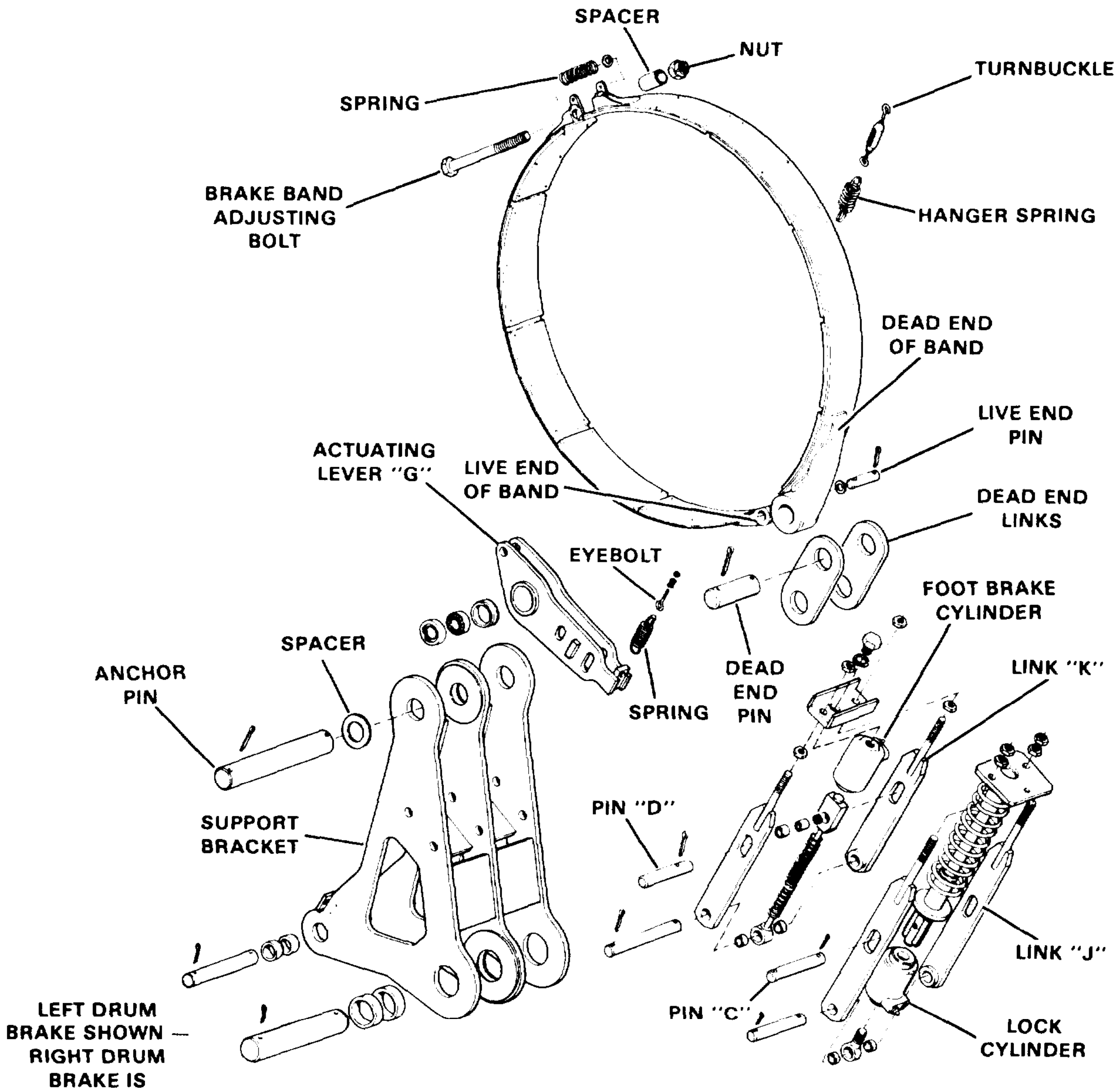


Figure 7C-2. Left and Right Drum Brakes (9215J107)

3. If the cylinders leak or have been performing erratically, remove and overhaul if necessary. See Subsection 5D.

4. Check the brake bands for distortion.

5. Inspect the brake drum surfaces for cracks, scoring or other damage.

6. Check the condition of needle bearings in lever "G". If worn or binds on link pins, replace the bearings.

INSTALLATION. After relining the brake bands, install the band halves as follows (see Figure 7C-2):

1. Set the brake band halves on the drum. Install the live end pin through the actuating levers and the live end of the band. Install the dead end pin through the dead end links and the dead end of the band. Install all cotter pins.

2. Install the spring, adjusting bolt and spacer on the band halves. Hold these items in place with the adjusting nut.

3. Install the hanger springs on the brake band. Initially adjust the hanger springs with the turnbuckles so that the brake band clears the drum.

4. Bleed the hydraulic cylinders to remove any air trapped in the hydraulic lines (see the Bleeding Procedure in Subsection 5A). See Subsection 5A for packing the spring recess of the cylinder.

ADJUSTMENT. The adjustment procedure listed below should be performed with the brake set spring applied and with no hydraulic pressure in either the brake set cylinder or the brake release cylinder. To adjust the main brakes when the bands have been removed or the brake operating mechanism has been disturbed, proceed as follows (see Figure 7C-1):

1. If either brake actuating cylinder has been repaired or removed, the cylinder must be bled to remove any air from thecylinder and lines. See Subsection 5A of this manual for the cylinder bleeding procedure.

2. The set-up dimension for the brake release cylinder is 4-3/4 inches. Measure this dimension from the center of the cylinder eyebolt to the edge of the cylinder. To alter this dimension, rotate the cylinder on the eyebolt.

3. Adjust the brake band adjusting bolt to obtain a dimension of 1/2 inch of piston extension at the brake release cylinder.

4. The set-up dimension for the brake set spring is 7-3/4 inches of spring height. To obtain this dimension,loosen or tighten adjusting nuts "B".

5. Rotate adjusting nuts "C" to obtain a clearance of 1/4 inch between pin "D" and the bottom of the slot in lever "G". This should positron pin "D" near the top of slot "F" in link "K".

ADJUSTMENT CHECK. Perform the following checks to be sure that the load drum brakes are properly adjusted (see Figure 7C-1):

1. Depress the drum brake pedal in the upper cab. This will extend the brake set cylinder and thereby apply the load drum brake At this point, pin "C" should not contact the top of slot "L" (slot "L" is located in lever "G").

2. Move the drum brake switch (located in the upper cab) to the ON position. At this point, pin "D" should not touch the top of slot "K" (slot "K" is located in lever "G"). Also, the piston of the brake release cylinder should be projecting about 1/2 inch from the cylinder body.

3. Pins "C" and "D" should never come into contact with the ends of the slots in links "K" and "J".

OPERATION CHECK. To be sure that the load drum brakes are operating properly, perform the following steps:

1. Lift a capacity load an inch or two off of the ground and depress the drum brake pedal to hold the load. Move the drum brake switch to the ON position. Slowly release the drum brake pedal to see if the load will drift downward.

CAUTION

Reapply the drum brake pedal before moving the drum brake switch to the OFF position.

2. Move the drum brake switch to the OFF position, and lower the load to the ground using the drum brake pedal.

3. If there was any downward drift of the load during the test performance in step 1, the nut on the brake band adjusting bolt must be tightened (see Figure 7C-1).

4. Tighten the nut as much as is necessary to prevent the load from drifting downward during the test described in step 1.

5. The brake band must be tightened until the test described in step 1 can be properly performed. Do not overtighten the band to the point where the weight of the unloaded hook block is not heavy enough to lower the drum rope when the drum control lever is in the neutral position.

6. Adjust the band support turnbuckles so that the clearance between the brake drum and the brake lining is equal at all points around the drum.

7. See Subsection 5C of this manual for instructions on the adjustment of the brake drum pedal.

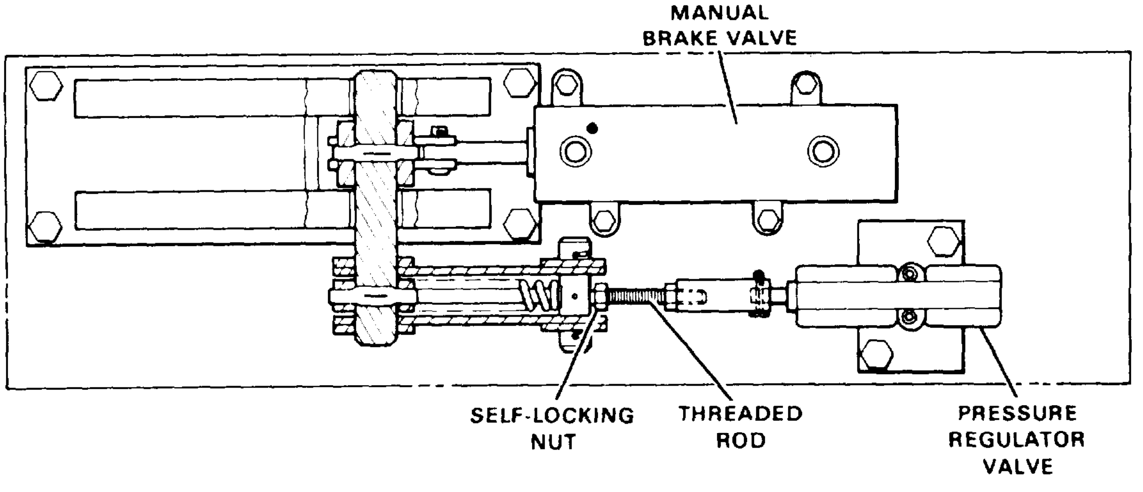


Figure 7C-3. Pedal Linkage Adjustment (2100J978)

PLANETARY BRAKES (9215J107-14)

DESCRIPTION. The left and right drum planetary brakes are provided with power lowering on these drums and are mounted over the planetary spiders. These brakes are hydraulically set, spring released type brakes. When there is no pressure in the planetary brake cylinder, its piston is retracted and the planetary brake is held in the released position by springs.

When the operator engages a planetary brake by means of the control lever, hydraulic fluid is directed to the planetary brake cylinder. With hydraulic pressure applied to the cylinder, its piston extends and applies force to the linkage which contracts the brake bands and sets the brake (see Figure 7C-4):

When the linings are new and the brakes are in proper adjustment, the length of the cylinder piston extension with the brake set (hydraulic pressure applied) should be 5/8 inch. When the brake lining starts to wear, this dimension will increase (with the brake set). See the Operator's Manual for the method of adjusting the brakes for normal lining wear.

The planetary brakes should be relined when brake lining thickness reaches 3/16 inch as measued at the dead end of the band.

REMOVAL. To remove the planetary brake bands, proceed as follows (see Figure 7C-5):

1. Shut down the engine and operate a control lever until all hydraulic pressure is exhausted from the system.

2. If any rope remains on the drum to be worked on, set the drum pawl to prevent rotation of the drum.

3. Remove the sheet metal from around the brake band to be worked on.

4. Release the tension on the hanger springs by loosening the turnbuckles. Remove the hanger springs from the band.

5. Remove the brake band adjusting bolt and spring by removing the nut and spacer.

6. Remove the dead end link pin to free the dead end of the band from the dead end links. Remove the live end pin to free the live end of the band from the actuating levers.

7. Remove the brake band halves from the machine and reline them.

NOTE

A lining kit is available. See the Replacement Parts Manual.

8. After replacing the lining on the brake bands, file the linings with a half round file, or sandpaper, to take out the high spots. This will assure total contact with the drum.

9. Bevel the edges between each segment of the lining. This will reduce drag on the drum. Be sure to remove all filing dust from the rivet holes prior to installation.

INSPECTION AND REPAIR. Before reinstalling the band halves on the drum, inspect the following items (see Figure 7C-5):

1. Check the springs for sufficient tension. Replace any weak springs.

2. Inspect all pins, bushings and linkages for wear. Replace any worn parts. Also checkthat links, guides, and pins are not bent.

3. If the operating cylinders leak or have been performing erratically, remove and overhaul if necessary. See Subsection 5D.

4. Check the brake bands for distortion.

5. Inspect the brake drum surfaces for cracks, scoring or other damage.

INSTALLATION. After relining the brake bands, install the band halves as follows (see Figure 7C-5):

1. Install the band halves on the drum. Install the live end pin through the actuating levers and the live end of the band. Install the dead end pin through the dead end links and the dead end of the band. Install all cotter pins.

2. Install the spring, adjusting bolt and spacer on the band halves. Hold these items in place with the adjusting nut.

3. Install the hanger springs on the brake band. Initially adjust the hanger springs with the turnbuckles so that the brake band clears the drum.

4. Bleed the hydraulic cylinders to remove any air trapped in the hydraulic lines. See the Bleeding Procedure in Subsection 5A.

ADJUSTMENT. To adjust the planetary brakes when the bands have been removed, proceed as follows (see Figure 7C-4):

1. With the planetary brake released, check the piston extension of the cylinder. The piston should extend a minimum of 1/8 inch; if not, adjust by means of adjusting nut "C".

2. With the brake set (hydraulic pressure to the cylinder) the length of the piston extension should be 5/8 inch. Adjust the brake band adjusting bolt until this dimension is reached.

NOTE

Loosening the brake band adjusting bolt will increase the piston extension. Tightening the adjusting bolt will decrease the piston extension.

3. After the machine has been operated long enough to warm the drums and the brakes have been properly adjusted, check the adjustment of the hanger springs. The hanger springs should be adjusted so that the brake band clears the drum uniformly around its circumference, with the brake in the released position (hydraulic pressure released).

4. Recheck dimensions given in steps 1 and 2 with the brakes warmed and adjust as necessary. Be sure that pin "D" does not come in contact with slot "F"of link "K". If this occurs, step 1 and 2 must be repeated to eliminate the pin to slot contact.

5. Replace any sheet metal removed.

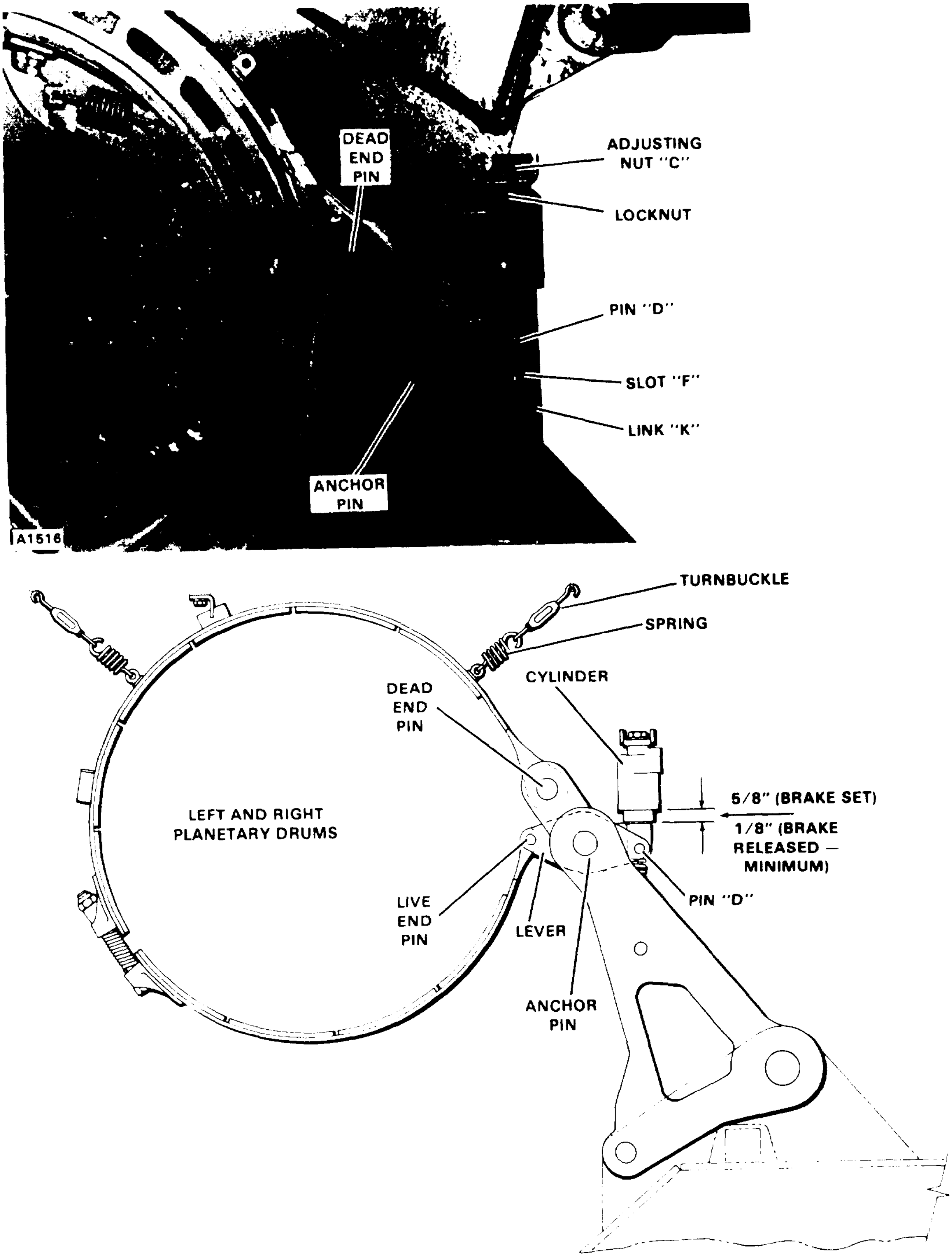


Figure 7C-4. Planetary Brake (9215J107-14)

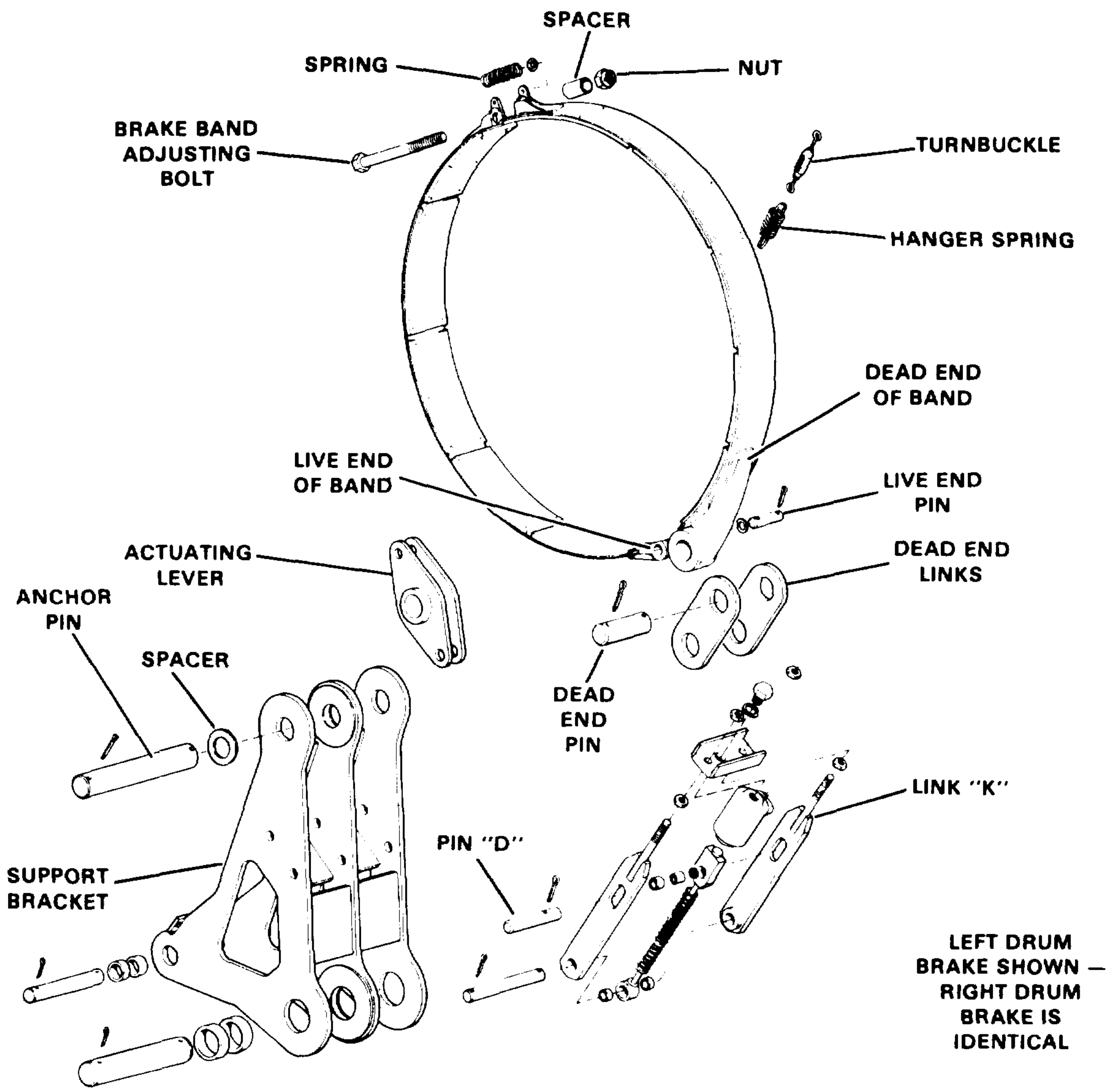


Figure 7C-5. Planetary Brakes (9215J107-14)

THIRD DRUM BRAKE (2100N464-1)

DESCRIPTION. The third drum brake is spring set-hydraulically released brake and is supplied with the third drum. When there is no pressure in the third drum brake cylinder, the piston is retraced and springs apply the third drum brake.

When the operator moves the third drum control lever, hydraulic fluid is directed to the third drum brake cylinder. With hydraulic pressure applied to the cylinder, the piston extends and applies force to the linkage, overcoming the spring and releasing the brake.

When the linings are new and the brake is in proper adjustment, the brake spring length with the brake applied (hydraulic pressure released), should be 6-3/16". When the brake lining starts to wear, thisdimension will increase.

See the Operator's Manual for the method of adjusting brakes for normal lining wear.

The third drum brake should be relined when brake lining thickness reaches 3/16 inch (0.48 cm) as measured at the dead end of the band.

REMOVAL. To remove the third drum brake band, proceed as follows (see Figure 7C-6):

1. Shut down the engine and operate a control lever until all hydraulic pressure is exhausted from the system.

2. Unspool any rope left on the third drum.

3. Remove the brake band adjusting bolt and spring by removing the nut and spacer.

4. Remove the dead end pin to free the dead end of the band from the dead end bracket. Remove the live end pin to free the live end of the band from the actuating rod.

5. Remove the brake band halves from the machine and reline them.

NOTE

A lining kit is available. See the Replacement Parts Manual.

INSPECTION AND REPAIR. Before installing the band halves on the drum, inspect the following items (see Figure 7C-6):

1. Replace any weak or distorted spring.

2. Inspect the pins and actuating rod for wear. Replace any worn parts.

3. If the cylinder leaks or has been performing erratically, remove and overhaul if necessary. See Subsection 5D.

4. Check the brake bands for distortion. Replace if necessary.

5. Inspect the brake drum surface for cracks, scoring or other damage. See Subsection 7B.

INSTALLATION. After relining the brake band, install the band halves as follows (see Figure 7C-6):

1. Set the brake band halves on the drum. Install the live end pin through the actuating rod and the live end of the band. Install the dead end pin through the dead end bracket and the dead end of the band. Install all washers and cotter pins.

2. Install the spring, adjusting bolts and spacer on the band halves. Hold these items in place with the adjusting nut.

3. Bleed the hydraulic system See Subsection 5A.

4. Turn the brake band adjusting bolt to get a spring dimension of 6-3/16” as shown.

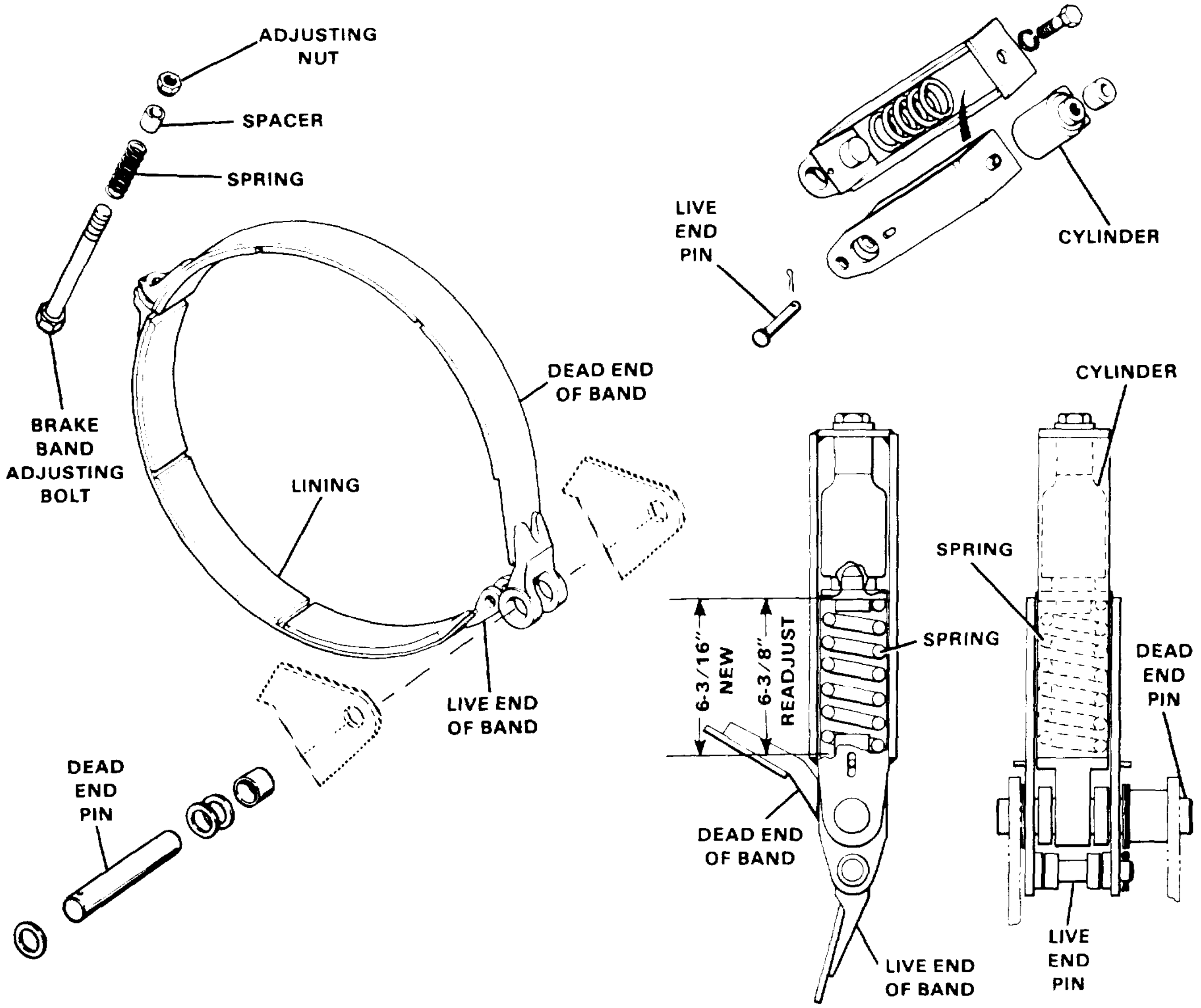


Figure 7C-6. Third Drum Brake (2100N464)

SUBSECTION 7D

CLUTCHES

GENERAL

This subsection contains the information necessary to remove, repair, install and adjust the left and rightdrum clutches.

MAIN DRUM CLUTCHES (2915J64)

DESCRIPTION. The left and right drum clutches are located on the ends of the hoist drumshaft. These clutches are hydraulically applied, spring released. When there is no pressure in the clutch cylinder, the return spring applies force to the actuating levers to contract the band and release the clutch. When the operator moves a clutch control lever to apply a clutch, hydraulic fluid is forced into the cylinder. This causes the piston to extend and apply force on the actuating levers to expand the band and apply the clutch.

Since the lining will wear with time and constant usage, a periodic check must be made to determine the need for replacing the lining. When wear has reduced the lining to within 1/16 inch of the rivets, it should be replaced. This distance would amount to 7/32 inch measured from the outside.

REMOVAL AND DISASSEMBLY. To remove and disassemble the clutch, proceed as follows (see Figure 7D-1):

1. If any rope remains on the drum to be worked on, set the drum pawl to prevent the rotation of the drum.

2. Remove any material that may interfere with the removal of the clutch assembly.

3. Loosen jam nuts (15) and turn in stopscrews (14) until there is adequate clearance around the clutch band (01).

4. Disconnect and cap the hydraulic line to the clutch swivel. Unscrew the swivel from the drumshaft.

5. Disconnect the line that runs from cylinder (21) to the drumshaft and remove the clutch assembly from the machine.

6. Remove springs (05) from band (01). Remove nuts (30) from capscrews (27) and remove shims (28) The band, in two pieces, can now be removed for relining.

7. Inspect the clutch drum to see that it is not cracked, scored or otherwise damaged.

INSPECTION AND REPAIR. Prior to reinstalling the clutch, inspect and repair the following items (see Figure 7D-1):

1. Replace return springs (05).

2. Remove bushing (20) from spider (19) and replace it.

3. If cylinder (21) leaks or has been performing erratically, remove, overhaul, and/or replace it. See Subsection 5D.

4. Check the clutch band for distortion and reline it.

NOTE

A lining kit is available. See the Replacement Parts Manual.

5. Check actuating levers (09), trunnion (10) and spider (19) for wear. Replace if necessary.

6. Remove spring (26) by turning out eyebolt (11). Check the compression quality of the spring. If acceptable, assemble to the clutch spider Preload spring (26) to 5-1/2 inches.

ASSEMBLY AND INSTALLATION To assemble and install the clutch, proceed as follows (see Figure 7D-1):

1. Assemble band (01) with two shims (28), lockwashers (29) and nuts (30).

NOTE

Shims (28) can be used to adjust the clutch when linings are worn.

2. Place the clutch band on the spider assembly and attach springs (05).

3. Insert O-ring (37) in the groove of the hub.

4. Attach the clutch assembly to the drumshaft.

5. Attach the hydraulic swivel to the shaft. Connect the hydraulic lines and bleed cylinder (21) to remove any air trapped in the lines (see Subsection 5A).

ADJUSTMENT. To adjust the clutch after it has been removed, proceed as follows (see Figure 7D-1):

1. Loosen the jam nuts on all stopscrews (14).

2. Backoff on all stopscrews (14) until clutch band (01) is no longer in contact with the heads of the stopscrews.

3. Adjust setscrew (23) at the dead end of the clutch shoe so that there is approximately 0.030 inch clearance between the clutch lining and the clutch drum, with clutch band guide (16) located on the top of the clutch.

4. Adjust setscrew (24) at the live end of the clutch so that there is approximately 0.035 inch of clearance between the clutch lining and the clutch drum.

5. Loosen jam nut (15) and turn push rod (22) so that cylinder (21) is completely retracted with the clutch control lever in the neutral position.

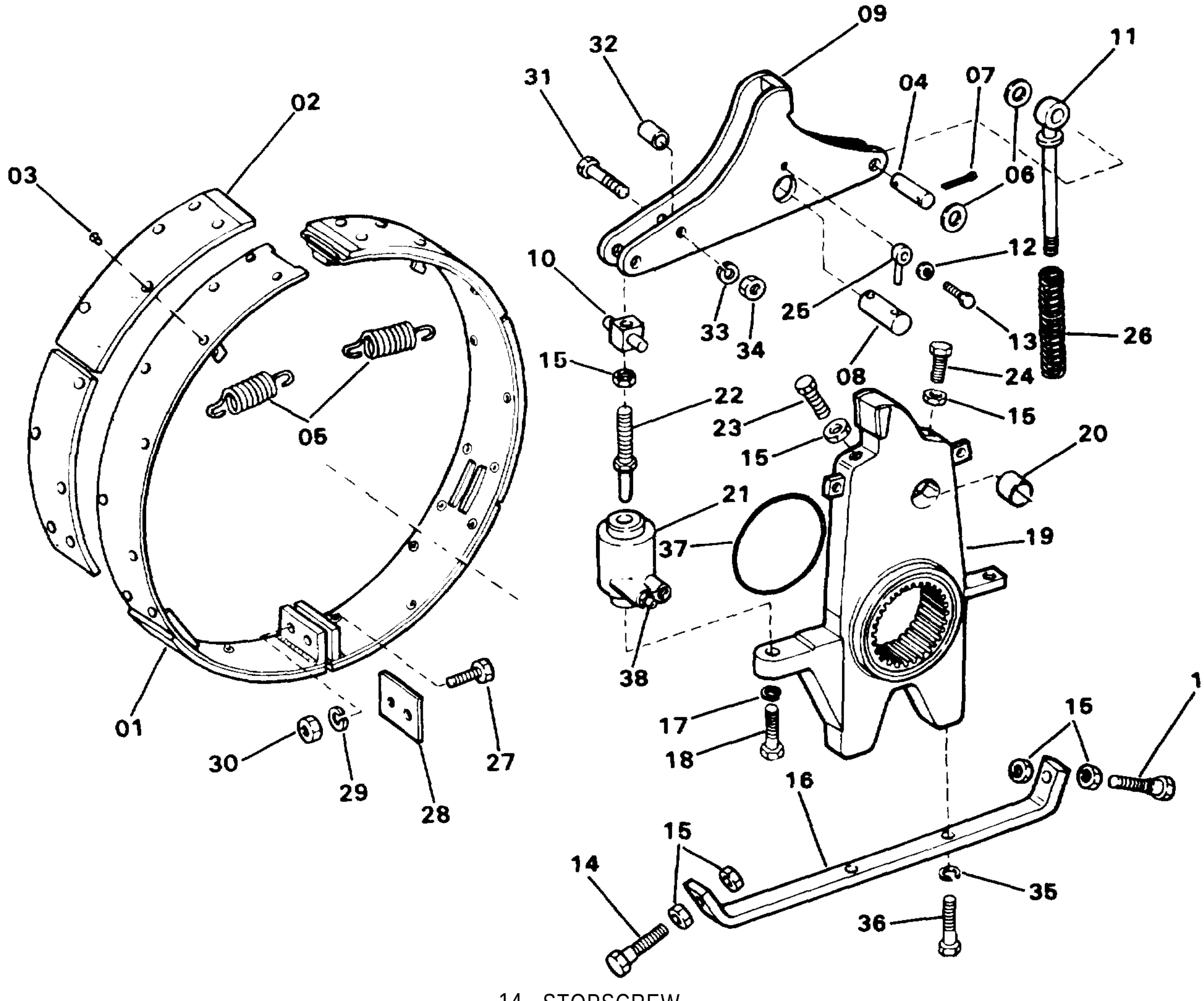
6. With the clutch in the released position, turn stopscrews (14) to center the clutch band in the clutch drum. The band must be centered to prevent the lining from rubbing against the drum, There should be no pressure against the clutch band from any of the stopscrews.

7. Starting at the top of lever (09), check for at least 0.030 inch clearance between the clutch lining and the drum at 60 degree intervals.

8. Check that the piston in the cylinder returns to contact push rod (22) each time the clutch is released.

9. Tighten all the jam nuts after the adjustment has been completed.

10. Start the engine and check the clutch for proper operation.



01. BAND
02. LINING
03. RIVET
04. PIN
05. SPRINGS
06. WASHER
07. COTTER PIN
08. PIN
09. LEVER
10. TRUNNION
11. EYEBOLT
12. WASHER
13. CAPSCREW
14. STOPSCREW
15. JAM NUT
16. GUIDE
17. WASHER
18. CAPSCREW
19. SPIDER
20. BUSHING
21. CYLINDER
22. PUSH ROD
23. SETSCREW
24. SETSCREW
25. ROD END
26. SPRING
27. CAPSCREWS
28. SHIMS
29. LOCKWASHER
30. NUT
31. CAPSCREW
32. SPACER
33. LOCKWASHER
34. NUT
35. LOCKWASHER
36. CAPSCREW
37. O-RING
38. BLEED SCREW

Figure 7D-1, Main Drum Clutch (2915J64)

THIRD DRUM CLUTCH (9215J105-2)

DESCRIPTION. The third drum clutch is located on the end of the third drum shaft. This clutch is hydraulically applied, spring released. When there is no pressure in the clutch cylinder, the return spring applies force to the actuating levers to contract the band and release the clutch. When the operator moves the third drum control lever to raise a load on the third drum, hydraulic fluid is forced into the cylinder. This causes the piston to extend and apply force on the actuating levers to expand the band and apply the clutch.

Since lining wear will usually be greatest at the dead end of the clutch band, the clutch band may be rotated 180° when wear has reduced the thickness of the lining at the dead end to 1/4 inch. When wear has reduced the thickness of the lining to within 1/16 inch of the rivets, the band should be relined.

REMOVAL AND DISASSEMBLY. To remove and disassemble the clutch, proceed as follows {see Figure 7D-2):

1. If any rope remains on the third drum, set the third drum brake to prevent the rotation of the durm.

2. See Subsection 7B, Third Drum (2100J1132-9) and remove the following:

A. Remove the hydraulic line from the swivel and remove the swivel.

6. Remove the nut, lockwasher and spacer from the end of the shaft.

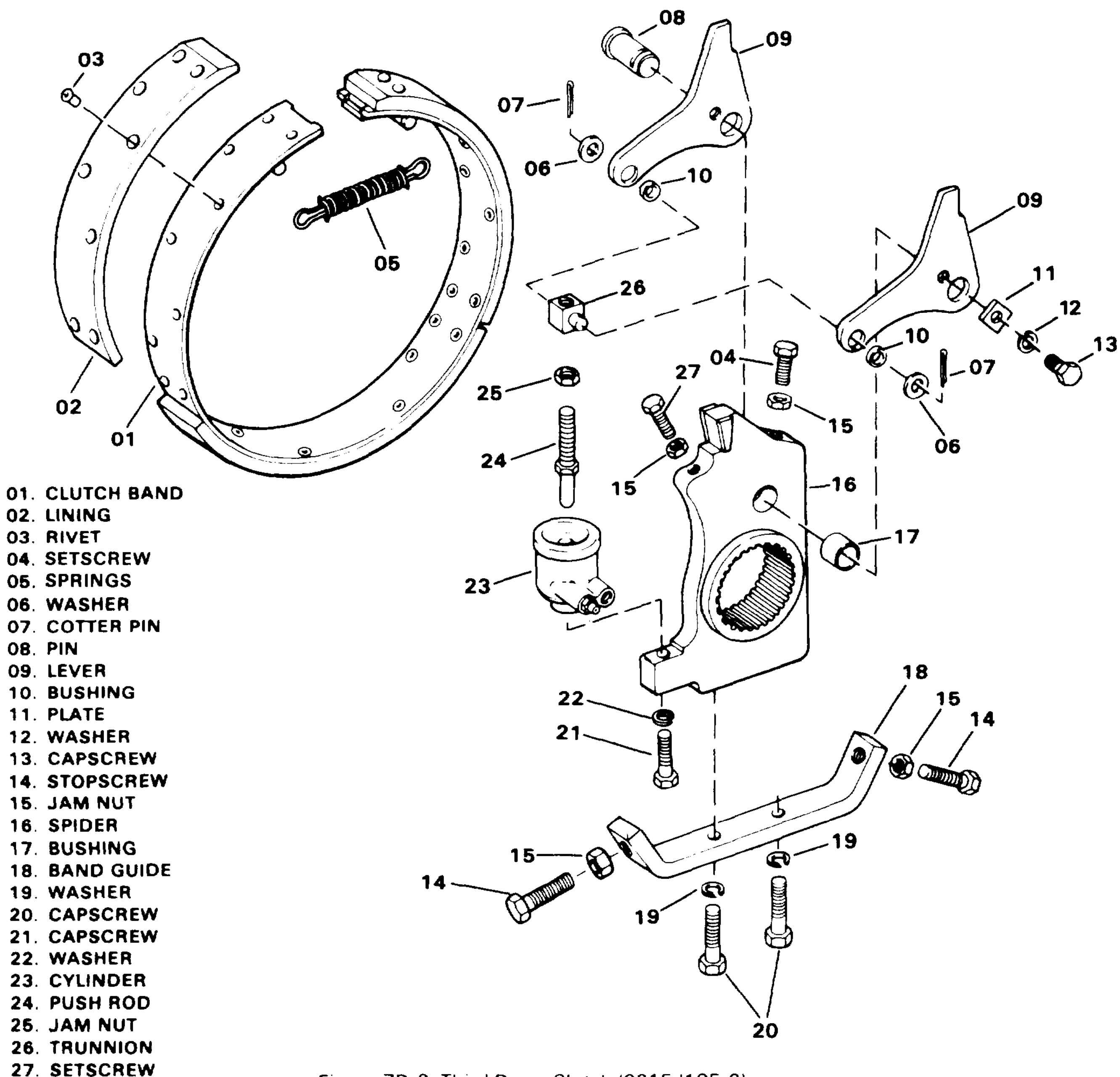


Figure 7D-2. Third Drum Clutch (9215J105-2)

C. Support the drumshaft and remove bearing retainer, bearing support, bearing and sleeve.

3. Loosen jam nuts (15) and turn stopscrews (14) until there is adequate clearance around clutch band (01).

4. Disconnect the line that runs from cylinder (23) to the shaft and remove the clutch assembly from the machine.

5. Remove springs (05) from band (01). The band can now be removed for relining.

INSPECTION AND REPAIR. Prior to reinstalling the clutch, Inspect and repair the following items (see Figure 7D-2):

1. Replace return springs (05)

2. Remove bushing (17) from spider (16) and replace it.

3. If cylinder (23) leaks or has been performing erratically, remove and overhaul or replace it. See Subsection 5D.

4. Check the clutch band for distortion and reline it.

NOTE

A lining kit is available. See the Replacement Parts Manual.

5. Check actuating levers (09) and spider (16) for wear. Replace if necessary.

6. Inspect the clutch drum to see that it is not cracked, scored or otherwise damaged.

ASSEMBLY AND INSTALLATION. To assemble and install the clutch, proceed as follows (see Figure 7D-2):

1. Place the clutch band on the spider assembly and attach springs (05).

2. Install a new O-ring in the groove of spider (16).

3. Install the clutch assembly to the drumshaft and the third drum.

4. Install bearing retainer, bearing support, bearing and sleeve. Tighten bearing retainer using capscrews, lockwashers and nuts.

5. See Subsection 7B, Third Drum (2100J1132-9) step 9 and adjust drum rotation.

6. Attach the hydraulic swivel to the shaft. Connect the hydraulic lines and bleed cylinder (23) to remove any air trapped in the lines. See Subsection 5A.

ADJUSTMENT. To adjust the clutch after it has been removed, proceed as follows (see Figure 7D-2):

1. Loosen the jam nuts on all stopscrews (14).

2. Backoff on all stopscrews (14) until clutch band (01) is no longer in contact with the heads of the stopscrews.

3. Adjust setscrew (27) at the dead end of the clutch shoe to approximately 0.058 inch clearance between the clutch lining and the clutch drum, with clutch band guide (18) located on the top of the clutch.

4. Adjust setscrew (04) at the live end of the clutch to approximately 0.063 inch of clearance between theclutch lining and the clutch drum.

5. Loosen jam nut (25) and turn push rod (24) so the piston in the cylinder (23) is completely retracted with the clutch control lever in the neutral position.

6. With the clutch in the released position, turn stopscrews (14) to center the clutch band in the clutch drum. The band must be centered to prevent the lining from rubbing against the drum. There should be no pressure against the clutch band from any of the stopscrews.

7. Start the engine and check the adjustment by engaging the clutch. Also check to see that the piston in the hydraulic cylinder returns to contact push rod (24) each time the clutch is released.

NOTE

After making several clutch engagements, starting at the top of lever (09). check for at least 0.063 inch clearance between the clutch lining and the drum at 60 degree intervals.

8. Tighten all jam nuts after the adjustment has been completed.

TABLE OF CONTENTS

SUBSECTION 7E

DRUM PAWLS

GENERAL

This subsection covers the removal, installation and adjustment of the right and left drum pawls.

DRUM PAWLS (2100J1320-1)

DESCRIPTION. Both the right and left drums are provided with identical drum pawls (01 and 02), see Figure 7E-1. The pawls are spring engaged and hydraulically disengaged. They are controlled by drum switches located in the operator's module. The pawls should be engaged whenever a load is suspended for an extended period of time. Also, engage and lock the pawls whenever the machine is shut down

01. LEFT DRUM PAWL
02. RIGHT DRUM PAWL
03. WASHERS
04. COTTER PIN
05. CLEVIS
06. NUT
07. CYLINDER
08. CAPSCREW
09. LOCKWASHER
10. MOUNTING BRACKET
11. NUT
12. BRACKET
13. CAPSCREW
14. LOCKWASHER
15. ADJUSTING NUTS
16. BRACKET
17. EYEBOLT
18. SPRING

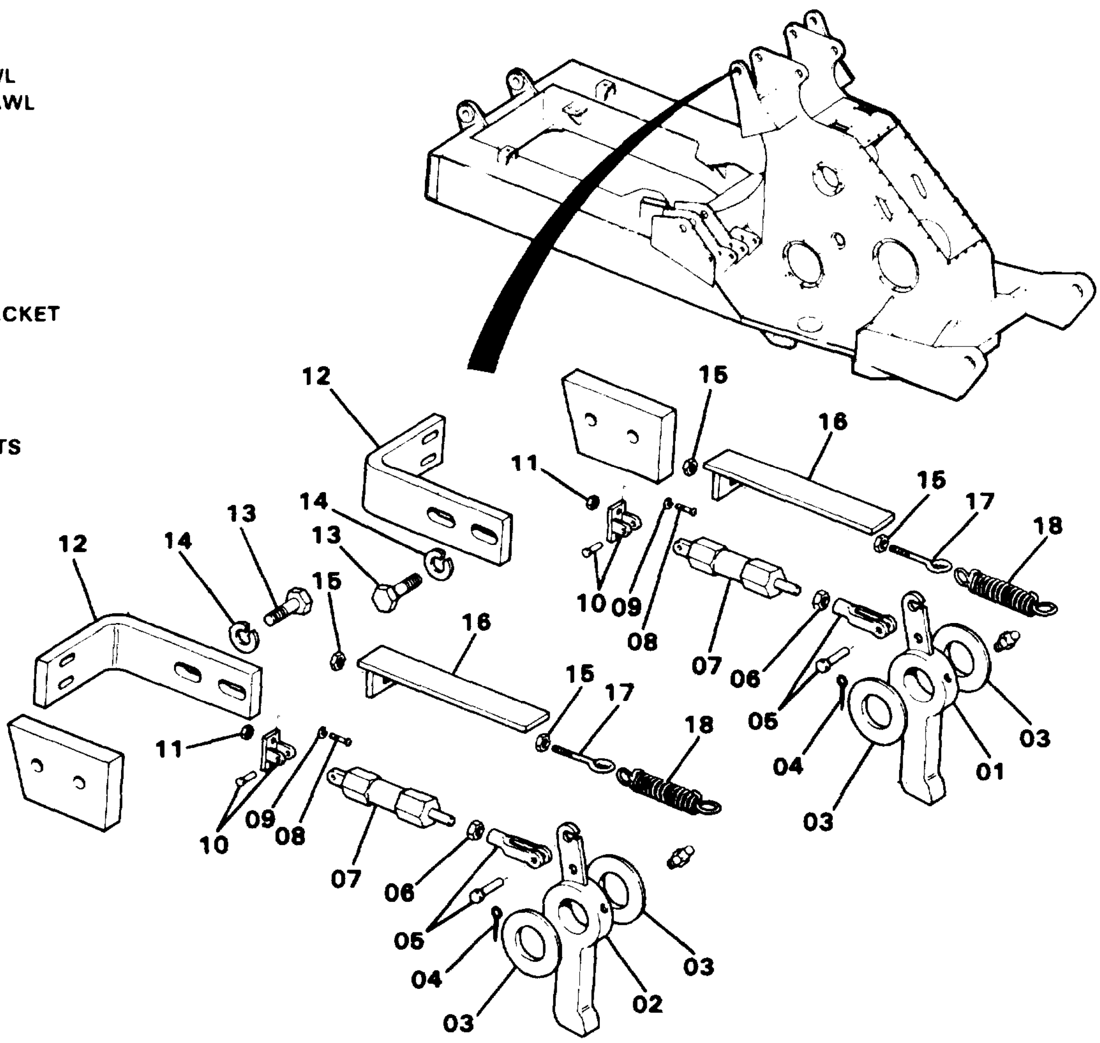


Figure 7E-1. Drum Pawls (2100J1320-1)

When the pawl switch is in the ON position hydraulic pressure is released from the cylinder and the spring engages the pawl in the drum ratchet, When the switch is OFF, hydraulic pressure overcomes the spring tension and releases the pawl.

REMOVAL AND INSTALLATION. If upon inspection, it is revealed the pawl is damaged in any way, the pawl must be replaced. Also, if the hydraulic cylinder does not function as described above, it must be replaced with a new one. To replace either or both of these items, proceed as follows:

1. Start the engine and lower the hook block, or any lifting device that may be connected to the left and right main drum, to the ground.

2. Render the machine inoperable by disconnecting the ground cable to the battery.

3. To change the pawl, proceed as follows (see Figure 7E-1):

A. Loosen jam nuts (15) and release tension in spring (18). Remove spring (18). Disconnect hydraulic cylinder clevis (05) from pawl (01 or 02).

B. Remove cotter pin (04) and washer (03). Remove pawl (01 or 02) and install a new pawl, washersand cotter pin (04).

C. Install clevis (05) to pawl. Connect spring (18) to the pawl and adjust the pawl as explained later.

4. To replace hydraulic cylinder (07), proceed as follows:

A. Move the drum pawl switch to the OFF position. Make sure all hydraulic pressure is released from the cylinder. Disconnect the hydraulic lines from cylinder (07).

B. Remove clevis (05) from pawl and remove cylinder (07) from mounting bracket (10).

C. Remove clevis (05) and nut (06) from cylinder (07) and install on new cylinder. See Figure 7E-2 and set clevis distance to 1" dimension shown. Tighten nut (06).

D. Install cylinder (07) on mounting bracket (10) and install clevis (05) on pawl. Adjust pawl as explained below.

ADJUSTMENT. To adjust the pawl after pawl and/or cylinder replacement, proceed as follows (see Figure 7E-2):

CAUTION

The following procedure must be done very carefully to arrive at the right settings. If not correct, serious damage could result to the machine when operated.

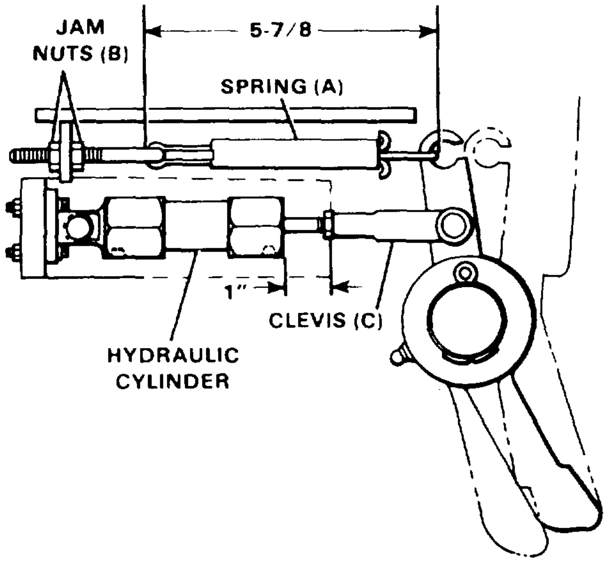


Figure 7E-2. Drum Pawls (2100J1320-1)

1. Engage the pawls into the drum teeth.

2. Check both pawls for complete engagement to the drum teeth.

NOTE

It may be necessary to push the drum control levers to the "lower" position momentarily to enage the pawls in the drum teeth.

3. Release the left and right drum pawl switches and allow them to return to the OFF position and pull the drum control levers to the "raise" position momentarily to disengage the pawls from the drum teeth.

4. Check both pawls for complete release from the drum ratchet teeth.

5. If the pawls do not operate properly, proceed as follows:

A. Repeat steps 1 and 2.

B. The length of pawl spring (A) should be 5-7/8" and the pawls must be fully engaged in the drum ratchet teeth.

C. If the spring is not the dimension given in step B, adjust to 5-7/8" using jam nuts (B).

D. The pawls should be disengaged from the drum teeth by a minimum of 1/4" when the pawl is disengaged. If necessary adjust clevis (C) and jam nut (D) to get the pawl to disengage from the drum teeth.

6. As a final check, repeat steps 1 through 4.

SECTION VIII

BOOM HOIST SYSTEM AND COMPONENTS

SUBSECTION PAGE

SUBSECTION 8A

BOOM HOIST SYSTEM

GENERAL

This section describes the components required to transmit boom hoist torque from the worm shaft to the boom hoist drum.

The boom hoist system consists of the worm shaft, boom hoist shaft, drum brakes, drum clutches and planetary pawls as illustrated in Figure 8A-1.

DESCRIPTION

The boom hoist system is powered by the engine through the worm shaft. The boom hoist shaft and clutch turn continuously while the engine is running and the torque converter clutch is engaged. However, the operator must engage the boom hoist control lever to rotate the boom hoist drum (see Figure 8A-2).

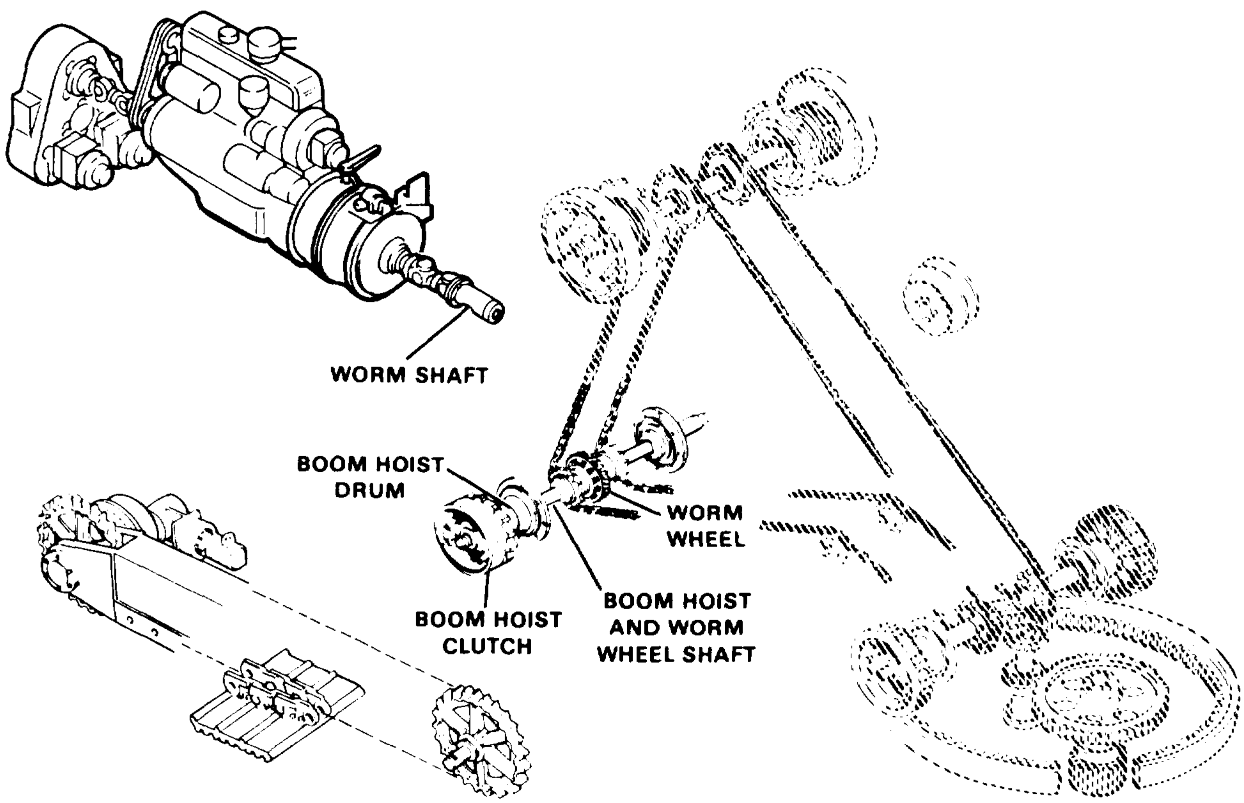


Figure 8A-1. Boom Hoist System

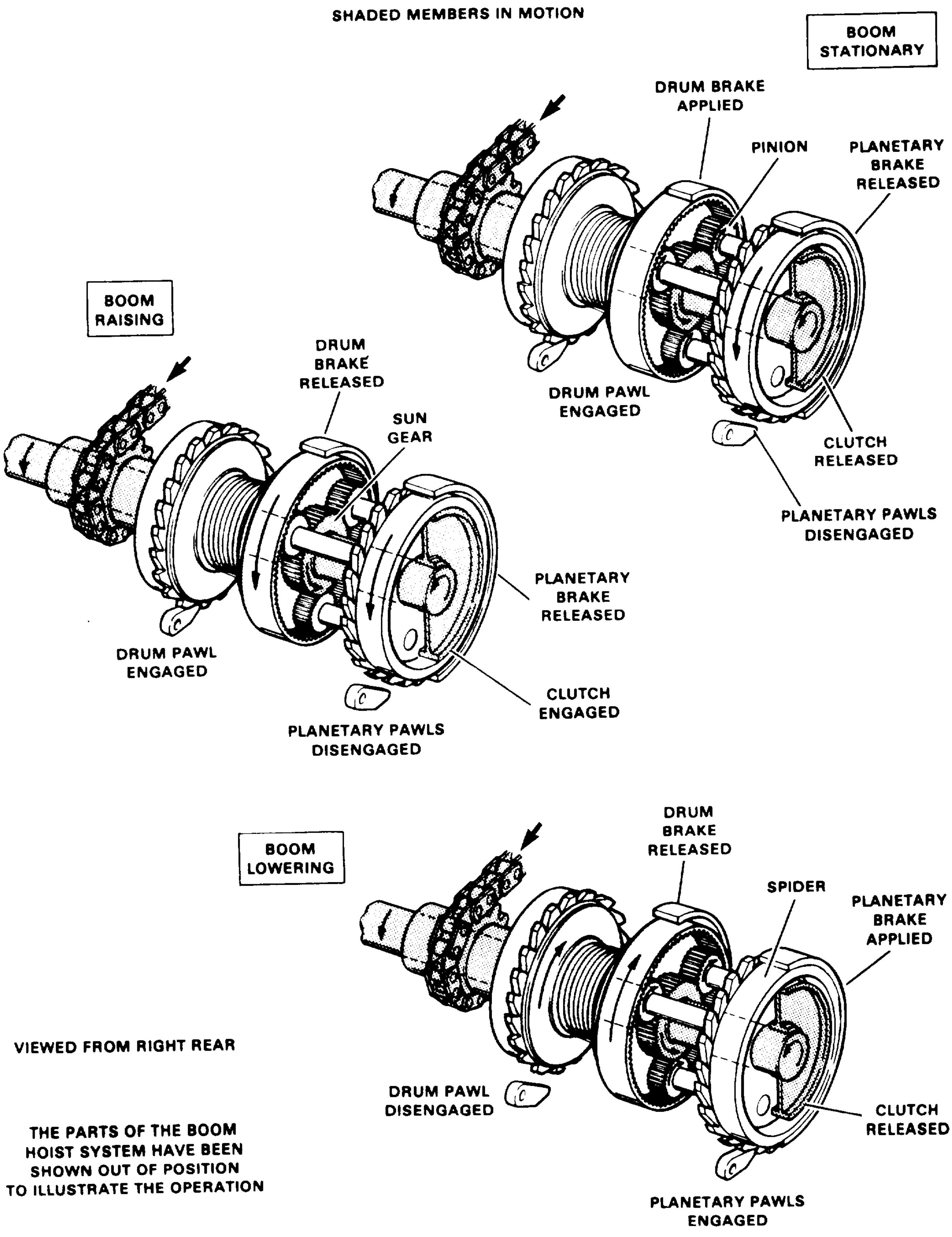


Figure 8A-2. Boom Hoist Planetary Operation

A hydraulically operated pawl engages in the ratchets of the drum to prevent the rotation of the drum when the operator so desires. The pawl should be adjusted as described in Section V of the Operator's Manual.

A planetary lowering system is included on the boom hoist drum. To raise a load, the drum clutch is engaged and shaft rotation is transmitted through the clutch to the drum spool and lagging. The lagging rotates in the same direction as the drumshaft to take up on the horst line and raise the boom.

When lowering the boom, power is transmitted through the planetary system which reverses the direction of shaft rotation. See Table 8A-1 for boom hoist brake, clutch, and pawl operation.

Table 8A-1

	Boom Raising	Boom Lowering	Boom Stationary
Drum Brake	Released	Released	Applied
Drum Clutch	Engaged	Released	Released
Drum Pawl (Hydraulic)	Engaged	Disengaged	Engaged
Planetary Pawls (Automatic)	Dis-engaged	Engaged	Disengaged

SUBSECTION 8B

WORM SHAFTS

GENERAL

This subsection covers the removal, disassembly, inspection and repair, and the assembly and installation of the worm shaft.

WORM SHAFT (2100N503-1)

GENERAL. The worm shaft is mounted in the rear of the chain case and is flange coupled to the torque converter propeller shaft. The worm shaft meshes with the worm wheel on the boom hoist shaft. It is necessary to remove the boom hoist shaft prior to removal of the worm shaft.

REMOVAL AND DISASSEMBLY. Remove and disassemble the worm shaft as follows (see Figure 8B-1):

1. Disconnect the propeller shaft from flange (09).

2. Remove cotter pin (04). nut (03), flange (09) and key (10) from the worm shaft.

3. Remove the boom hoist shaft. See Subsection 8C.

4. Remove nuts (02) and washers (01). Pull shaft (11) and sleeve (14) from the chain case.

5. Pull retainer (05) out of sleeve (14). Remove the shaft and bearings from the sleeve.

6. Remove O-ring (15) from sleeve (14).

INSPECTION AND REPAIR. Prior to assembly, all worm shaft parts should be inspected as follows:

1. Replace gasket (13), seal (07) and O-ring (15). The seal must be installed so the lip faces toward bearing (08).

2. Replace any bearing that shows signs of wear or damage.

NOTE

Bearing (12) is a thrust bearing, and must be assembled as shown in Figure 8B-1. If the bearing is improperly installed, it will be unable to absorb the thrust for which it was designed.

3. Inspect the worm shaft for wear or damage. If it is scored, pitted, ridged or worn it should be replaced.

4. Remove nicks, mars or burrs on machined or ground surfaces. Be sure all threaded items are clean and threads are not damaged.

ASSEMBLY AND INSTALLATION. To assemble and install the worm shaft, proceed as follows (see Figure 8B-1):

1. Install the bearings on the worm shaft. Be sure the bearings are firmly against the shoulder on the worm shaft.

2. Install O-ring (15) into sleeve (14). Slide the worm shaft into sleeve (14) until bearing (12) is against the sleeve shoulder.

3. Install gasket (13) onto the chain case.

4. Install shims (06) on the face of sleeve (14) and place retainer (05) into the sleeve with seal (07) in place.

5. Clamp the retainer firmly to the sleeve. Using a dial indicator, check worm shaft end play. End play should be 0.003 to 0.005 inch. If end play is not within these limits, add or subtract shims (06) until end play is correct.

6. Place the entire assembly into the chain case and secure with washers (01) and nuts (02).

7. Install the boom hoist shaft. See Subsection 8C.

8. Install key (10) and press flange (09) onto the shaft over the key. Install nut (03) and cotter pin (04).

9. Connect the propeller shaft to flange (09).

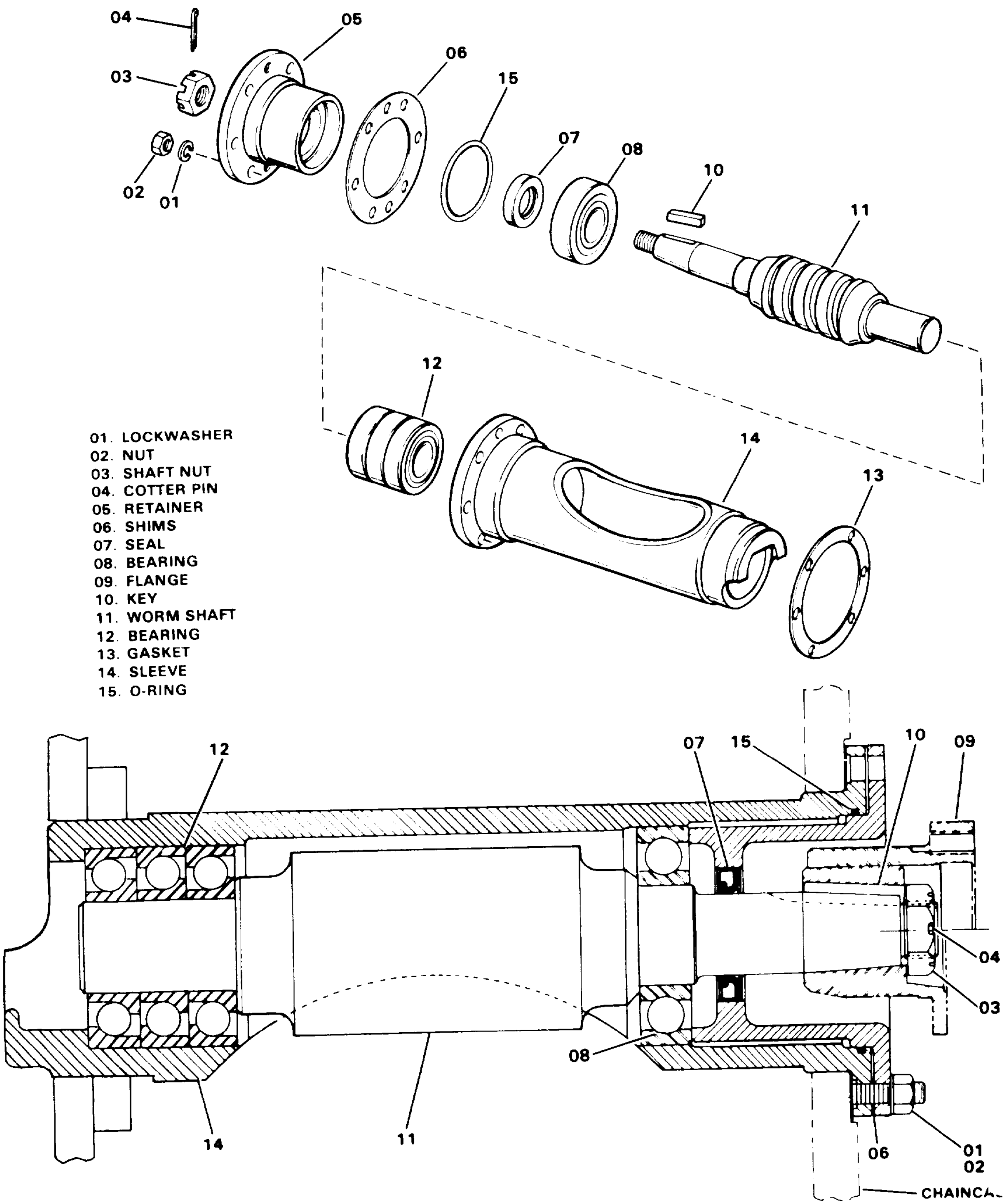


Figure 8B-1. Worm Shaft (2100H503-1)

SUBSECTION 8C

BOOM HOIST SHAFTS

GENERAL

This subsection contains the information necessary to remove, repair and install the boom hoist shaft assembly.

BOOM HOIST SHAFT (2100J1132-1 & 5)

GENERAL. The boom hoist shaft is driven by the worm shaft, which meshes with the worm wheel on the boom hoist shaft. Chains, sprocketed to the boom hoist shaft, provide power for the swing shaft and main hoist shaft. When replacement of the worm wheel, worm shaft or sprockets is necessary, the boom hoist shaft must first be removed.

REMOVAL. To remove the boom hoist shaft, proceed as follows (see Figure 8C-1):

1. Remove the third drum material. See Subsection 7B.

2. Disconnect and cap all the hydraulic lines to the drumshaft assembly. Plug all connections where the hydraulic lines are removed. Also remove any hydraulic lines which might interfere with drum shaft removal.

3. Disconnect and remove all brake bands on the boom hoist drum (see Subsection 8D).

4. Remove the hydraulic swivel from the end of the shaft.

5. Remove nut (39) and washer (40) and spacer (41) from shaft (33).

6. Remove sleeve (05) and spacer (04).

7. Remove clutch assembly and O-ring (37). Place clutch in a clean area.

8. Support the drum and planetary assembly with a hoist and slide it off of the shaft. Remove bearing (21) from the shaft.

9. Remove the chain case cover, loosen both drive chains and remove the chains from the boom hoist shaft drive sprockets. It is not necessary to disconnect the chains.

10. Block both ends of the boom hoist shaft and remove the hardware holding retainers (11 and 27). Remove the retainers with shims (07 and 24), gaskets (14 and 17), and retainers (06 and 23) intact.

11. Lower the shaft enough to disengage worm wheel (30) from the worm shaft.

12. Remove shaft (33) through the opening in the *left* side of the chain case.

DISASSEMBLY. To disassemble the boom hoist shaft and the drum and planetary assembly, proceed as follows (see Figure 8C-1):

1. Remove retainer (48) from the planetary drum assembly.

2. Pull gear (50) from drum (34). Remove pins (54) from drum (56) and remove the pinions from the drum.

3. Remove the bearings from drum (34) and (56). Do not remove seal (38) unless replacement is required.

4. Remove seal (45) and bearing (49) from retainer (48).

INSPECTION AND REPAIR. Before installing the boom hoist shaft, inspect the following items (see Figure 8C-1):

1. Replace all oil seals and O-rings. Any bearing which shows signs of wear or damage should be replaced.

NOTE

Replacement of seal (38) is necessary only if the seal has been leaking or is damaged.

2. Inspect the bushings in pinions (52) for wear or damage.

3. Inspect worm wheel (30), sprockets (29), gear (50) and pinions (52) for wear or damage. If they are scored, pitted, ridged or worn, they should be replaced.

4. Inspect the shaft for excessive wear and/or distortion.

5. Clean out all lube lines and grease passages to insure free flow of lubricant.

6. Repair or replace any damaged or broken parts. Be sure all threaded items are clean and that threads are not damaged. Studs must be tight before installing parts that are mounted to them.

7. Inspect all clutch and brake linings at this time. Replace the linings, if necessary, before installing them on the drum shaft.

8. Inspect the drum cooling fins for cracks or broken fins. Repair or replace if necessary.

9. Inspect the brake and clutch rims for cracks, scratches, or discoloration. Repair or replace if necessary.

ASSEMBLY AND INSTALLATION. To assemble, and install the boom hoist shaft, proceed as follows (see Figure 8C-1):

1. Lubricate all O-rings and seals prior to assembly.

2. Position drum (34) with the ratchet side up, and pack the drum with grease. See Section III for the recommended grease (P&H Number 472).

3. Turn the drum and complete packing the drum cavity with grease.

4. Pack bearings (55 and 21) with grease and install seal (58) in bearing (21). Press the bearings into the bore of drum (34) until each one is snug against the shoulders in the drum bore.

5. Install seal (38) in position in the drum, if the seal has been removed. Always pack the seal with grease and be sure the sealing lip and spring face inward toward pinions (52).

6. Press worm wheel (30) hub onto shaft (33). The worm wheel hub faces must be flush with the shaft shoulders. Then install spacers (31) and sprockets (29). The sprocket should be tight against the spacers.

NOTE

Sprockets (29) are match marked during manufacture and must be installed in matched pairs. Be sure that both sprockets have the same number stamped on the outer edge. The match marked internal spline on the sprockets must line up with the marked splines on the shaft.

Also, paint the worm wheel with a coat of white lead or Prussian blue, This will be used later to adjust the worm gear to worm wheel contact.

7. Install the boom hoist shaft in the chain case bore and block it securely in position, with the shaft centered in the bore, and the worm wheel engaged in the worm shaft.

8. Apply No. 2 Permatex on the points indicated in Figure 8C-1. Install gaskets (14 and 17) in retainers (11 and 27). Install the retainers and secure them in positron with the lockwashers and nuts.

9. Install seals (08 and 20) into retainers (06 and 23). Be sure the seals are installed with the springs facing the sprockets, and that the areas between the seal lips are packed with grease. Check the seal seating surface on the shaft for nicks or burrs, since minor imperfections on the shaft surfaces can cause rapid wear on the seals.

10. Pack bearings (15 and 16) with multipurpose grease as recommended in Section Ill.

11. Install sufficient shims (07 and 24) between bearing retainers (06 and 23). so that shaft end play is 0.003 to 0.005 inch. Temporarily fasten the two retainers for the check in step 12.

12. Adjust the worm-to-worm wheel contact by shifting shims from beneath one retainer to the other as follows:

A. Turn the worm through one complete revolution.

B. Check the point of contact between the worm and the worm shaft as shown in Figure 8C-1. It is most important that all contact, under no load conditions, be to the left of the vertical centerline of the worm shaft.

C. If all contact is not on the left side of the worm, shift shims from beneath the two oil seal retainers until this contact is properly established. Note that the proper contact area is shown on the worm wheel in Figure 8C-1, which is a view from the rear of the shaft.

13. With proper worm-to-worm wheel contact established, install retainers (06 and 23). Apply Permatex No. 2 to capscrews (09 and 25) threads, and to the adjacent surfaces.

14. Place new O-ring (05) in spacer (04) and assemble to the boom hoist shaft.

15. Install spacer (22) on the shaft and slide drum (34) with bearing (21) firmly seated against it.

16. Install spacer (28), then slide drum (56) onto the shaft.

17. Install pinions (52) in drum (56). Lubricate O-rings (51) and install them on pins (54). Install pins (54) in pinions (52). Turn the pins so that the flats on the outer ends of the pins will allow bearing retainer (48) to be installed.

18. Install spacer (36) and slide sun gear (50) onto the shaft. Then install spacer (46) followed by O-ring (47).

19. Pack the cup of bearing (49) with grease and press it into retainer (48). Then place the retainer onto the shaft and install the bearing cone into the bearing cup.

20. Place the assembly tool (218T1470) as shown in Figure 8C-2, onto the shaft and secure in place with washer (41) and nut (39).

NOTE

Do not install shims (53) at this time. Also, assembly tool (218T1470) may be fabricated using the dimensions shown on the illustration

21. Install and tighten snugly the capscrews that hold bearing retainer (48) in place. Clamp the two drums together to keep preload pressure on bearing (35).

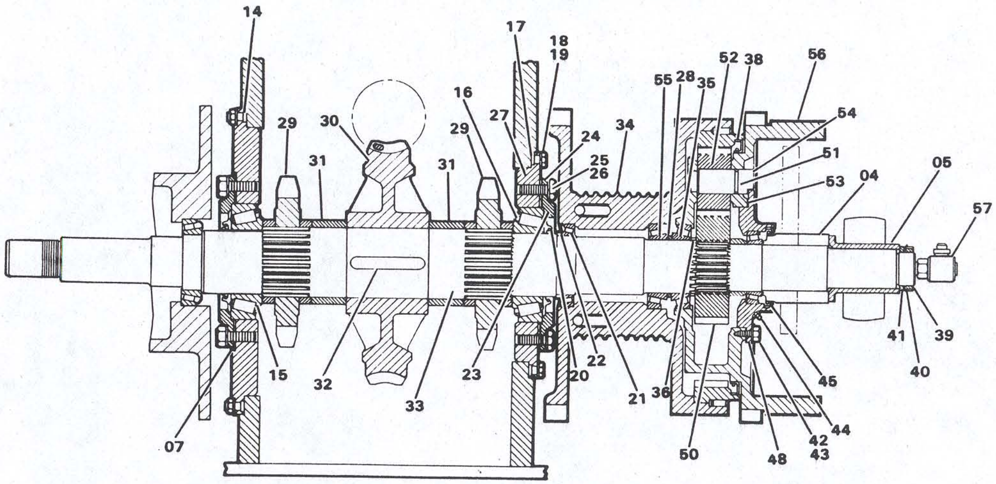
22. Attach a dial indicator to the shaft and set the tip against the flat surface of the retainer. Take a reading, then remove the capscrews and pull out on the retainer. Take another reading of the indicator and subtract the two readings to obtain the total clearance which is the total end play of the bearings.

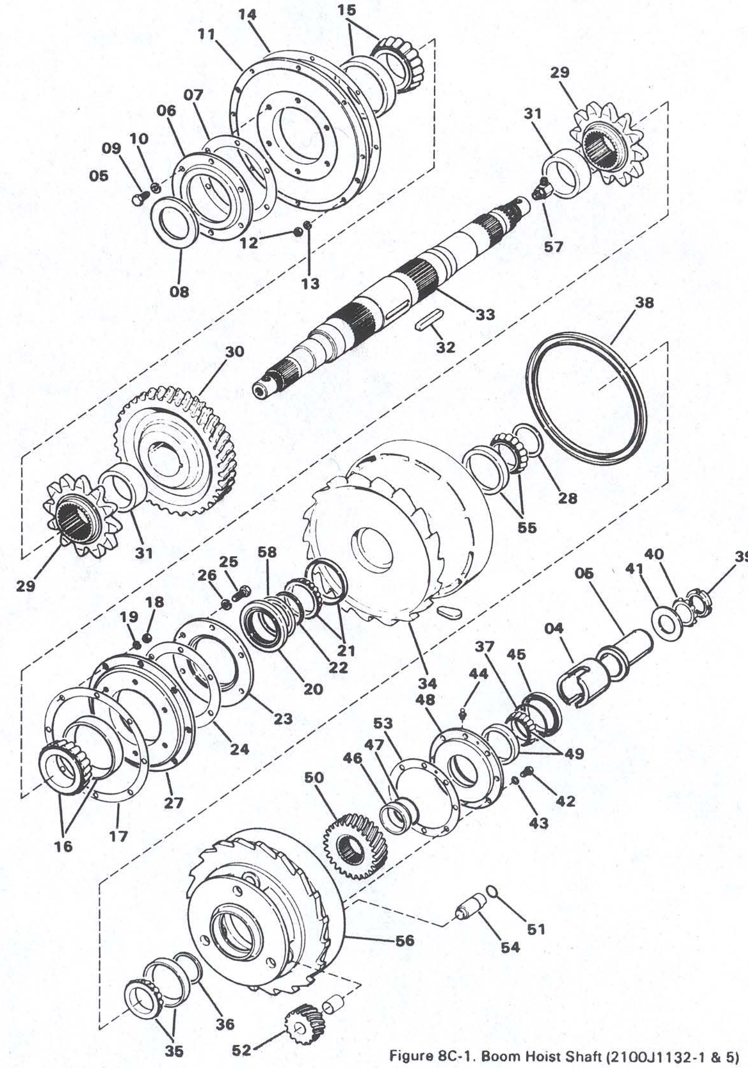
NOTE

As an example, if the total clearance measuredabove was 0.028, and the desired bearing preload is 0.003 inch, then the amount of shims required should measure 0.025 inch.

23. Remove the dial indicator, nut (39). washer (41). the assembly tool, capscrews (42) and retainer (48) with bearing (49) included.

24. Following the example in the note above, determine the amount of shims required and install them between retainer (48) and drum (56). Bear in mind the desired bearing preload is 0.003 inch.





01. NOT USED
02. NOT USED
03. NOT USED
04. SPACER
05. SLEEVE
06. RETAINER
07. SHIMS
08. SEAL
09. CAPSCREW
10. LOCKWASHER
11. RETAINER
12. NUT
13. LOCKWASHER
14. GASKET
15. BEARING
16. BEARING
17. GASKET
18. NUT
19. LOCKWASHER
20. SEAL
21. BEARING
22. SPACER
23. RETAINER
24. SHIMS
25. CAPSCREW
26. LOCKWASHER
27. RETAINER
28. SPACER
29. SPROCKET
30. WORM WHEEL
31. SPACERS
32. KEY
33. SHAFT
34. DRUM
35. BEARING
36. SPACER
37. O-RING
38. SEAL
39. NUT
40. WASHER
41. SPACER
42. CAPSCREW
43. WASHER
44. FITTING
45. SEAL
46. SPACER
47. O-RING
48. RETAINER
49. BEARING
50. GEAR
51. O-RING
52. PINION
53. SHIMS
54. PIN
55. BEARING
56. DRUM
57. SWIVEL
58. SEAL

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Figure 8C-1. Boom Hoist Shaft (2100J1132-1 & 5)

25. Install bearing (49), retainer (48), and secure with washers (43), and lubricated capscrews (42). Torque the capscrews to 90 ft-lbs.

26. Pack seal (45) with grease and install into bearing retainer (48) with the spring and lip pointing towards the bearing.

27. Place O-ring (37) in the groove of the clutch hub and slide the clutch assembly onto the shaft and adjust (see Subsection 8E).

28. Install spacer (04) and sleeve (05).

29. Place spacer (41) and washer (40) on the shaft and tighten nut (39) until the drum does not rotate by hand. Loosen up on nut (39) until drum just rotates freely by hand. Lock the nut in place with the tab on washer (40). Remove the clamps installed in step 21.

30. Install the hydraulic swivel and attach the line to it.

31. Install the boom hoist brakes (see Subsection 8D). Bleed the hydraulic cylinders to remove any air trapped in the lines (see Subsection 5A).

32. Install all sheet metal removed during disassembly.

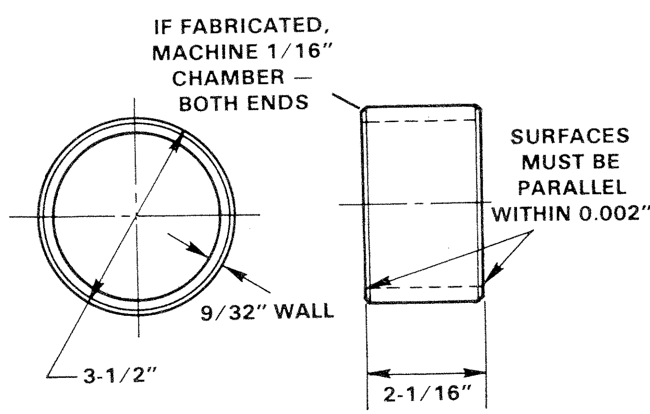


Figure 8C-2. Assembly Tool (218T1470)

SUBSECTION 8D

BOOM HOIST BRAKES

GENERAL

This section covers the removal, relining, installation and adjustment of the boom hoist brake and the boom hoist planetary brake.

Several terms are often misunderstood when used in reference to brake bands on this machine. The following definitions, as used in this manual, are as follows:

1. Brake Set. This means the brake band is tightened around a rotating member to stop, or prevent, the rotationof that member.

2. Live End. This is the end of a brake band to which force is applied.

3. Dead End. This is the anchor end of a brake band. Typically, most lining wear will occur at this end of the band.

BOOM HOIST AND PLANETARY BRAKES (2100J1008-2)

DESCRIPTION. The boom hoist brake is a spring set, hydraulically released type brake. When there is no pressure in the boom hoist brake cylinder, its piston is retracted and a spring applies the boom hoist brake.

When the operator moves the boom hoist control lever back to raise the boom, hydraulic fluid is directed to the boom hoist brake cylinder. With hydraulic pressure applied to the cylinder, its piston extends and applies force to the linkage overcoming the spring and releasing the brake (see Figure 8D-1).

When the linings are new and the brake is in proper adjustment, the length of the operating mechanism spring, with the brake set (hydraulic pressure released), should be 7-3/8 inches. When the brake lining starts to wear, this dimension will increase (with the brake set). See the Operator's Manual for the method of adjusting the brakes for normal lining wear.

The boom hoist brake should be relined when brake lining thickness reaches 3/16 inch as measured at the dead end of the band.

The boom hoist planetary brake is hydraulically set, spring released. When there is no pressure in the boom hoistbrake cylinder, its piston is retracted and springs release the planetary brake.

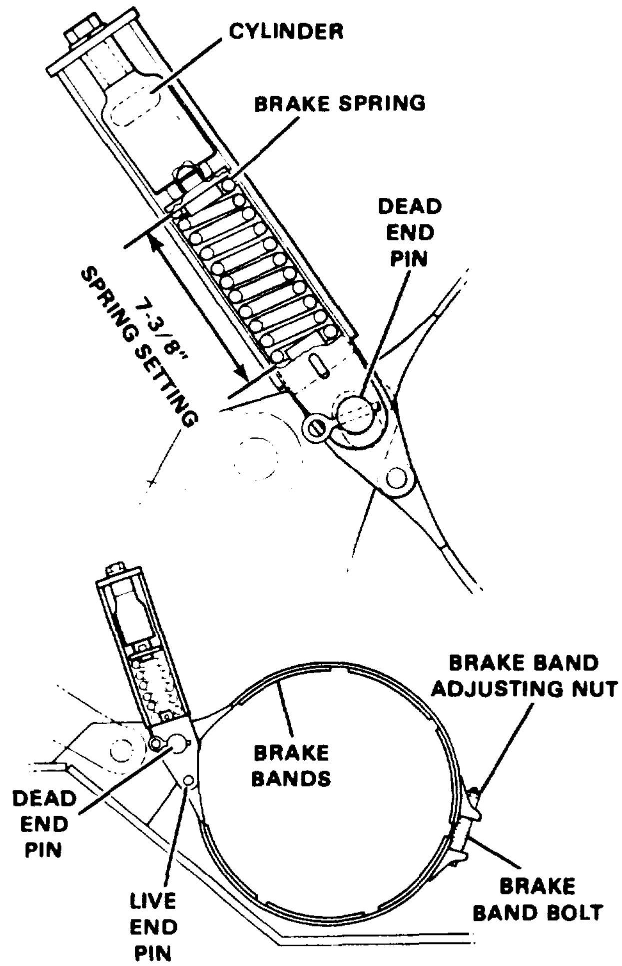
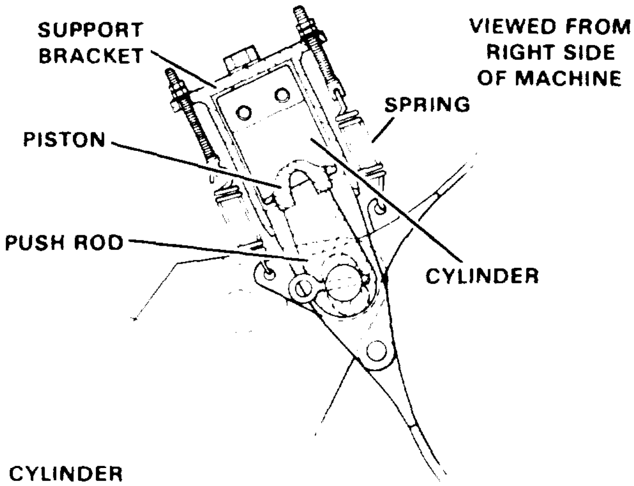


Figure 8D-1. Boom Hoist Drum Brake (2100N457)

When the operator moves the boom hoist control lever forward to lower the boom, hydraulic fluid is directed to the planetary brake cylinder. With hydraulic pressure applied to the cylinder, its piston extends and applies force to the linkage to wrap the band around the drum and set the brake (see Figure 8D-2).



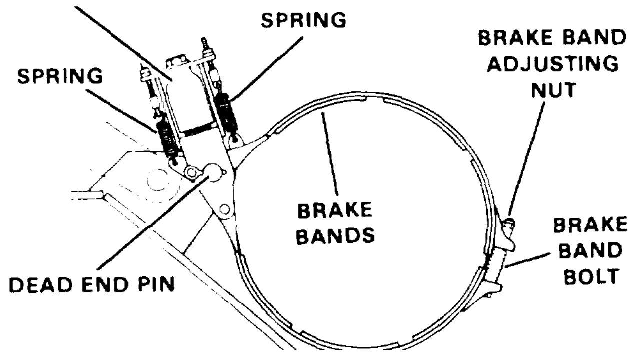


Figure 8D-2. Boom Hoist Planetary Brake (2100N458)

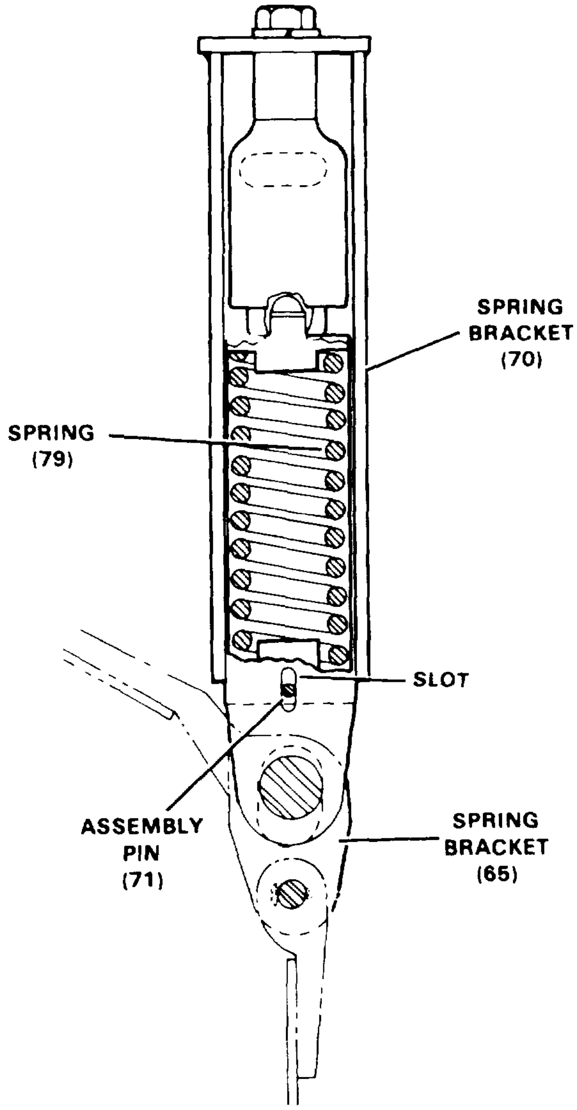


Figure 8D-2. Boom Hoist Planetary Brake (2100N458)

When the linings are new and the brake is in proper adjustment, the length of the cylinder piston extension, with the brake set (hydraulic pressure applied), should be 1/2 inch. When the brake lining starts to wear, this dimension will increase (with the brake set). See the Operator's Manual for the method of adjusting the brakes for normal lining wear.

The boom hoist planetary should be relined when brake lining thickness reaches 3/16 inch as measured at the dead end of the band.

REMOVAL. To remove the boom hoist brake band, proceed as follows (see Figure 8D-5):

1. Lower the boom and support it on blocking. Make sure all tension is removed from the boom hoist rope.

2. Shut down the engine and move the boom hoist lever forward to release the boom hoist brake. With the brake released, slide pin (71) through the slot in bracket (65) and on through the drilled hole in bracket (70) as shown in Figure 8D-3. This will lock the brake in the released position.

NOTE

> If adequate pressure is not available to release the brake, the engine will have to be started to build system pressure.
>
> Also, the assembly pin (71) may be made from 3/8 inch steel rod stock cut to a length of 6 inches.

3. With the engine shut down, operate a control lever until all hydraulic pressure is exhausted from the system.

4. Disconnect and cap the hydraulic lines from the boom hoist brake and the boom hoist planetary brake cylinders. Plug all connections where hydraulic lines were removed.

5. Remove the upper deck panel immediately to the right of the access door. This will make access to the boom hoist brakes easier. If necessary, remove the sheet metal shroud between the boom hoist drum and the main hoist drum.

6. Release the tension in springs (17) by loosening jam nuts (20). Remove springs (17) from pin (21). Remove pin (21) from the band lever.

7. Remove brake band adjusting bolts (10 and 77) and springs (09 and 76) by removing nuts (07 and 74).

8. Disengage boom hoist pawls (53 and 56) from the ratchets as follows:

A. Remove pins (22 and 45) to release the tension in cables (31 and 32).

B. Disengage pawls (53 and 56) from the drum ratchets.

9. Remove capscrew (62) from bracket (51) and remove rod end (61) from pin (57).

CAUTION

The next step in this procedure involves removing pin (57) from the assembly. When removing pin (57), the drum brake operating mechanism should be supported so it will not fall.

10. Slowly pull pin (57) out of pawl (56), spacer (01), bracket (55) and the drum brake operating mechanism.

11. Remove the drum brake operating mechanism and the bottom half of the brake band along with it. Then remove the top half of the drum brake band.

12. Support the planetary brake operating mechanism and pull pin (57) completely out.

13. Raise the planetary operating mechanism into the space above its normal position, remove cotter pin (25) and pin (23).

14. Remove the planetary brake operating mechanism, then the top and lower halves of the brake bands.

INSPECTION AND REPAIR. Prior to installation of the brake bands on the drum, check and repair the brakecomponents as follows (see Figure 8D-5):

1. Disassemble the boom hoist brake cylinder and spring assembly as follows:

A. Remove capscrews (68) and lockwasher (69) from cylinder (66). Remove the cylinder and spacer (67) from the bracket.

6. Install a 3/4 x 8 inch bolt with nut into the hole at the top of bracket (70) as illustrated in Figure 8D-4.

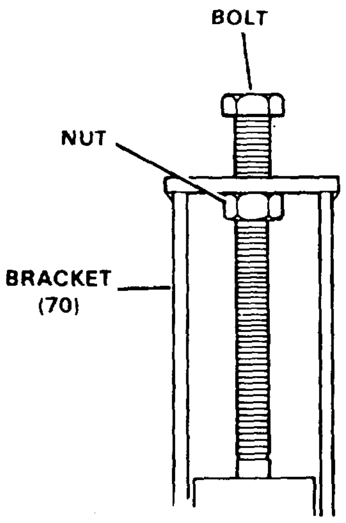


Figure 8D-4. Assembly Bolt

C. Tighten the nut against the top of the spring bracket until assembly pin (71) that was installed during the removal procedure can be removed.

D. Pull the assembly pin and back off on the nut to relieve the spring pressure. Remove spring bracket (65) and spring (79).

2. Replace springs (09, 17, 76 and 79).

3. If cylinders (13 and 66) leak or have been performing erratically, overhaul them. See Subsection 5D.

4. Assemble the boom hoist brake cylinder and spring assembly, as follows:

A. Set spring (79) and bracket (65) into bracket (70).

B. Install a 3/4 x 8 inch bolt into the top of bracket (70) as shown in Figure 8D-4.

C. Tighten the nut against the bracket until assembly pin (71) can be installed through bracket (65) and the drilled hole in bracket (70).

NOTE

The assembly pin is removed after the bracket assembly is installed on the machine.

D. Remove the nut and bolt from the top of bracket (70) and install cylinder (66) and spacer (67). Secure with lockwasher (69) and capscrew (68).

5. Remove the lining from the bands, check the bands for distortion, then install new lining (06 and 73).

NOTE

A lining kit is available. See the Replacement Parts Manual.

6. Inspect the brake drums to see that they are not cracked, scored or otherwise damaged.

7. Inspect the pawls and ratchet teeth for breaks, cracks or excessive wear. Replace if necessary.

ASSEMBLY AND INSTALLATION. To assemble the boom hoist brakes and related parts, proceed as follows (see Figure 8D-5):

1. Check the adjustment of pawls (53 and 56). See Subsection 8F for this procedure.

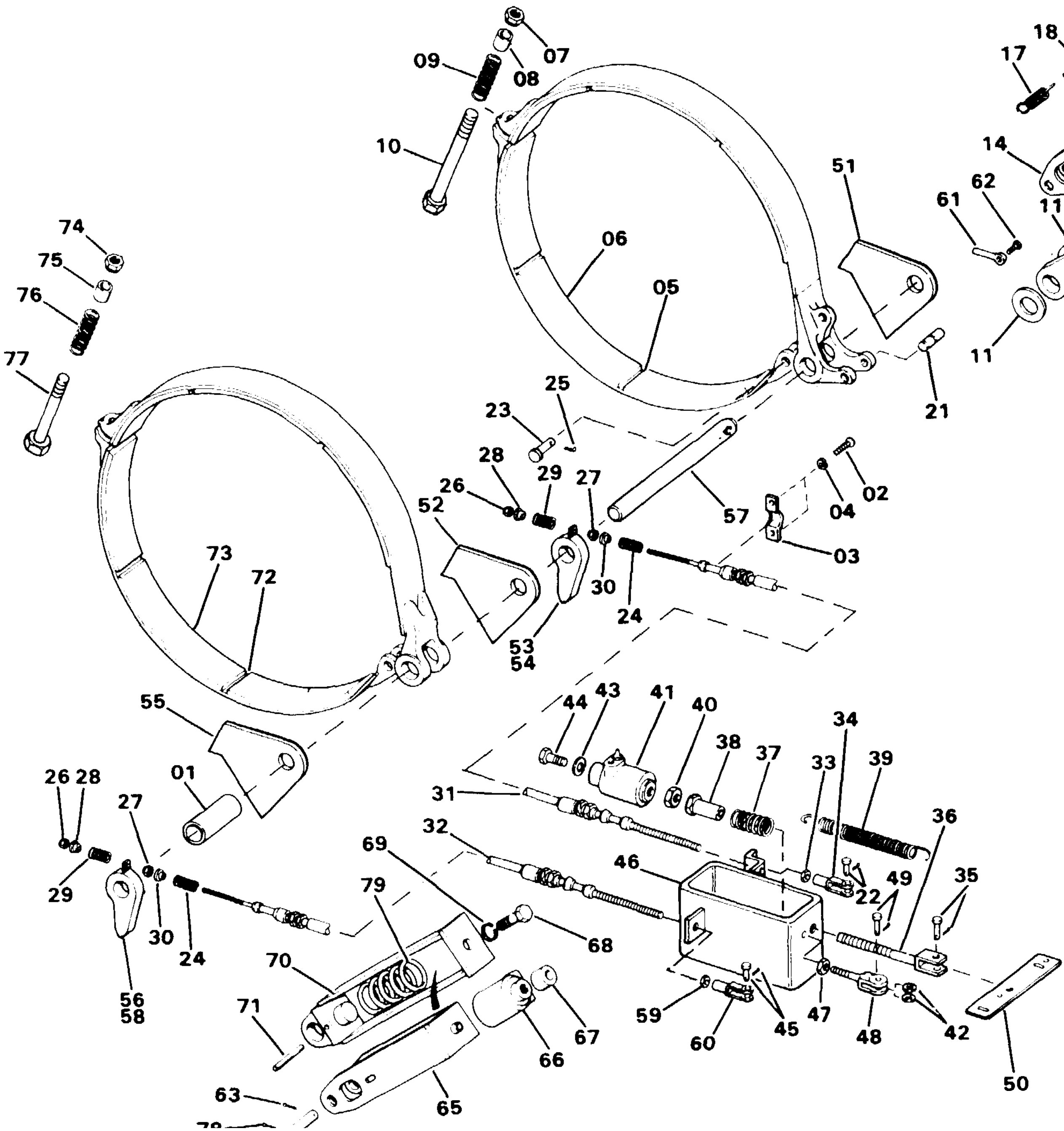
2. Attach the planetary brake operating mechanism to lower band (05) with pin (23). Install with the head end of the pin towards pawl (53) and fasten with cotter pin (25).

3. Install lower band (05). then upper band (05). Now insert pin (57) through the dead end of the upper band into pawl (53).

4. Assemble the drum brake operating mechanism to lower band (73) with pin (64). Install cotter pins (63 and 78).

5. Install lower half of band (72) and operating mechanism. Support the operating mechanism and install the upper half of the band.

6. Press pin (57) through the dead end of the upper band and bracket (55).



01. SPACER
02. SCREW
03. CLAMP
04. LOCKWASHER
05. BAND
06. LINING
07. NUT
08. SPACER
09. SPRING
10. BOLT
11. SPACER
12. PUSH ROD
13. CYLINDER
14. BRACKET
15. CAPSCREW
16. WASHER
17. SPRING
18. STUD
19. WASHER
20. NUTS
21. PIN
22. PINS
23. PIN
24. SPRING
25. PIN
26. NUT
27. LOCKNUT
28. SPRING SEAT
29. SPRING
30. SPRING SEAT
31. CABLE
32. CABLE
33. NUT
34. YOKE
35. PINS
36. PUSH ROD
37. SPRING
38. SPRING GUIDE
39. SPRING
40. NUT
41. CYLINDER
42. WASHERS
43. LOCKWASHER
44. CAPSCREW
45. PINS
46. BRACKET
47. NUT
48. YOKE
49. PIN
50. LEVER
51. BRACKET
52. BRACKET
53. PAWL
54. FITTING (NOT SHOWN)
55. BRACKET
56. PAWL
57. PIN
58. FITTING (NOT SHOWN)
59. NUT
60. YOKE
61. ROD END
62. CAPSCREW
63. PIN
64. PIN
65. BRACKET
66. CYLINDER
67. SPACER
68. CAPSCREW
69. LOCKWASHER
70. BRACKET
71. ASSEMBLY PIN
72. BAND
73. LINING
74. NUT
75. SPACER
76. SPRING
77. BOLT
78. PIN
79. SPRING

Figure 8D-5. Boom Hoist Brakes (2100J1008-2)

NOTE

If difficulty is encountered when pushing pin (57) through the operating mechanism, connect the hydraulic line and operate the cylinder to align bracket (70) with the pin.

7. Place spacer (01) and pawl (56) in alignment and push the pin all the way into the support bracket on the chain case.

8. Pull assembly pin (71) from bracket (70) of the drum brake operating mechanism. Again it may be necessary to actuate the cylinder to free the pin.

9. Insert rod end (61) into pin (57) and secure with locking capscrew (62).

10. Hook spring (17) into the bracket of upper band (05). Install pin (21) and attach the other spring (17) to it.

11. Attach studs (18) to springs (17). Install washers (19) and nuts (20); then, tighten the nuts to ensure the return of the piston in the cylinder (see step 2A under the following topic, ADJUSTMENTS).

12. Install adjusting bolts (10 and 77) from the bottom bands, springs (09 and 76), spacers (08 and 75) and nuts (07 and 74).

13. Adjust the boom hoist and planetary brakes as described under the following topic, ADJUSTMENTS.

14. Remove the caps and plugs from all hydraulic lines and connections. Attach the hydraulic lines.

15. Bleed the hydraulic cylinders to remove any air in them and the lines. See the bleeding procedure in Subsection 5A.

NOTE

The springs at either ends of the pawls were adjusted in step 1.

16. Connect the cables to lever (50) with pins (22 and 45) and adjust the other pawl linkages as described in Subsection 8F.

17. After testing and adjustments are completed, replace any panels or sheet metal removed.

ADJUSTMENTS. To adjust the boom hoist brakes when the bands have been removed, proceed as follows:

1. To adjust the spring set boom hoist brake, proceed as follows (see Figure 8D-1):

A. With the brake set (hydraulic pressure released from the cylinder) tighten the brake band adjusting nut until the brake spring length is 7-3/8".

B. Test the adjustment by releasing and setting the brake and remeasuring the spring length.

2. To adjust the boom hoist planetary brakes, proceed as follows (see Figure 8D-2):

A. Using the jam nuts on top of the support bracket, adjust the return springs so that the support bracket is firmly resting on the support pin.

B. With the brake applied (hydraulic pressure applied), check the planetary brake cylinder piston extension. This dimension should be approximately 1/2 inch. Adjust to this dimension using the adjusting bolt at the band split.

C. Operate the brake several times to be sure the bands do not drag when the brake is released (hydraulic pressure released). Repeat steps 1 and 2 if necessary.

SUBSECTION 8E

BOOM HOIST CLUTCHES

GENERAL

This subsection covers the removal, repair, installation and adjustment of the boom hoist clutch.

BOOM HOIST CLUTCH (9215J105-1)

DESCRIPTION. The boom hoist clutch is located on the end of the boom hoist shaft This clutch is hydraulically applied, spring released. When there is no pressure in the clutch cylinder, the return spring applies force to the actuating levers to contract the band and release the clutch. When the operator moves the boom hoist control lever to raise or lower the boom, hydraulic fluid is forced into the cylinder. This causes the piston to extend and apply force on the actuating levers to expand the band and apply the clutch.

Since lining wear will usually be greatest at the dead end of the clutch band, the clutch band may be rotated 180° when wear has reduced the thickness of the lining at the dead end to 1/4 inch. When wear has reduced the thickness of the lining to within 1/16 inch of the rivets, the band should be relined.

REMOVAL AND DISASSEMBLY. To remove and disassemble the clutch, proceed as follows (see Figure 8E-1):

1. If any rope remains on the boom hoist drum, set the boom hoist drum pawl to prevent the rotation of the drum.
2. Remove any material that may interfere with the removal of the clutch assembly.
3. Loosen jam nuts (15) and turn stopscrews (14) until there is adequate clearance around clutch band (01).
4. Disconnect and cap the hydraulic line to the clutch swivel. Unscrew the swivel from the shaft.
5. Disconnect the line that runs from cylinder (23) to the shaft and remove the clutch assembly from the machine.
6. Remove springs (05) from band (01). The band can now be removed for relining.

INSPECTION AND REPAIR. Prior to reinstalling the clutch, inspect and repair the following items (see Figure 8E-1):

1. Replace return springs (05).
2. Remove bushing (17) from spider (16) and replace it.
3. If cylinder (23) leaks or has been performing erratically. remove and overhaul or replace it. See Subsection 5D.
4. Check the clutch band for distortion and reline it.

NOTE

A lining kit is available. See the Replacement Parts Manual.

5. Check actuating levers (09) and spider (16) for wear. Replace it necessary.
6. Inspect the clutch drum to see that it is not cracked, scored or otherwise damaged.

ASSEMBLY AND INSTALLATION. To assemble and install the clutch, proceed as follows (see Figure 8E-1):

1. Place the clutch band on the spider assembly and attach springs (05).
2. Install a new O-ring in the groove of spider (16).
3. Install the clutch assembly to the drumshafts and the boom hoist drum.
4. Attach the hydraulic swivel to the shaft. Connect the hydraulic lines and bleed cylinder (23) to remove any air trapped in the lines. See Subsection 5A.

ADJUSTMENT. To adjust the clutch after it has been removed, proceed as follows (see Figure 8E-1):

1. Loosen the jam nuts on all stopscrews (14).
2. Back off on all stopscrews (14) until clutch band (01) is no longer in contact with the heads of the stopscrews.
3. Adjust setscrew (27) at the dead end of the clutch shoe to approximately 0.058 inch clearance between the clutch lining and the clutch drum, with clutch band guide (18) located on the top of the clutch.
4. Adjust setscrew (04) at the live end of the clutch to approximately 0.063 inch of clearance between the clutch lining and the clutch drum.
5. Loosen jam nut (25) and turn push rod (24) so the piston in the cylinder (23) is completely retracted with the clutch control lever in the neutral position.
6. With the clutch in the released position, turn stopscrews (14) to center the clutch band in the clutch drum. The band must be centered to prevent the lining from rubbing against the drum. There should be no pressure against the clutch band from any of the stopscrews.

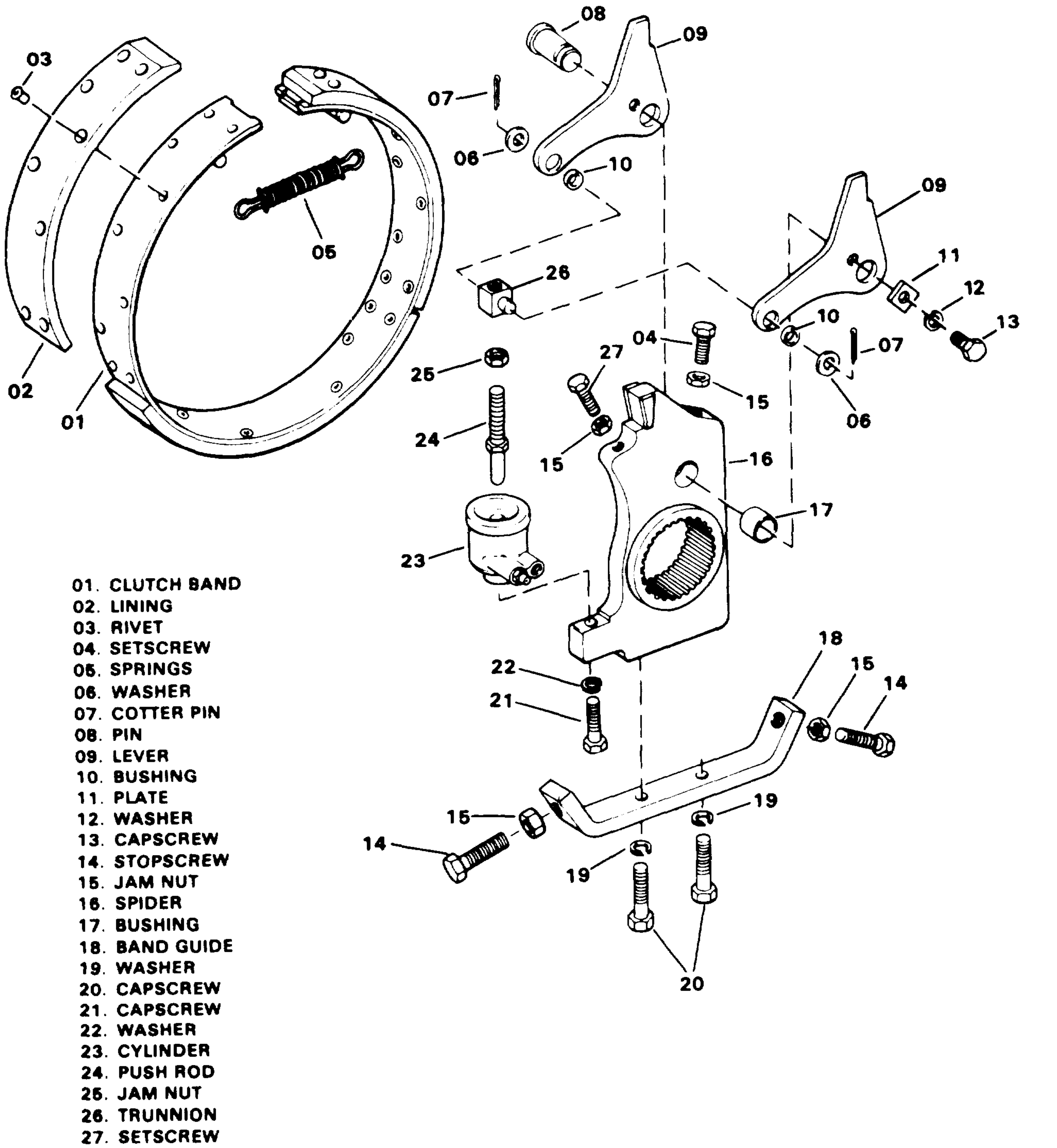


Figure 8E-1. Boom Hoist Clutch (9215J105-1)

7. Start the engine and check the adjustment by engaging the clutch. Also check to see that the piston in the hydraulic cylinder returns to contact push rod (24) each time the clutch is released.

NOTE

After making several clutch engagements, starting at the top of lever (09), check for at least 0.063 inch clearance between the clutch lining and the drum at 60 degree intervals.

8. Tighten all jam nuts after the adjustment has been completed.

SUBSECTION 8F

BOOM HOIST PAWLS

GENERAL

This subsection contains the information necessary to remove, disassemble, assemble, install and adjust the boom hoist pawls.

BOOM HOIST PAWL ASSEMBLY (2100J1008-2)

DESCRIPTION. Two pawls are provided to prevent the possibility of a "live" boom when the boom is being raised or lowered. These pawls engage the ratchets on the boom hoist drum assembly. One pawl prevents the boom from falling if the planetary brake band should slip while the boom is being lowered; the other pawl is normally engaged and prevents the boom from falling while it is being raised or when it is in the raised position.

With the boom hoist control lever in the neutral position, no hydraulic pressure is applied to the pawl cylinder and only the boom hoist pawl is engaged in the ratchet of the boom hoist drum (see Figure 8F-3). When the boom hoist control lever is moved by the operator to raise the boom, no hydraulic pressure is applied to the pawl cylinder and the boom hoist pawl remains engaged in the ratchet of the boom hoist drum. When the boom hoist control lever is moved by the operator to lower the boom, hydraulic pressure is applied to the pawl cylinder extending the piston and moving the linkage to disengage the boom hoist pawl from the ratchet of the boom hoist drum. Simultaneously the boom hoist planetary pawl will be engaged in the ratchet of the planetary spider.

REMOVAL. If upon inspection it is revealed that a pawl is worn down, cracked or broken it will be necessary to remove the pawl and replace it. To remove the boom hoist pawls, proceed as follows (see Figure 8F-2):

1. Lower the boom and support it on blocking. Make sure all tension is removed from the boom hoist rope.

2. Shut down the engine and move the boom hoist lever forward to release the boom hoist brake. With the brake released, slide pin (71) through the slot in bracket (65) and on through the drilled hole in bracket (70) as shown in Figure 8F-1. This will lock the brake in the released position

NOTE

If adequate pressure is not available to release the brake, the engine will have to be started to build system pressure.

Also, the assembly pin (71) may be made from 3/8 inch steel rod stock cut to a length of 6 inches.

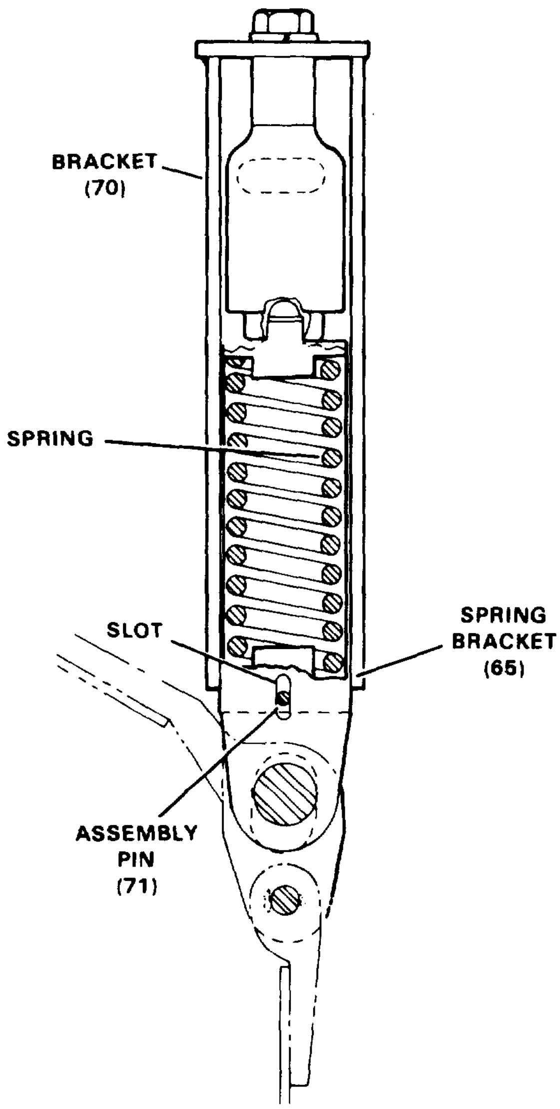


Figure 8F-1. Spring Bracket Assembly (2100N404)

3. With the engine shut down, operate a control lever until all hydraulic pressure is exhausted from the system.

4. Disconnect and cap the hydraulic lines from the boom hoist brake and boom hoist planetary brake cylinders. Plug all connections where hydraulic lines were removed.

5. Remove the upper deck panel immediately to the right of the access door. This makes access to the boom hoist pawls easier.

NOTE

If necessary, remove the shroud between the boom hoist drum and the right hoist drum.

6. Release the tension in springs (17) by loosening jam nuts (20). Remove springs (17) from (21). Remove pin (21) from the band lever.

7. Loosen brake band adjusting bolts (10 and 77). Do not remove nuts (07 and 74). This will reduce the binding tension of the brake operating mechanisms on pin (57).

8. Disengage boom hoist pawls (53 and 56) from the ratchets, as follows:

A. Remove pins (22 and 45) to release the tension in cables (31 and 32).

B. Disengage pawls (53 and 56) from the drum ratchets.

9. Remove capscrew (62) from bracket (51) and remove rod end (61) from pin (57).

CAUTION

The next step in this procedure involves removing pin (57) from the pawls. When removing pin (57) the drum brake operating mechanism should be supported so it will not fall.

10. Slowly pull the pin out of the drum brake operating mechanism, out of the two pawls, and stop.

NOTE

If only planetary pawl (56) must be removed, pull pin (57) out only the distance necessary to remove the planetary pawl.

11. Remove nuts (26), spring seats (28). and springs (29). Then remove pawls (53 and 56).

DISASSEMBLY. To disassemble the pawl operating mechanism and to remove the pawl cylinder, proceed as follows (see Figure 8F-2):

1. If cylinder (41) must be removed, loosen jam nut (40) and remove spring (39). Remove pins (22, 35 and 49) and remove push rod (36), spring (37), spring guide (38) and nut (40).

2. Remove cylinder (41) by removing capscrew (44) and lockwasher (43).

INSPECTION AND REPAIR. Prior to assembly, the following items should be Inspected (see Figure 8F-2):

1. If either pawl is worn, cracked or broken, replace the pawl.

2. If the cylinder leaks or has been performing erratically, remove and overhaul. See Subsection 5D.

3. Inspect the boom hoist drum ratchets for wear, cracks or broken teeth. Repair or replace if necessary. See Subsection 8B.

4. Inspect the boom hoist brake linings and reline if necessary. See Subsection 8C.

5. Inspect the boom hoist planetary brake linings and reline if necessary. See Subsection 8C.

6. Inspect cables (31 and 32) for condition. Check for freedom of movement.

7. Check the condition of springs (24) which are mounted towards the inside of the pawls. Replace as required.

ASSEMBLY. To assemble the boom hoist pawls and operating mechanism, proceed as follows (see Figure 8F-2):

1. Place cylinder (41) into the cylinder support and secure in place with the attaching hardware.

2. Place push rod (36) into support bracket (46) and insert spring (37) on the push rod. Thread spring guide (38) and nut (40) on the push rod.

3. Install pins (22, 35 and 49). Adjustment to the springs and operating mechanism are made later. Connect spring (39) to lever (50) and the spring bracket on support bracket (46).

NOTE

Pawls (53 and 56) are similar and are assembled in the same manner.

4. Install pawls (53 and 56) on cables (31 and 32). Install spring seats (28). springs (29) and stop nuts (26) on cables (31 and 32).

INSTALLATION. To install the boom hoist pawls, proceedas follows (see Figure 8F-2):

NOTE

If only pawl (56) was removed, proceed to step 3.

1. Place pawl assembly (53) up to pin (57). Push the pin through the pawl and bracket (52).

2. Align the boom hoist brake and push pin (57) through it into bracket (55).

3. Place spacer (01) and pawl assembly (56) up to pin (57). Push the pin through the spacer, the pawl and into the support receptacle on the revolving frame.

4. Insert rod end (61) into pin (57) and secure with capscrew (62) to bracket (51).

5. Install pin (21) in the planetary brake band lever and attach springs (17), studs (18), washers (19) and nuts (20).

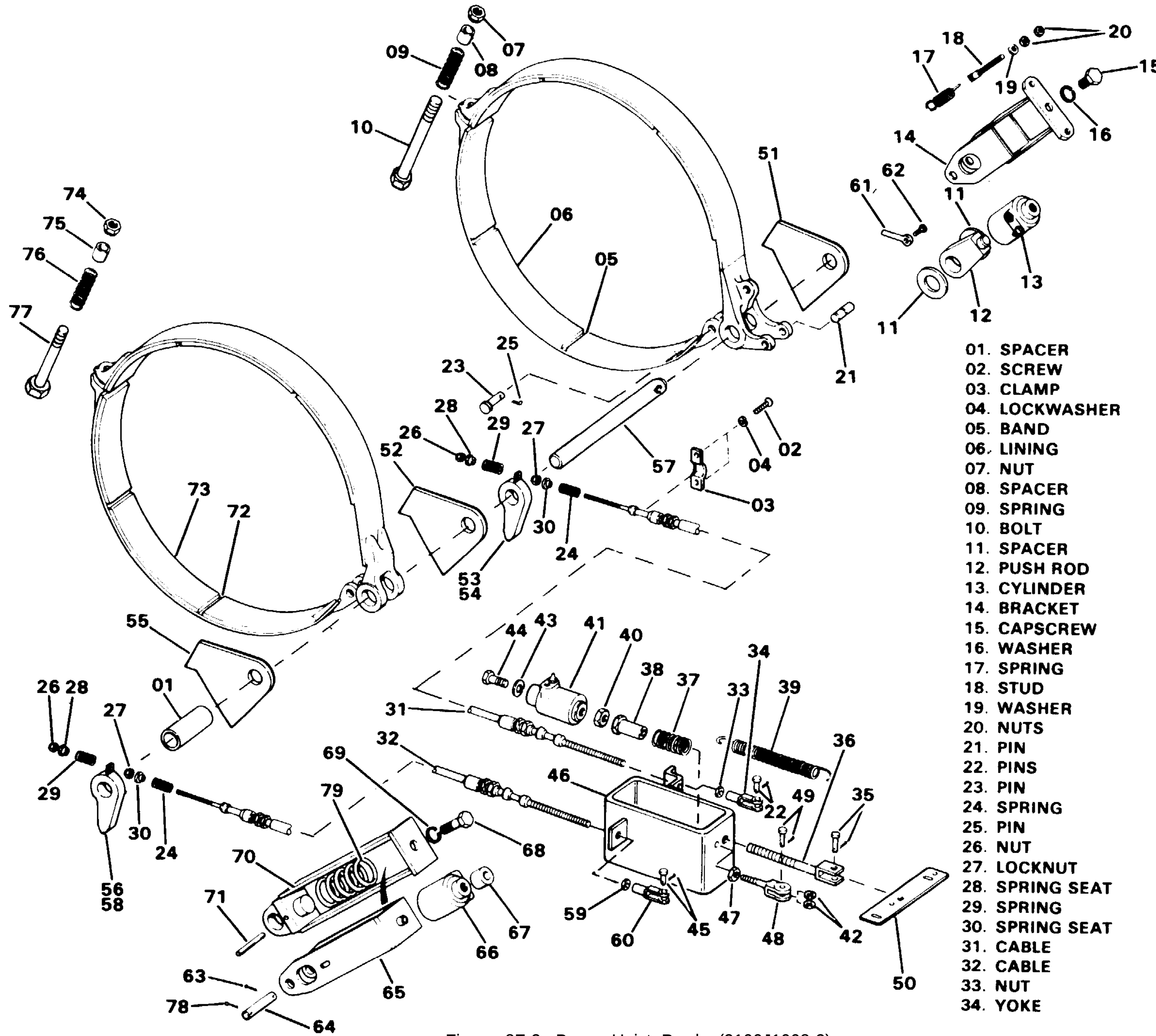
6. Remove the caps and plugs from all hydraulic lines and connections. Install the hydraulic lines.

7. Bleed the hydraulic cylinders to remove any air trapped in the hydraulic lines. See the bleeding procedure in Subsection 5A.

8. Move the boom hoist lever forward to compress spring (79). Pull assembly pin (71) out of brackets (65 and 70). Place the boom hoist lever back to neutral.

9 See Subsection 8C and adjust the boom hoist brakes.

10. See SubsectIon 8C and adjust the boom hoist planetary brakes.



01. SPACER
02. SCREW
03. CLAMP
04. LOCKWASHER
05. BAND
06. LINING
07. NUT
08. SPACER
09. SPRING
10. BOLT
11. SPACER
12. PUSH ROD
13. CYLINDER
14. BRACKET
15. CAPSCREW
16. WASHER
17. SPRING
18. STUD
19. WASHER
20. NUTS
21. PIN
22. PINS
23. PIN
24. SPRING
25. PIN
26. NUT
27. LOCKNUT
28. SPRING SEAT
29. SPRING
30. SPRING SEAT
31. CABLE
32. CABLE
33. NUT
34. YOKE
35. PINS
36. PUSH ROD
37. SPRING
38. SPRING GUIDE
39. SPRING
40. NUT
41. CYLINDER
42. WASHERS
43. LOCKWASHER
44. CAPSCREW
45. PINS
46. BRACKET
47. NUT
48. YOKE
49. PIN
50. LEVER
51. BRACKET
52. BRACKET
53. PAWL
54. FITTING (NOT SHOWN)
55. BRACKET
56. PAWL
57. PIN
58. FITTING (NOT SHOWN)
59. NUT
60. YOKE
61. ROD END
62. CAPSCREW
63. PIN
64. PIN
65. BRACKET
66. CYLINDER
67. SPACER
68. CAPSCREW
69. LOCKWASHER
70. BRACKET
71. ASSEMBLY PIN
72. BAND
73. LINING
74. NUT
75. SPACER
76. SPRING
77. BOLT
78. PIN
79. SPRING

Figure 8F-2. Boom Hoist Pawls (2100J1008-2)

ADJUSTMENTS. To prevent a live boom condition from occurring when both pawls become disengaged from the ratchets as the linkage crosses the neutral positron, adjust the pawls as follows (see Figure 8F-3):

1. Make certain that the pawls pivot freely on support pin (57).

2. With the boom hoist control lever in the neutral position, perform the following checks and adjustments.

A. The clearance between the pawl cylinder spring guide and the support bracket should be 0.132 inch. Adjust to this dimension by loosening the jam nut and turning the spring guide. Tighten the jam nut to the spring guide.

B. The distance between the pivot pin and the end of the support bracket should be 3 inches. Adjust to this dimension by means of the jam nut and the pivot yoke.

NOTE

All the pins except pin (22) must be removed to allow lever (50) to swing clear of yoke (48). Turn the yoke to the proper setting.

C. Make certain the boom hoist drum pawl is fully engaged in the ratchet teeth, and the length of the pawl spring "A" is approximately 2-1/16 inches. Adjust to this dimension by means of adjusting nut "A", if necessary.

NOTE

The length of pawl spring "A" may vary slightly. However, the length of pawl spring "B" *must be exactly* 1-3/4 inches. *This applies to both pawls.* Maintain this dimension by turning adjusting screw "B" in or out as required.

D. The planetary pawl must clear the ratchet teeth by a minimum of 1/8 inch. Adjust to this dimension by means of adjusting nut "A", if necessary. Refer to the note in step C if any adjustment was made.

3. With the boom hoist control lever in the lowering position. perform the following checks and adjustments.

A. Make certain the planetary pawl is fully engaged in the ratchet teeth. The length of pawl spring "A" should be

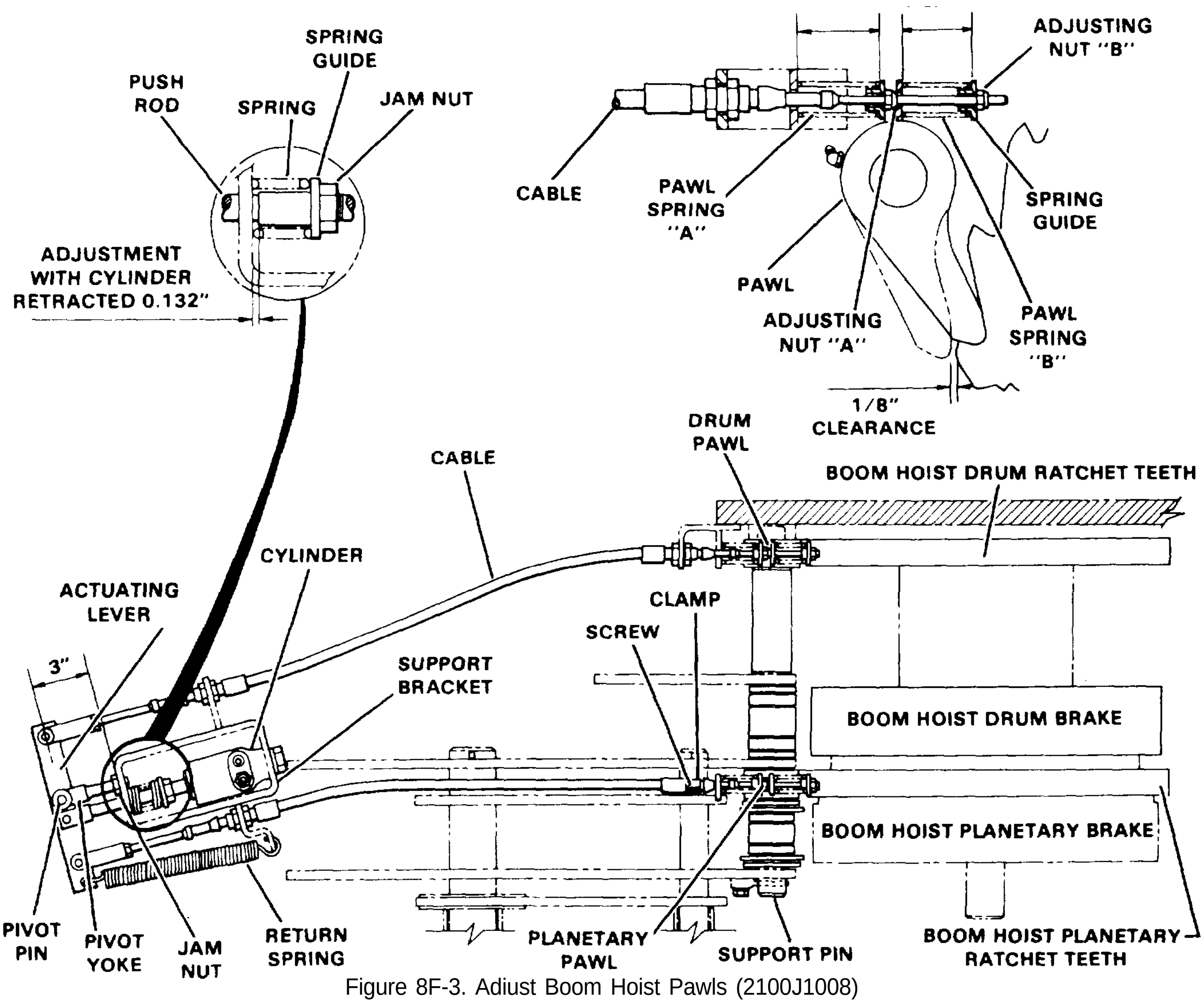


Figure 8F-3. Adiust Boom Hoist Pawls (2100J1008) approximately 2-1/16 inches. Adjust to this dimension by means of the adjusting nut "A", if necessary. Refer to the note in step 2C if any adjustment was made.

B. The boom hoist drum pawl must clear the ratchet teeth by a minimum of 1/8 inch. Adjust to this dimension by means of adjusting nut "A" if necessary. Refer to the note in step 2C if any adjustment was made.

4. Check that all jam nuts on cables and yokes are tightened securely. Also, be sure all cotter pins are installed in their required places.

5. Check for secure installation of the machine screws holding clamp (03) and the pawl end of cable (31).

6. Start the engine and operate the boom hoist controls. Check the operation of the pawls and brakes. Make certain they are operating properly before lifting the boom or any loads.

7. Replace the panel and shroud if removed for overhaul.

SECTION IX

PROPEL SYSTEM AND COMPONENTS

SUBSECTION 9A

PROPEL SYSTEM

GENERAL

This section covers the mechanical and hydraulic components that are used to propel the machine. Crawler side frame and axle removal and installation procedures are also included in this section information pertaining to the propel anti-stall control system is located in Section X.

The propel system consists of the propel transmission, propel brake, propel gear case and the crawler components as shown in Figure 9A-1

DESCRIPTION

The propel transmission consists of two engine driven variable displacement pumps and two fixed displacement motors. One motor is provided for each side of the machine. The torque converter is controlled by an electronic anti-stall control system which automatically prevents engine stalling while propelling.

The propel motors are mounted on reduction gear cases at the rear of the crawler side frames. A spring set holding brake is located between the output shaft of the motor and the input of the gear case. Rotation of the gear case output shaft drives the crawler track drive sprocket The crawler idler sprocket is located at the front of the machine and is adjustable to compensate for crawler track wear.

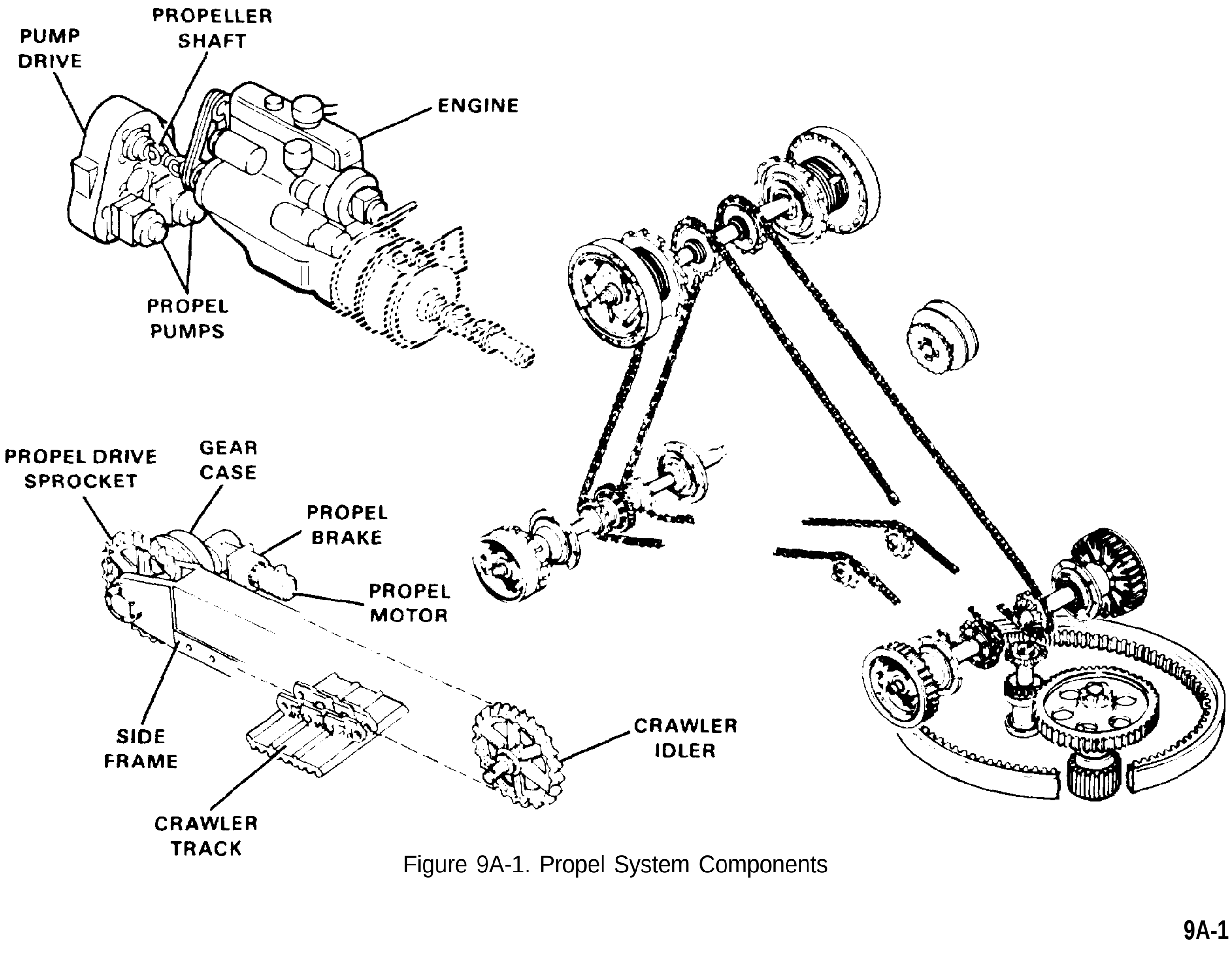


Figure 9A-1. Propel System Components

SUBSECTION 9B

PROPEL TRANSMISSION

GENERAL

The propel transmission includes the hydraulic components used to propel the machine. The components-include the propel pumps, motors, controls, filters, heat exchanger and reservoir. The pumps, controls, filters, heat exchanger and propel reservoir are located at the left rear of the upper. The propel motors are mounted on the propel brakes at the rear of the crawler frames. An independent pump and motor is provided for each side of the machine.

This subsection covers the description, maintenance, start-up, troubleshooting and repair of the propel transmission.

The description and troubleshooting of the electronic propel control system is covered in Subsection 10C.

DESCRIPTION

GENERAL

Each propel hydrostatic transmission consists of a variable displacement pump connected to a fixed displacement motor (see Figure 9B-1). The pumps rotate in one direction only, whereas the motors rotate in either direction.

The main ports of the pumps are connected by hydraulic lines to the main ports of the motors. Fluid flows, in either

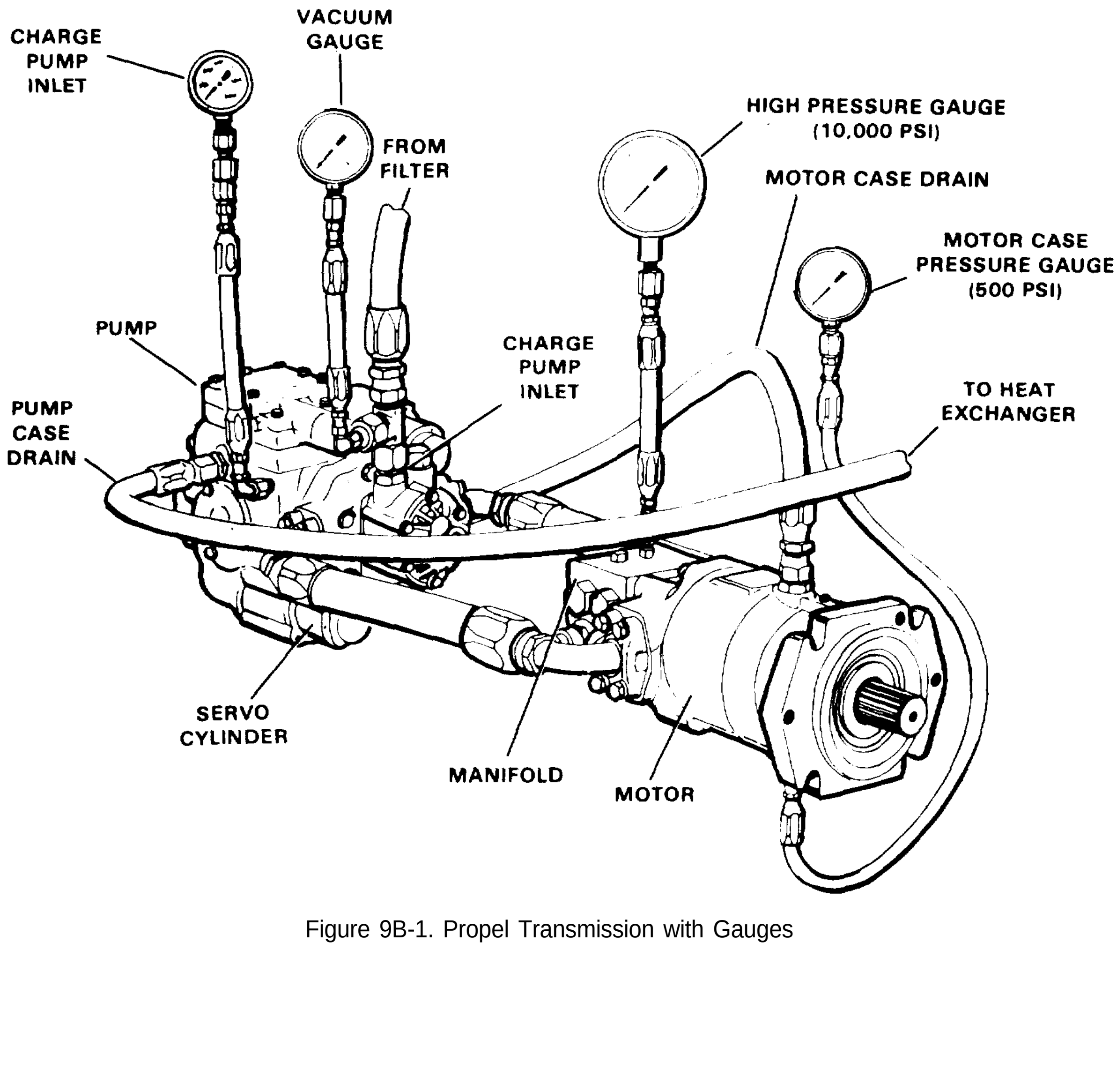


Figure 9B-1. Propel Transmission with Gauges direction, from the pump to the motor, then back to the pump in the closed circuit (see Figure 9B-10). The position of the pump swash plate determines which line is high pressure as well as the direction of flow.

PUMPS

The variable displacement pumps use a tiltable swash plate to vary displacement (output flow). The swash plate is mounted on trunnion bearings and IS connected to hydraulic control (servo) cylinders. The control directs fluid to and from the servo cylinders causing the swash plate to tilt and change displacement of the pump. The swash plate can be tilted in either direction from 0 angle to provide pump flow in either direction.

Since the angle of the swash plate causes the pistons to stroke in and out of the cylinder block bores as it is rotated, changing this angle varies the piston stroke, and therefore, the amount of fluid being displaced (pumped) to the motor. This results in a change in the output speed of the motor Tilting the swash plate in the opposite direction reverses fluid flow to the motor and its direction of rotation. Since each servo control cylinder is spring loaded, loss of control pressure or charge pressure will cause the swash plate to return to the neutral position.

CHARGE SYSTEM

A fixed displacement (gear type) charge pump is mounted on each variable displacement pump and driven off the main pump shaft (see Figure 9B-2). The charge pump supplies cool fluid to the system, keeps the systern charged and supplies fluid to operate the control system. Charge pressure, with the purnp in neutral (0 flow), is limited by a relief valve which is normally factory set for 190-210 psi (above case pressure).

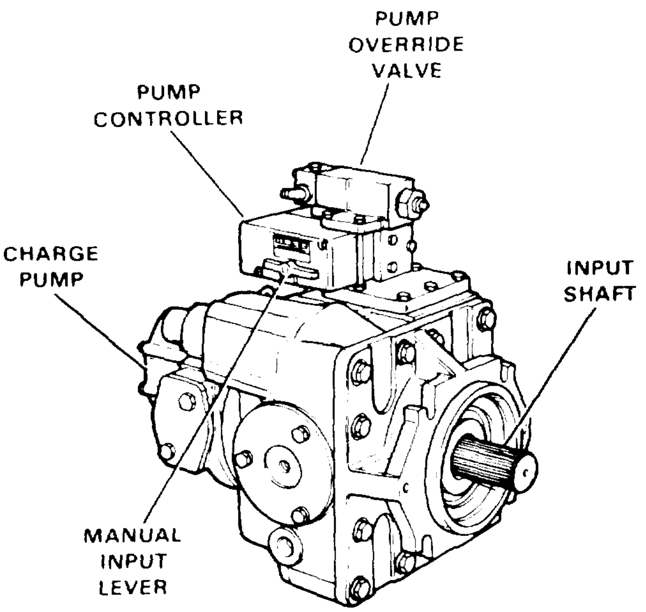


Figure 9B-2. Propel Pump

Since either of the main hydraulic lines can be high pressure, two charge check valves are used to direct the charge supply into the low pressure line. The check valves are contained in the pump end cap beneath the charge pump

The charge pump draws the fluid from the reservoir An inlet filter insures that only clean fluid enters the system This filter has a 10 micron rating and does not have a bypass.

RELIEF VALVES

Two system relief valves are provided for overload protection on each pump and motor and are located in the manifold assembly mounted on the motor (see Figure 9B-3). These relief valves are factory set and are of the pilot operated, cartridge type The first two digits of the pressure setting are stamped on the end of the relief valve cartridge.

SYSTEM PRESSURE GAUGE PORT IS LOCATED ON SIDE OPPOSITE THE CORRESPONDING HIGH PRESSURE RELIEF VALVE CARTRIDGE

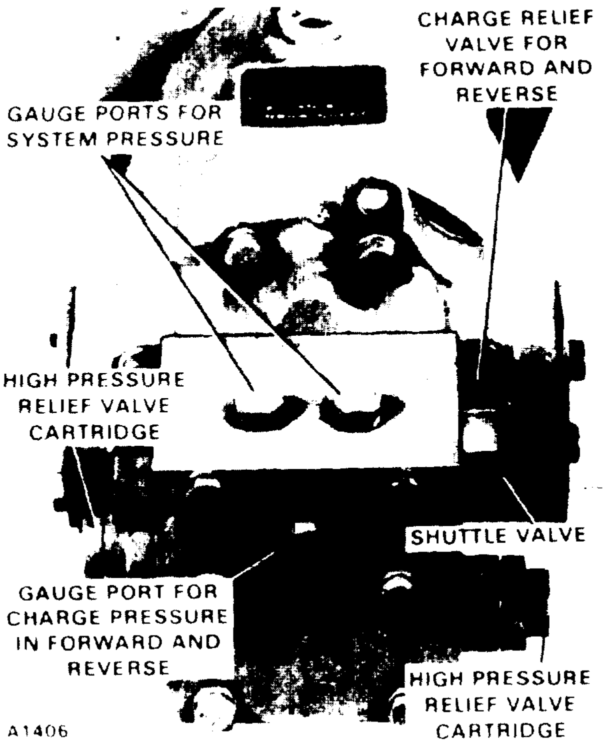


Figure 9B-3 Propel Motor

CAUTION

The relief valves are factory set and should not be tampered with except to replace the entire cartridge.

COOLING CIRCUIT

A shuttle valve and second charge relief valve are included in the motor manifold assembly The shuttle valve provides a circuit between the low pressure hydraulic line of the closed circuit to the second charge relief valve. This charge relief valve is set at a lower pressure (160-180 psi) than the relief valve located in the charge pump. This charge relief valve limits charge pressure when the pump is in forward or reverse (swash plate stroked out of neutral).

This system provides a means of removing hot fluid from the main closed circuit so that cooler fluid entering from the charge pump can be used to help reduce heat build-up.

The shuttle valve is spring centered to the closed position so that during the transition of reversing pressures in the main hydraulic lines, no high pressure fluid is lost from the closed circuit.

When the pump is in neutral (0 swash plate angle) the manifold charge pressure should be at 190-210 psi (above case pressure) When the pump IS in forward or reverse (other than Oswash plate angle) the charge pressure should be at 160-180 psi (above case pressure).

CAUTION

Charge pressure must not be less than 160 psi for satisfactory operation.

CONTROLLER

This system uses an electric displacement controller that provides pump output flow (displacement) in either direction that is approximately proportional to an electrical input signal. The controller has a manual input lever located on the top of the electrical section.

A pressure override is mounted on the electric controller to provide overload protection. The override will automatically destroke the pump once the desired maximum system pressure (load) is reached. It wiIl maintain that system pressure so the load can be held. This prevents operation of the system relief valves for prolonged periods and helps reduce lost heat build-up in the system.

An engine anti-stall feature is incorporated in the control system. Engine speed is sensed through a magnetic pulse pickup mounted on the flywheel housing and the throttle position through a potentiometer connected to the throttle linkage A predetermined engine speed is maintained at a given throttle positron by comparing the signal from the pulse pickup to the desired signal as determined by the potentiometer position and, if lower than desired, reducing the voltage to the displacement controls on the pumps. This causes the pumps todestroke, reducing the horsepower demanded from the engine, thus preventing engine stall. Maximum tractive effort is maintained since pressure is not reduced.

MAINTENANCE

The following points should be kept in mind when working on the propel hydraulic system or any of the hydraulic components:

1. Any structure has limits of strength and durability To prevent the failure of structural part of hydraulic components, relief valves which limit pressure to safe operating values are included in the circuit. *The settings of these relief valves must never be changed.*

2. Tolerances of working parts in the hydraulic system are very close. Even small amounts of dirt or foreign material in the system can cause wear or damage to components, as well as general faulty operation of the system. *Every precaution must be taken to assure absolute cleanliness of the hydraulic oil.*

3. Samples of hydraulic oil should be drawn from the reservoir every six months. These samples should be about two quarts, and should be taken while the oil is warmed through normal operation. If possible, the sample should be analyzed by a qualified lubrication specialist to determine whether it is suitable for further use. The intervals between oil changes depend on operating conditions, and on the care used in keeping the oil clean

4. Whenever there is a hydraulic component malfunction which gives reason to believe that there are metal particles or other foreign materials in the system, drain and clean the entire system, and replace the filter cartridges. A complete change of hydraulic oil must be made under these circumstances.

CAUTION

If the system should become contaminated, DO NOT use a flushing solution to clean the system. The entire system must be disassembled and cleaned.

5. Do not use synthetic or fire resistant oils in this system. The packings in this system are designed for the fluid specified in Section Ill.

6. All containers and funnels used in handling hydraulic oil must be absolutely clean. Use a 10 micron filtering screen for filling the propel reservoir, and fill the reservoir only through the filler opening The use of cloth to strain the oil should be avoided to prevent lint from getting into the system.

7. When removing any hydraulic component, be sure to cap and tag all hydraulic lines involved. Also plug the ports of the removed components.

9. All hydraulic components must be disassembled in spotlessly clean surroundings. During disassembly, pay particular attention to the identification of parts to assure proper reassembly. Clean all metal parts in a clean mineral oil solvent. Be sure to thoroughly clean all internal passages. After the parts have been dried thoroughly lay them on a clean, lint-free surface for inspection.

9. Replace all O-rings and seals when repairing any component Lubricate all parts with clean hydraulic oil before reassembly. Use small amounts of petroleum jelly to hold O-rings in place during reassembly.

10. Be sure to replace any lost hydraulic oil when completing the installation of the repaired component.

11. All hydraulic connections must be kept tight. A loose connection in a pressure line will permit the oil to leak out or air to be drawn into the system. Air in the system can cause damage to the components and noisy or erratic system operation.

START-UP PROCEDURE

This is a closed loop system which requires the build-up of pressures and replenishment of hydraul oil whenever any component has been removed and reinstalled.

Whenever a pump or motor is replaced or air has entered the hydraulic lines, use the following procedure to build system pressure and replenish fluid:

1. Fill the reservoir with the hydraulic fluid specified in Section III. The fluid should be passed through a 10 micron filter prior to entering the reservoir. Never reuse fluid.

2. Fill the inlet line leading from the reservoir to the pump if it has drained. Check the inlet line for properly tightened fittings and make sure it is free of restrictions and air leaks.

3. Be certain the main pump and motor housings are filled with clean hydraulic fluid prior to start-up by pouring filtered oil in the uppermost case drain port.

4. Install a 600 psi pressure gauge in the charge pressure gauge port of each pump.

5. Disconnect the electrical wires attached to the controllers. This will allow the pumps to remain in neutral during initial start-up.

6. Disconnect the wires at the engine fuel solenoid to prevent the engine from starting. Jog the starting circuit until the charge pressure reaches 80 psi at both charge pumps.

CAUTION

Do not start the engine unless the pumps are in neutral (0 swash plate angle). Take safety precautions to prevent machine movement in case a pump is actuated during initial start-up.

7. Start the engine and run it at the lowest possible rpm until the charge pressure has been established. Air can be bled from the high pressure lines by using the high pressure gauge ports on the motor manifold.

8. Once charge pressure has been established, increase speed to normal operating rpm. Charge pressure should be 190-210 psi minimum. If charge pressure is not at the proper value, shut down the engine and determine the cause.

9. Shut down the engine and connect the wires to the controllers. Start the engine, checking to be certain the pump remains in neutral. With the engine at normal operating speed, slowly check for forward and reverse machine operation.

10. Continue to cycle slowly from forward to reverse for five minutes. The charge pressure should remain at 160-180 psi minimum during forward or reverse operation.

11. Shut down the engine, remove the gauges and plug the ports. Check the reservoir level and add fluid if necessary. The transmission is now ready for operation.

TROUBLESHOOTING

GENERAL

Use the system description, Table 9B-1, and the hydraulic schematic (see Figure 9B-10) to isolate a problem in the propel transmission circuit. Figure 9B-1 illustrates the gauges and connections required for testing the hydraulic system.

Check with the machine operator to see how the propel transmission performed when it started to malfunction or if there is anything unusual about it. Operate the propel controls and check for unusual noises. Visually inspect the propel components, looking for oil leaks. Examine the pumps and motors, reservoir, filters and all lines, checking for heat, loose connections or collapsed hoses.

TROUBLESHOOTING PROCEDURES

Some minor parts removal is required to troubleshoot the propel hydraulic system. Cleanliness is a primary means of insuring satisfactory transmission life. Cleaning parts by using a solvent wash and air drying is adequate, provided clean solvent is used. As with any precision equipment, the internal mechanism and related items must be kept free of foreign materials and chemicals. Troubleshoot individual components as follows:

INSPECT THE PUMP CONTROLLER AND PRESSURE OVERRIDE. The electrically actuated controller mounted on the pump is provided with a manual controller to bypass the electrical system and manually test the control. Disconnect the control wire connected to the controller and activate the control by rotating the manual control to the left or right. If the machine will propel manually but not electrically, troubleshoot the electrical control system as described in Subsection 10C.

If the machine has a tendency to propel forward or backward when the controller is in neutral, the null should be adjusted as described under the topic, Controller, later in this subsection.

The setting of the pressure override mounted on the control can be checked and adjusted. This is normally not required, however, if a problem in this area is suspected, refer to the topic, Pressure Override, later in this subsection.

INSPECT SYSTEM RELIEF VALVES. When the problem occurs in one direction only, interchange the relief valve cartridges to see if the problem changes to the other direction (see Figure 98-4). If so, one relief valve cartridge is either malfunctioning or does not have the proper setting. The first two digits of the pressure setting are stamped on the end of the cartridge.

CAUTION

The relief valves are factory set and should not be disassembled further.

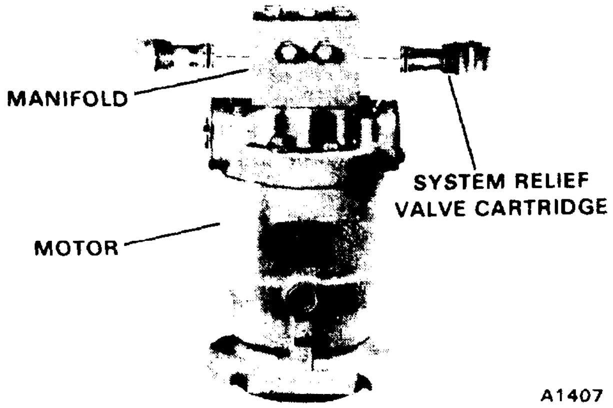


Figure 9B-4 Relief Valves

INSPECT THE SHUTTLE VALVE Remove the two hex plugs and the shuttle valve parts Inspect for broken or damaged parts and proper orientation (see Figure 9B-5) Washers must go between the spool and springs. Inspect to see if the spool moves smoothly in its bore.

NOTE

The spool and manifold are matched and cannot be replaced separately.

INSPECT THE CHARGE CHECK VALVES

CAUTION

Protect the exposed cavities into the pump from foreign material.

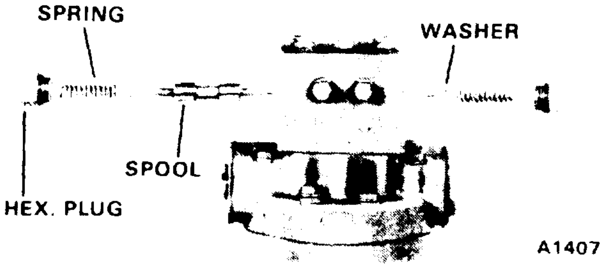


Figure 9B-5. Shuttle Valve

The charge check valves are located in the pump end cap, under the charge pump. Remove the charge pump as described later in this subsection (see Figure 9B-6). Remove both charge check valves and keep them in the same relation to the end cap.

Inspect the check valve for spring loading by pushing against the internal ball. A slight resistance should be felt as the ball is pushed off its seat. The internal spring should return the ball to its seat when force is removed. Check for any foreign material inside the valve.

When the problem occurs in one direction only, interchange the check valves and see if the problem changes to the other direction (see Figure 9B-7). If so, one check valve is malfunctioning and should be replaced.

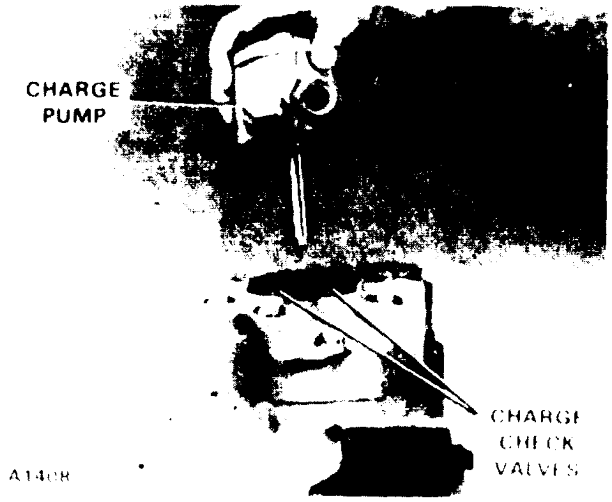


Figure 9B-6. Charge Pump Removal

Figure 9B-7. Check Valve Interchange

INSPECT THE PUMP CHARGE RELIEF VALVE. If the charge pressure is low (below 190 psi) in neutral only (okay in forward and reverse), the charge relief valve located in the charge pump should be inspected. Remove the hex plug and relief valve parts (see Figure 9B-8). Inspect for foreign material holding the poppet open, and for galling or wear on the poppet and seat in the charge pump.

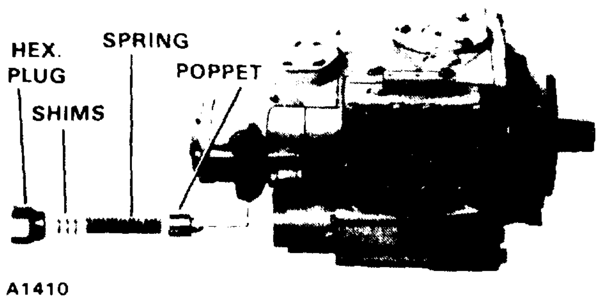


Figure 9B-8 Pump Charge Relief Valve

CAUTION

Make certain the pressure setting of the motor charge relief valve is below the pressure setting of the pump charge relief valve to assure that the cooling circuit will function properly.

Adjustment of the charge pressure in forward and reverse is accomplished by changing the shims behind the spring.

INSPECT THE MOTOR CHARGE RELIEF VALVE. If charge pressure is low (below 160 psi) in forward and reverse (okay in neutral), the charge relief valve located in the motor manifold should be inspected. Remove the hex plug and relief valve parts (see Figure 9B-9). Inspect for foreign material holding the poppet open, and for galling or wear on the poppet and seat in the manifold.

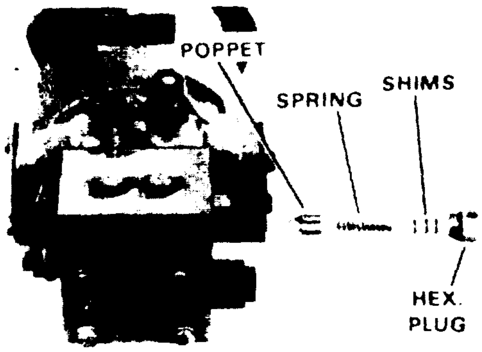


Figure 9B-9 Motor Charge Relief Valve

CAUTION

Make certain the pressure setting of the motor charge relief valve is below the pressure setting of the pump charge relief valve to assure proper operation of the cooling circuit.

Adjustment of the charge pressure in forward and reverse is accomplished by changing the shims behind the spring.

PUMP (37Z289)

DESCRIPTION

This is a variable displacement, axial piston pump. Two pumps are mounted on a pump drive in front of the engine. Engine horsepower is transmitted through the pump drrve to the pumps The pump swash plates remain in neutral until the operator moves the control lever in the cab. When the operator moves the control lever the swash plate in the pumps are tilted from neutral.

When the pump swash plates are tilted, a positive stroke to the pistons is created. This, in turn, at any given input speed, produces a specific flow from the pump. This flow is transferred through high pressure lines to the motors Moving the control lever to the opposite side of neutral, reverses the flow from the pumps and turns the motor output shafts in the opposite direction.

REMOVAL

To remove a pump proceed as follows

CAUTION

It is not necessary to remove the pump to perform repairs on the charge pump, controller, relief valve, or check valves. However, it is extremely important that the disassembled pump be protected from airborne dust. Contaminants introduced directly into the pump, have the greatest potential for causing damage. If this protection cannot be provided, it is suggested that the pump be removed from the machine and repaired in a clean environment.

1. Stop the engine and remove the battery ground cable.
2. Remove the sheet metal around the pump to allow removal of the pump from the side of the machine.
3. Disconnect the electrical lead on the controller.
4. Tag and disconnect the charge pump inlet line, high pressure pump inlet and outlet Iines, and the case drain line Cap all lines to prevent the entry of contaminants and plug all pump openings.
5. Wrap a sling around the pump, and attach a lifting device to the lifting sling.
6. Make a thorough inspection of the area around the pump being removed to ensure that all electrical and hydraulic lines are clear of the pump.
7. Remove the four capscrews which attach the pump to the drive unit and lift the pump out of the machine. Remove the gasket that seals the pump and drive unit.

OVERHAUL

GENERAL. These pumps should be replaced as complete units or repaired to the limits allowed by the service kits.

CAUTION

Repairs beyond the kits explained below will void the warranty on the pumps.

The following overhaul instructions describe the procedure for installing each of the kits.

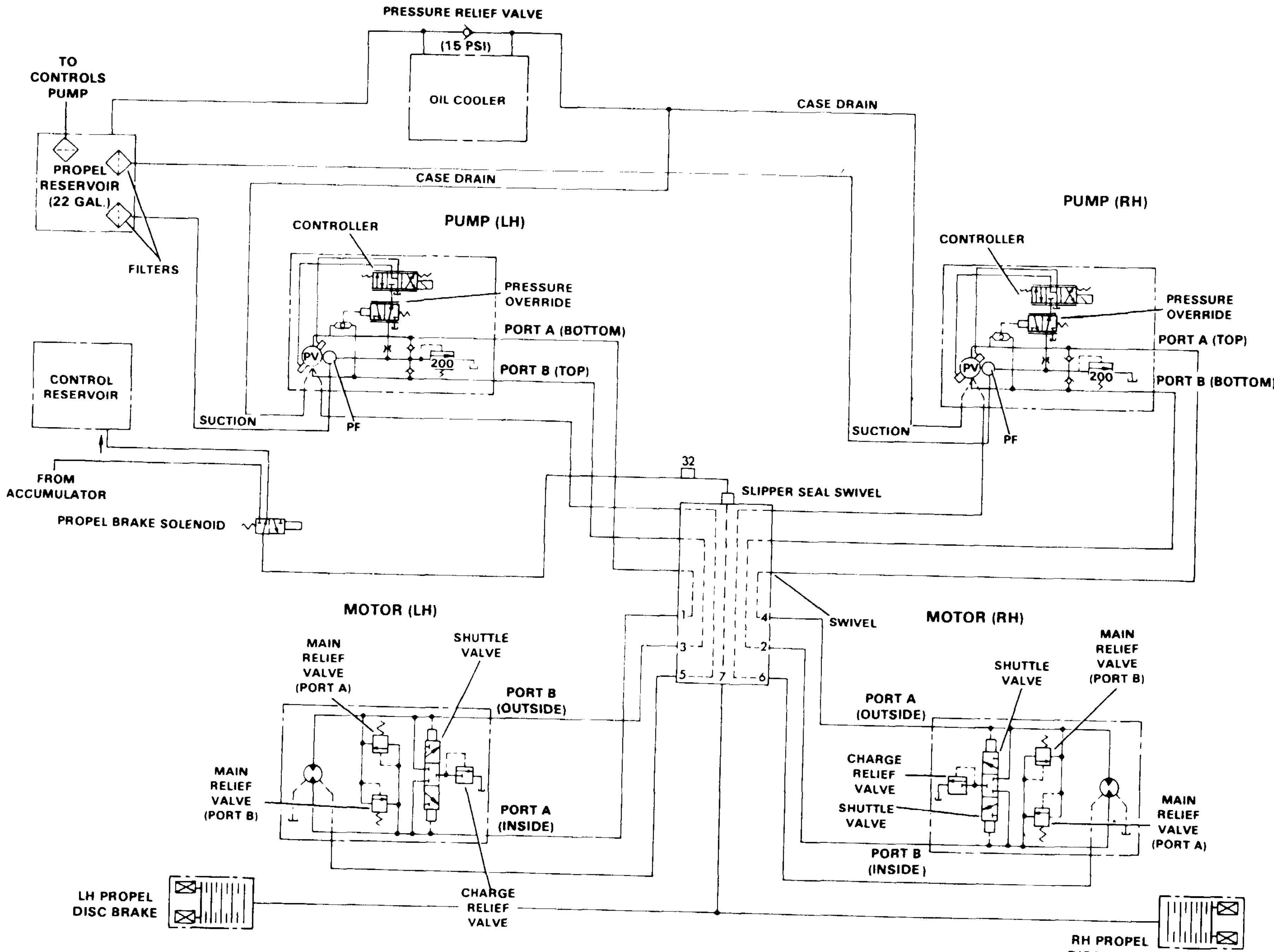


Figure 9B-10. Propel Hydraulic Schematic (2105J171)

Table 9B-1. Propel Transmission Troubleshooting

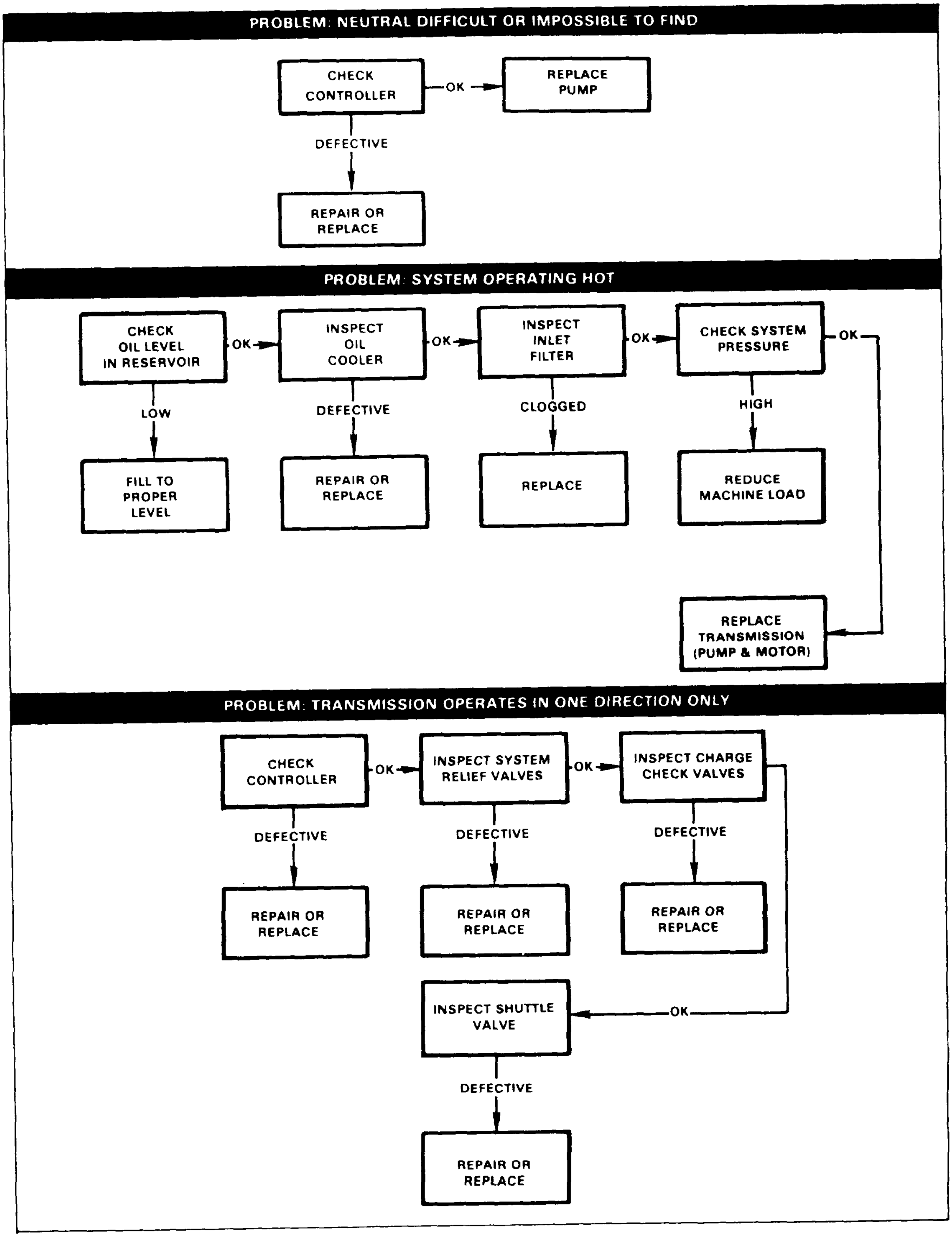
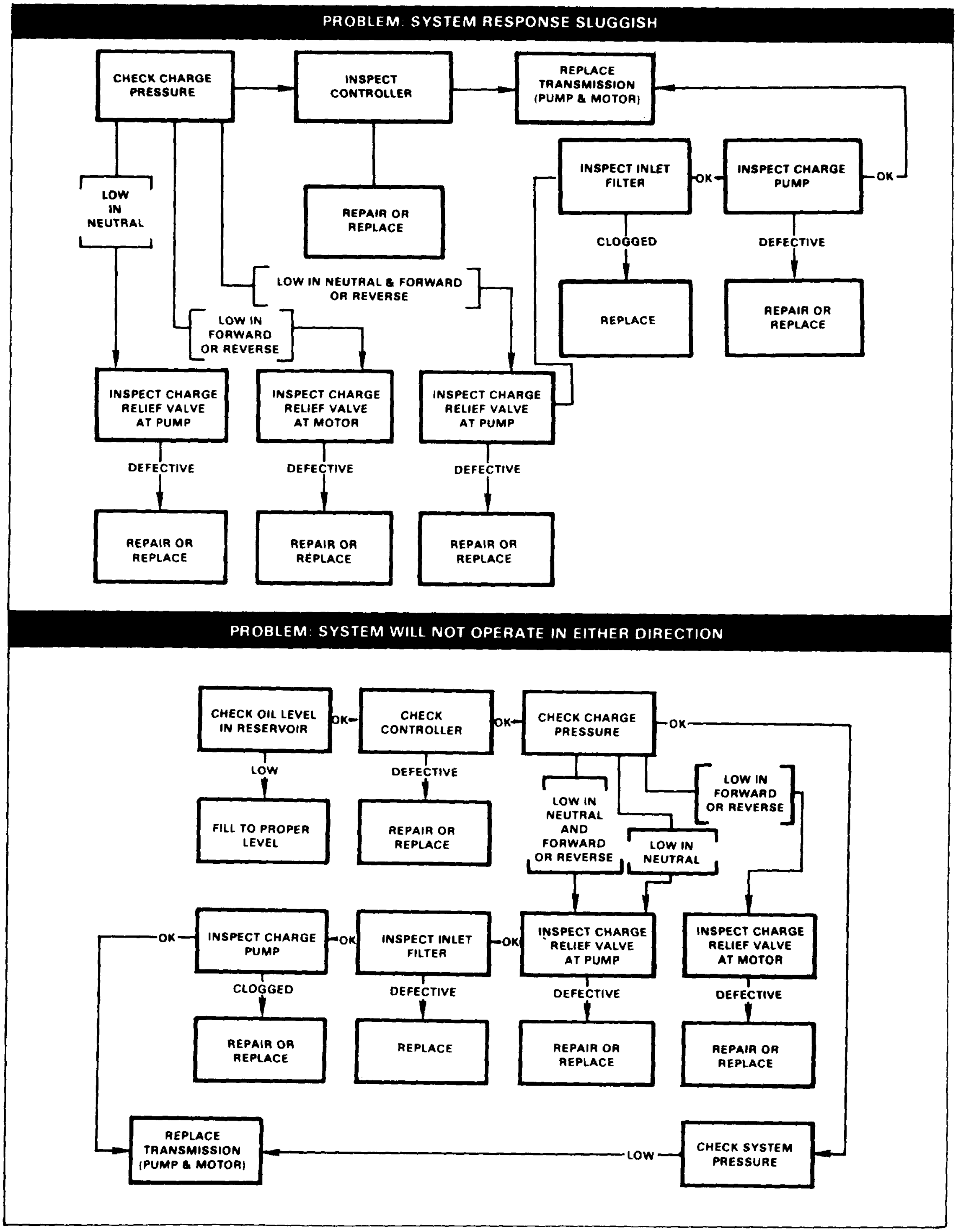


Table 9B-1. Propel Transmission Troubleshooting (Continued)



SHAFT SEAL REPLACEMENT. To replace the shaft seal, proceed as follows:

1. Using a suitable ring pliers, remove the large retaining ring located on the shaft end of the pump. Remove the ring from the groove starting at the side opposite the tang (see Figure 9B-11):

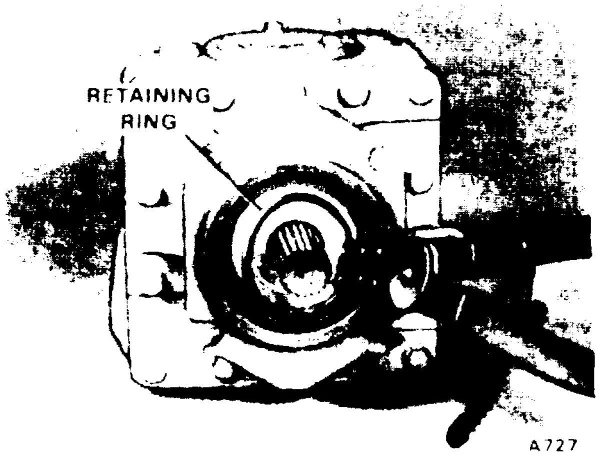


Figure 9B-11. Retaining Ring Removal

2. Using two screwdrivers, pry the aluminum housing toward the end of the shaft until the O-ring is free. The housing is held in place by the friction of the O-ring on the housing O.D. Remove the housing (see Figure 9B-12). The aluminum housing is an assembly that is held together by an O.ring. It will remain assembled until physically separated.

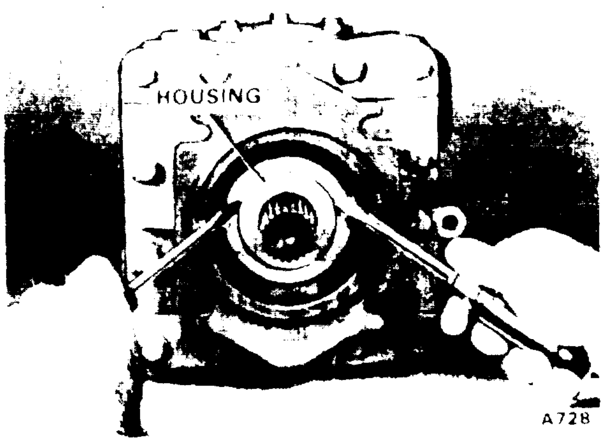


Figure 9B-12. Housing Removal

3. The bronze sealing ring is held in place by an internal O-ring. Using two fingers, carefully slide the sealing ring over the pump shaft (see Figure 9B-13).

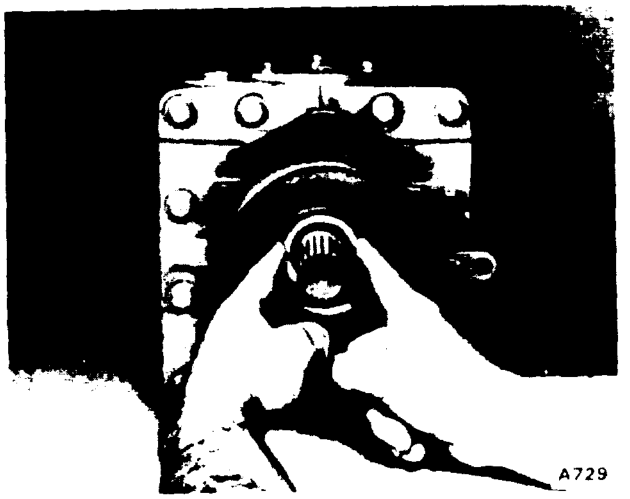


Figure 9B-13. Removing Bronze Sealrng Ring

4. Carefully separate and inspect the aluminum housing components if the seal is to be reused. It is recommended that this entire shaft seal be replaced.

5. Wash and air dry the new seal parts. Install one O-ring (dry) in the I.D. of the bronze sealing ring and one O-ring in the I.D. of the aluminum housing. Place the springs in the holes in the housing (see Figure 9B-14).

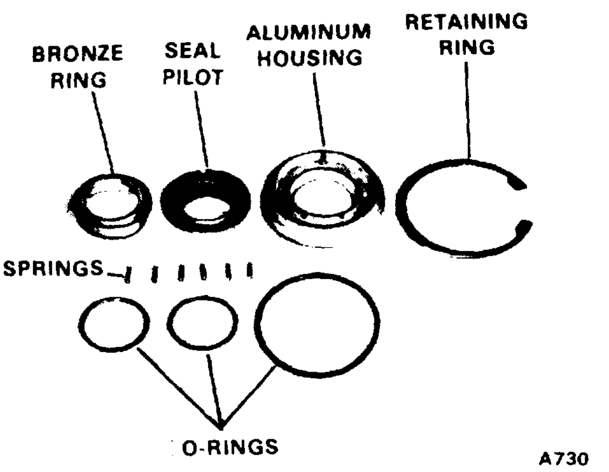


Figure 9B-14. Sealing Items

6. Wrap a piece of plastic around the drive shaft and slide the rotating bronze part over the shaft making sure it is seated. The O-ring should face the pump. Work the ring into place using the thumbs only (see Figure 9B-15).

7. Insert the stationary seal pilot into the aluminum housing, locating the notch in the stationary seal over the pin in the housing.

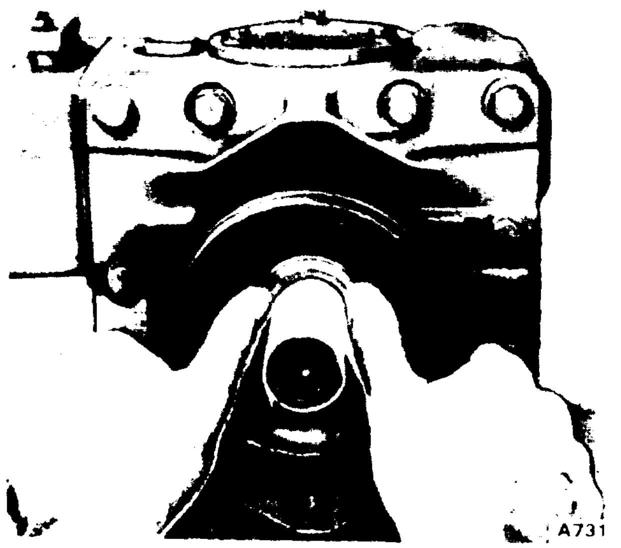


Figure 9B-15. Installing Bronze Ring

8. Install the large O-ring on the O.D. of the housing then slide the housing into place against the bronze sealing ring. Since this is a spring loaded assembly, it may be necessary to push against the aluminum housing to expose the retaining ring groove (see Figure 9B-16).

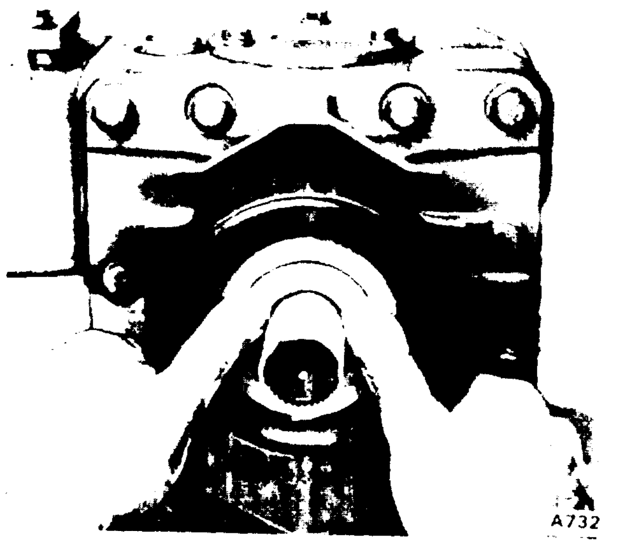


Figure 9B-16. Installing Aluminum Housing

9. Install the retaining ring with the beveled side out, putting the side opposite the tang into the pump groove first. Check that the ring has snapped into place completely (see Figure 9B-17).

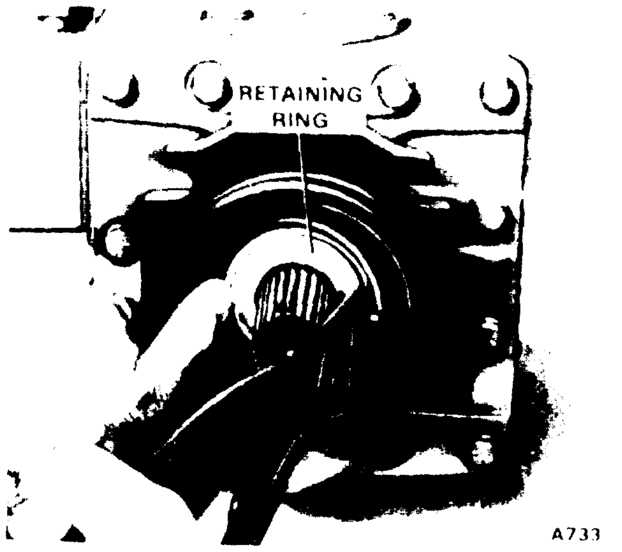


Figure 9B-17. Retaining Ring Installation

CHARGE PUMP, RELIEF VALVE, AND CHECK VALVE REPLACEMENT. To remove the charge pump, charge pump relief valve, and check valves, proceed as follows:

1. Before removing the charge pump, mark its housing and the main pump housing to insure proper orientation when reassembling. Loosen the four capscrews forming a rectangular pattern on the rear of the charge pump(see Figure 9B-18). Do not remove the screws at the top and bottom as these hold the charge pump together. Lift the charge pump straight off of the main pump.

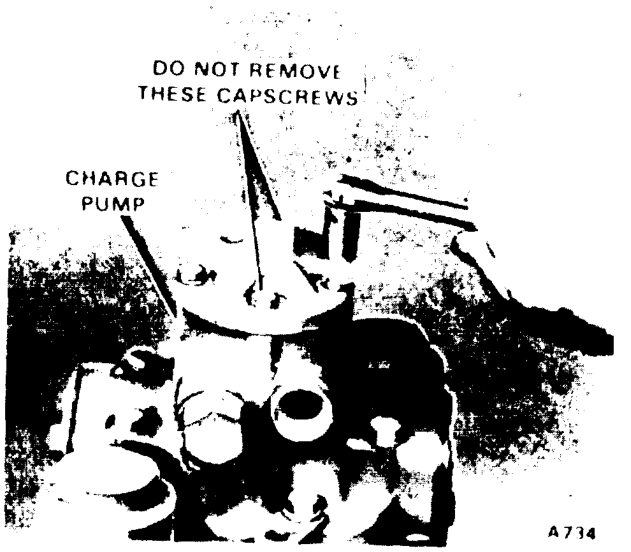


Figure 9B-18. Charge Pump Removal

2. Remove and discard the gasket between the charge pump and main pump.

3. The charge relief valve can be inspected by removing the plug, spring, and poppet. If any shims fall out of the plug be sure to reinstall them.

CAUTION

Do not lose any of the shims inside the plug (see Figure 9B-19).

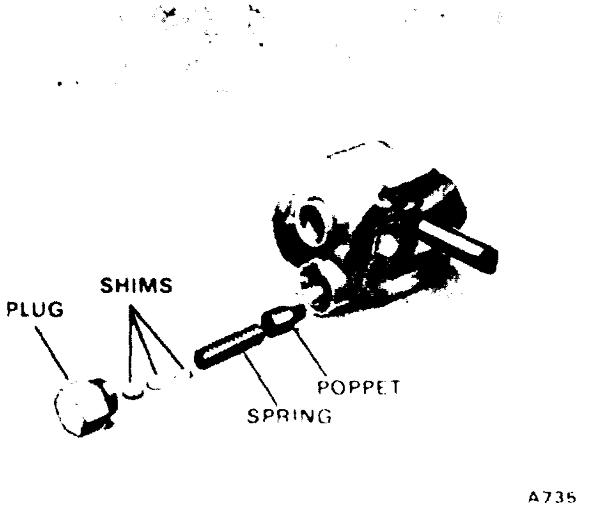


Figure 9B-19. Relief Valve Removal

Reinstall the valve by inserting the poppet, spring and plug.

4 . Using a slotted socket, remove the check valves from the main pump (see Figure 9B-20). These check valves are cartridges and are interchangeable with each other. It is suggested that these check valves be replaced in pairs.

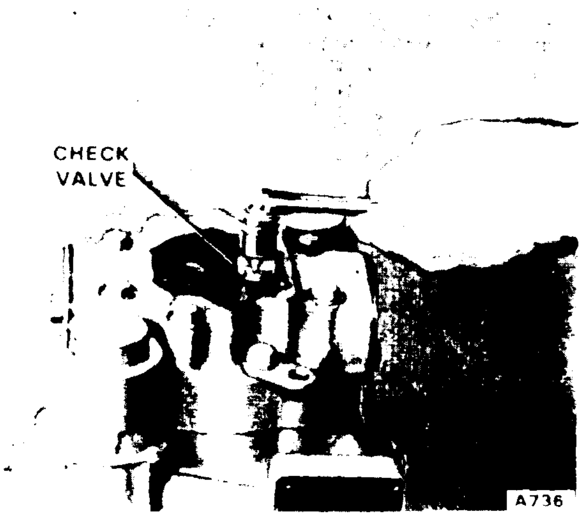


Figure 9B-20. Check Valves

5. Reinstall the check valves using caution to prevent damage to the O-ring on the cartridge as the check valve is inserted in the pump. Torque the check valve to 80-90 ft-lbs. Check that the valves are below the surface of the pump end cap.

6. When replacing the charge pump, align the gasket so that the small relief valve port is open and not blocked by the gasket. Rotate the gasket as necessary to align with the slot in the end of the pump drive shaft. Install the charge pump onto the pump end cap. Rotate the charge pump until the tang and slot engage. Be sure the charge pump sits solidly on the end cap.

7. Install the four capscrews and tighten to 27-37 ft-lbs torque.

INSTALLATION

Care must be exercised, when installing a new or overhauled pump, to prevent misalignment, which can lead to premature pump malfunction. Install a new or overhauled pump as follows:

1. Check the mounting flange on the drive unit, the pilot diameter on the pump, the splined coupling on the drive, and the splined pump input shaft for burrs or imperfections that could prevent the pump from seating properly on the drive unit. Carefully remove any imperfections by lapping.

2. Apply a slight amount of grease to the pilot diameter and the pump shaft splines.

3. Install the gasket on the pump and carefully install the pump on the drive unit. Install the capscrews. Care should be taken in tightening the capscrews to prevent misalignment. Torque lubricated capscrews to 55 ft-lbs.

4. Connect the charge pump inlet line, high pressure pump inlet and outlet lines, and the case drain line.

5. Connect the electrical line to the controller.

6. Install all sheet metal removed previously.

7. Perform the start-up procedure given at the beginning of this subsection.

MOTOR (41Q40)

DESCRIPTION

This is a fixed displacement, axial piston motor. One motor is mounted on the left crawler, while another motor is mounted on the right crawler. The motor receives flow, through high pressure lines, from the pump to turn the output shaft of the motor. Motor output shaft movement is transmitted, through a propel gear case, to the crawler driveshaft to propel the machine. Propel direction is determined by the positioning of the pump swash plate. The load (working pressure) is determined by the external conditions, (grade, ground conditions, etc.) and this establishes the demand on the system.

REMOVAL

To remove a motor, proceed as follows (see Figure 9B-21):

CAUTION

It is not necessary to remove the motor to perform repairs on the manifold or manifold components. However, it is extremely important that the disassembled motor be protected from airborne dust. Contaminants introduced directly into the motor have the greater potential for causing damage. If this protection cannot be provided, it is suggested that the motor be removed from the machine and repaired in a clean environment.

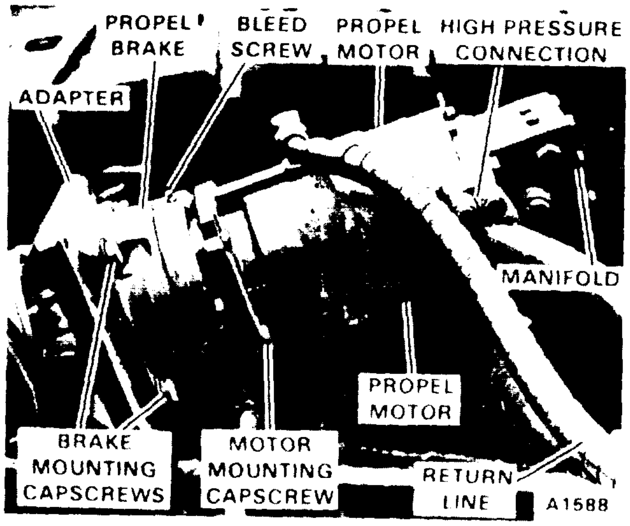


Figure 9B-21. Motor Removal and Installation

1. Move the propel brake switch to the ON position Stop the engine and disconnect the battery ground cable.

2. Tag and disconnect the high pressure lines and the motor case drain line. Cap all lines and plug all motor openings to prevent the entry of contaminants.

3. Wrap a sling around the motor and attach a lifting device to the lifting sling. The motor weighs approximately 155 lbs.

4. Remove the capscrews which attach the motor to the brake plate and pull the motor off the plate.

OVERHAUL

GENERAL. These motors should be replaced as complete units or repaired to the limits allowed by the service kits.

CAUTION

Any repairs attempted beyond the kits explained below will void the warranty on the motors.

The following overhaul instructions describe the procedure for installing each of the kits.

SHAFT SEAL REPLACEMENT. The motor shaft seal replacement is identical to the pump shaft seal replacement described earlier in this subsection.

HIGH PRESSURE RELIEF VALVE, SHUTTLE VALVE, CHARGE RELIEF VALVE, AND MANIFOLD REPLACEMENT. To remove and reinstall the high pressure relief valve, shuttle valve, charge relief valve, and the manifold, proceed as follows:

1. The high pressure relief valves are cartridges that are removed by unscrewing them from the manifold. These valves are factory set and require no adjustment. The pressure settings are the first two numbers stamped on the end of the valve. Before reinstalling new valves in the manifold, check that the two numbers on the new valve are the same as the first two numbers on the old valve. These valves are interchangeable and can be reinstalled in either side of the manifold as long as the pressure settings are the same (see Figure 9B-22).

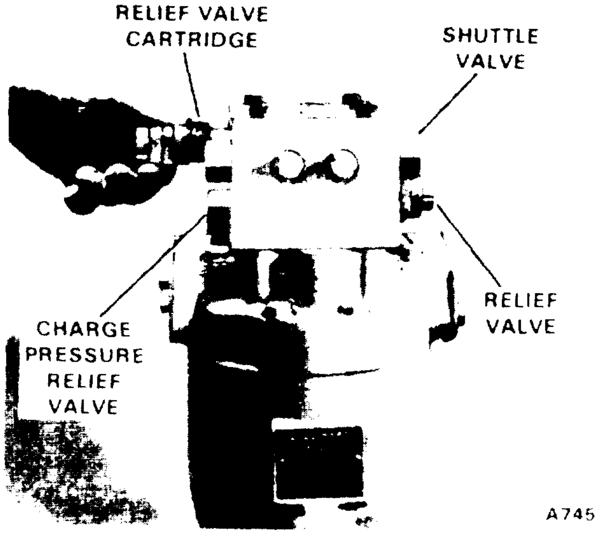


Figure 9B-22 High Pressure Relief Valve

2. To remove the shuttle valve, remove the plugs from both sides of the manifold. Remove the springs, washers, and spool from the manifold. All of these parts are interchangeable and can be installed from either side of the manifold. *The spool and manifold are a select fit and must be replaced together.* To install the shuttle valve, insert the spool in the manifold, place a washer on each end of the spool, then install both springs in place. Install the plugs and tighten. See Figure 9B-23.

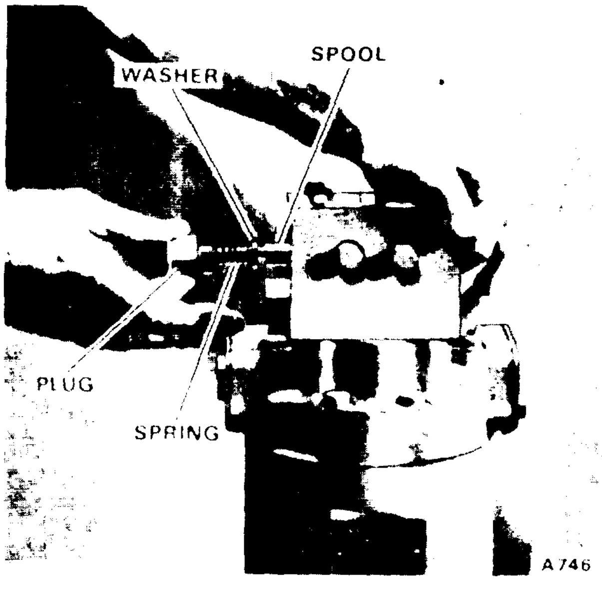


Figure 9B-23. Shuttle Valve Removal

3. To remove the charge relief valve, remove the plug, spring and poppet (see Figure 9B-24). If any shims fall out of the plug, be sure to reinstall them.

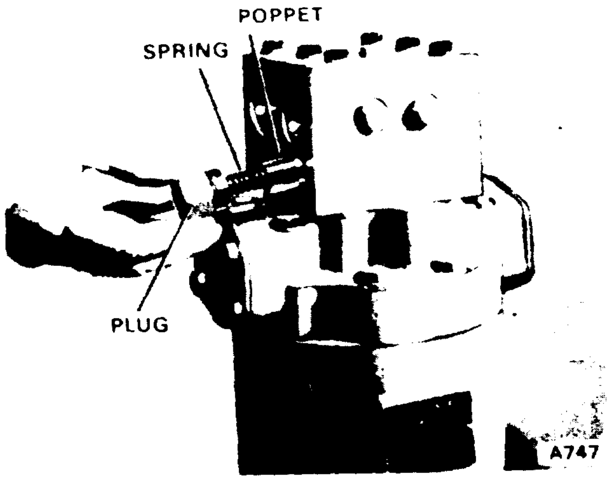


Figure 9B-24. Charge Relief Valve Removal

CAUTION

Do not lose any of the shims inside the plug.

Reinstall the valve by inserting the poppet, spring and plug.

4. The manifold can be removed and replaced as an assembly without removing any of the valves or it can be removed after all the valves have been removed. To remove and reinstall the manifold, proceed as follows.

A. Remove the capscrews and lift the manifold off the motor (see Figure 9B-25). The three ports are sealed with O-rings and the two adjacent ports also have back-up rings on top of the O-rings. These back-up rings are rectangular in cross section and slightly cupped on one side where they mate with the O-ring.

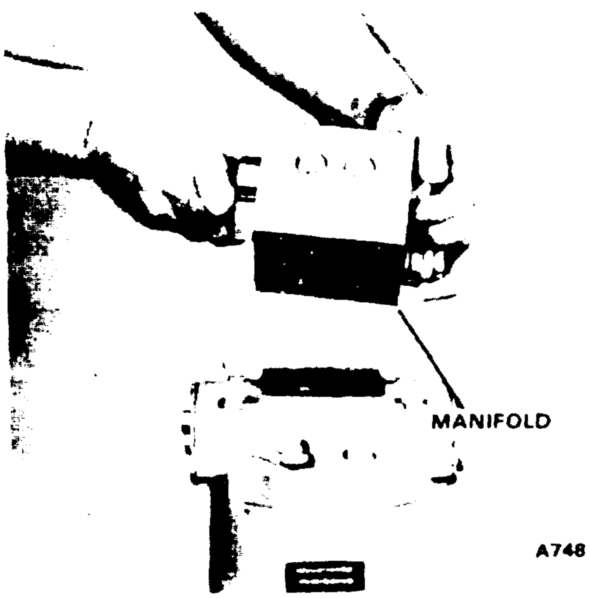


Figure 9B-25. Manifold Removal

B. The charge relief valve, high pressure relief valves, and the shuttle valve can now be removed and reinstalled as given in steps 1, 2 and 3 if they were not removed yet (see Figure 9B-26).

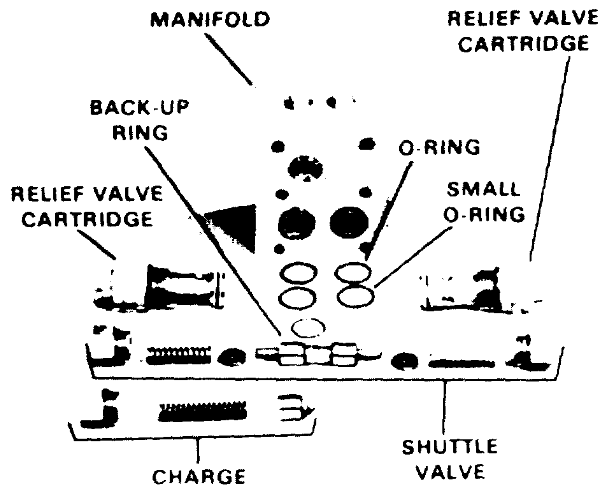


Figure 9B-26. Manifold and Valves

C. Install the smaller O-ring in the port with the full counterbore. The other O-rings and back-up rings fit in the ports with the machined grooves. The O-rings should be installed first, then the back-up ring (concave groove faces the O-ring).

D. Install the manifold on the motor checking that the back-up rings and O-rings remain in place. Install the capscrews and tighten to 16-21 ft-lbs.

4. Connect the high pressure lines and the case drain line.

5. Perform the start-up procedure described at the beginning of this subsection.

INSTALLATION

Care must be exercised when installing a new or overhauled motor to prevent misalignment, which can lead to excessive motor wear. Install a new or overhauled motor as follows (see Figure 9B-21).

1. Check the brake plate, the pilot bore diameter on the motor, the splined couplings on the brake, and the splined motor output shaft for burrsor imperfections that could prevent the motor from seating properly on the brake plate. Carefully remove any imprefections by lapping.

2. Apply a slight amount of grease to the pilot diameters and the shaft splines. Apply sealing compound (21Z587-D4) to the mating surfaces of the brake plate and motor.

3. Install the motor on the brake plate. Assemble the motor to the brake plate and install the capscrews. Care should be taken in tightening the capscrew to prevent misalignment. Torque the mounting capscrews to 65 ft-lbs lubricated.

NOTE

Install the left propel motor with Port B towards the side frame Install the right propel motor with Port A towards the side frame.

CONTROLLER (45Q39)

DESCRIPTION

Each pump has a controller mounted between the pressure override valve and the pump (see Figure 9B-27). The controller has internal linkage connected to the pump servo controls.

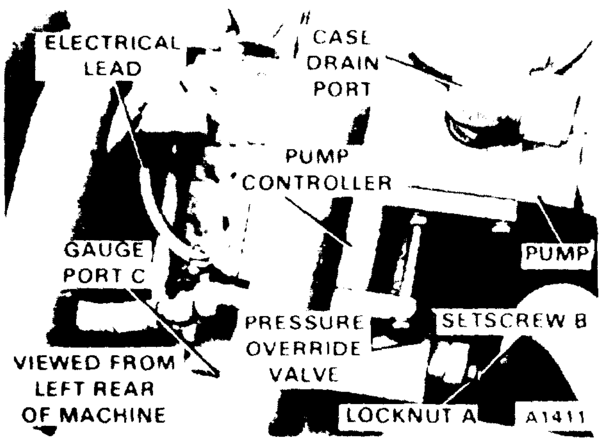


Figure 9B-27. Pump Controller and Pressure Override Valve

The controller is an electrohydraulic servo valve which-receives signals from the propel control module in the operator's cab. The controller converts the electrical signals to a mechanical movement of the control valve spool. The valve spool directs hydraulic fluid to the pump servos which change the angle of the pump swash plate and thus the output of the pump.

REMOVAL

To remove the controller, proceed as follows (see Figure 9B-27):

1. Stop the engine and disconnect the battery cable.
2. Remove the electrical lead from the controller.
3. Remove the capscrews securing the pressure override valve to the controller and lift the override valve away from the controller.
4. Remove the capscrews securing the controller to the pump.
5. Carefully pull the controller away frorn the pump case and disconnect and control linkage.

REPAIR

GENERAL. If a problem exists in a pump controller it is recommended that the valve be replaced with a new unit. The repair information provided here is limited to the replacement of seals, O-rings and orifices. At no time should any attempt be made to repair or alter the electronic amplifrer unit contained in the controller.

DISASSEMBLY To disassemble the propel controller, proceed as follows (see Figure 9B-30):

1. Place the controller with the nameplate up on a clean level surface. Orient the mounting face away from the assembler.
2. Use a 5/64 inch Allen wrench to remove screws (22).
3. Using a 9/64 inch Allen wrench, remove two capscrews (23) and lockwashers (24).
4. Slide motor cap (03) toward electrical connector (01) until the motor cap bottoms.
5. Carefully push the electrical connector into motor cap (03).
6. Remove the motor cap, gasket (06), and electrrcal connector gasket (02).
7. Mark the coil leadwires for assembly. Slide the teflon sleeving back, and note which coil leadwires are soldered to each connector pin to ensure wiring during assembly.
8. Use a 25-50 watt soldering iron to unsolder the coil leadwires from the electrical connector terminals Disconnect both tension springs from the top of the hydraulic amplifier assembly (see Figure 9B-28).
9. With a 3/32 inch Allen wrench, remove four socket head capscrews (25) and lockwashers (26). Do not let the screws or washers rub the magnets (see Figure 98-28).

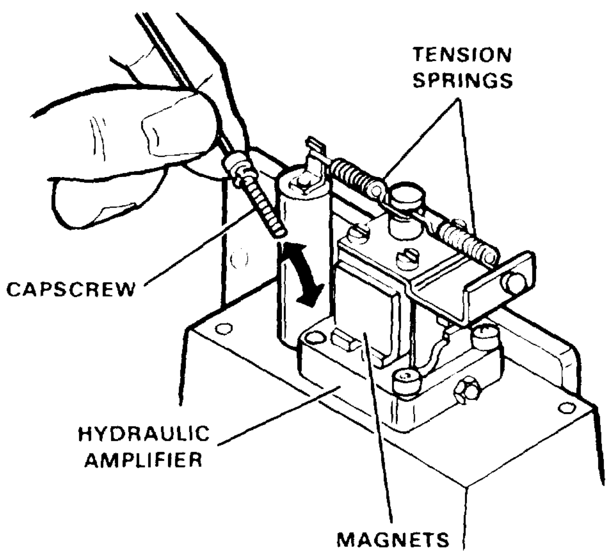


Figure 9B-28. Tension Spring and Capscrew Removal

CAUTION

The hydraulic amplifier assembly is a precision built component and must be handled with care. Avoid any contact of objects with the feedback wire protruding from the base of the assembly. Do not let metal particles or objects come in contact with the magnets.

10. Remove the hydraulic amplifier assembly by carefully lifting straight up on the base of the assembly.

11. Remove O-rings (08 and 20) from the base of the hydraulic amplifier assembly. Do not remove hydraulic amplifier screens (21) unless they are to be replaced with new ones.

12. Insert a pin extractor into bushing locating pin (09). Tighten down the pin extractor thumbscrew to grip the inside diameter of the locating pin.

13. Withdraw the bushing locating pin from valve body (27).

14. Use a 3/16 inch Allen wrench, to remove six capscrews (28) and lockwashers (29). Remove end plates (14).

15. Remove seal plates (15) and O-rings (16).

16. Insert the edge of a screwdriver under the lip of inlet orifice (12) and remove the inlet orifice assemblies and O-rings (11) from body (27). Unless they are new, the inlet orifice assemblies should be discarded and replaced each time they are removed.

17. Check that spool (30) moves freely within bushing (31). If the spool does not move freely, completely remove the bushing from the valve body as follows:

A. With a 1/2 inch diameter nylon dowel and a small hammer, tap bushing (31) out of the body.

B. Gently shake the bushing and spool or alternately push on the ends of the spool to loosen the spool and allow the material binding the spool to fall free.

C. Remove the spool. Exercise care when handling the bushing and spool to prevent damaging parts.

18. Remove six O-rings (18) from bushing (31).

19. Do not remove hollow hex plug (17) unless it is damaged or defective.

CLEANING AND INSPECTION. Clean and inspect the components of the controller as follows (see Figure 9B-30):

CAUTION

Most solvents react with O-ring compounds. Remove all O-rings from parts before cleaning.

1. Clean bushing (31) and spool (30) by immersing them in a clean commercial solvent.

2. Clean the air gaps of hydraulic amplifier assembly (07) by blowing clean, dry air through the air gaps (see Figure 9B-29).

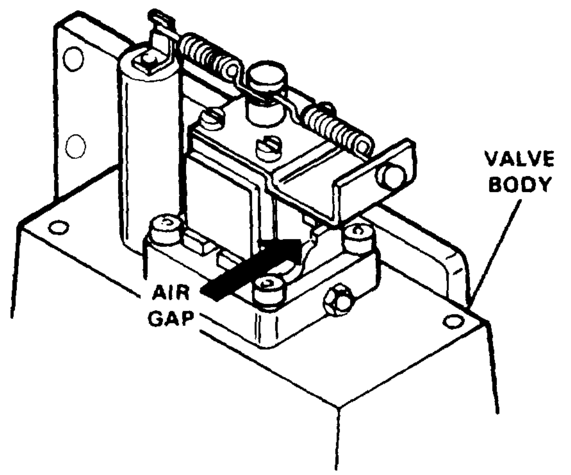


Figure 9B-29. Cleaning the Air Gap

3. Clean all remaining parts in a *clean* commercial solvent. Permit parts to air dry or dry using clean dry compressed air.

4. Visually inspect inlet orifice assemblies (12) and replace if damaged or foreign matter is present.

5. Inspect the hydraulic amplifier assembly for damaged coil leads, and a bent or broken feedback wire.

6. Inspect all O-ring sealing surfaces for scratches, scoring or other damage.

7. Replace all O-rings.

ASSEMBLY. Assembly should be performed in as clean an environment as possible. Exercise care to avoid cutting or nicking O-rings when installing them on parts, and when installing parts containing O-rings to prevent subsequent leakage. Assemble the controller as follows (see Figure 9B-30):

1. Install hollow hex plug (17) if it has been removed.

2. Insert all six O-rings (18) on bushings (31).

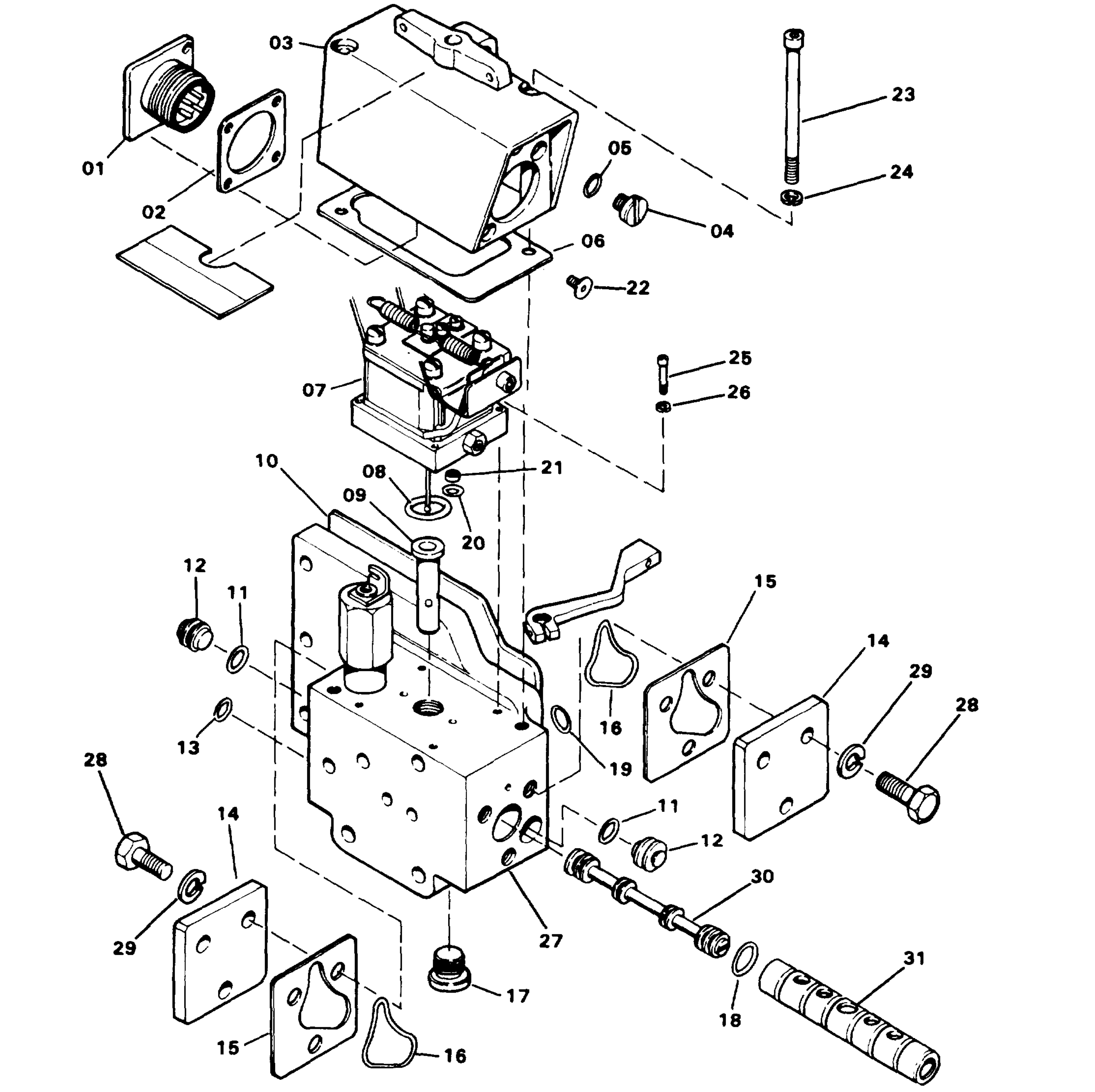
3. Orient the controller on a clean flat surface in such a manner that the mounting face is away from the assembler. Look in the large center hole in top of valve body (27) and install bushing (31) in the body as shown in Figure 9B-30. Center the bushing pin locating hole directly below this large center hole.

NOTE

Normally, the bushing can be installed in the controller body with reasonable hand force. If necessary, tap the bushing into the body using a 1/2 inch diameter nylon dowel and a small hammer.

4. Lubricate spool (30) with clean filtered hydraulic fluid. Install the spool in bushing (31) with the spool slot end oriented toward the right side of the valve body. This operation must be performed with care. Any misalignment will cause the spool to bind and not slide fully or easily into the bushing.

5. Insert bushing locating pin (09) into the large center hole in top of the valve body, using the pin extractor.



01. CONNECTOR
02. GASKET
03. CAP
04. SCREW
05. O-RING
06. GASKET
07. AMPLIFIER
08. O-RING
09. PIN
10. GASKET
11. O-RING
12. ORIFICE
13. O-RING
14. PLATE
15. PLATE
16. O-RING
17. PLUG
18. O-RING
19. O-RING
20. O-RING
21. SCREEN
22. SCREW
23. CAPSCREW
24. LOCKWASHER
25. CAPSCREW
26. LOCKWASHER
27. VALVE BODY
28. CAPSCREW
29. LOCKWASHER
30. SPOOL
31. BUSHING

Figure 9B-30. Propel Controller (45Q39)

6. Remove the pin extractor from the locating pin.

CAUTION

Failure to insert the bushing locating pin to a sufficient depth in the valve body will prevent proper installation of the hydraulic amplifier assembly. This will result in external leakage and probable damage to the hydraulic amplifier assembly.

7. Install O-rings (08) and (20) in the base of the hydraulic amplifier assembly. If hydraulic amplifier screens (21) were removed, install new ones by pressing them through the I.D. of the O-rings, coarse side first.

8. Install left side seal plate (15) and end plate (14) and secure with screws (28) and lockwashers (29).

9. Insert a small blade screwdriver into the spool end slot and rotate the spool end slot to a vertical position (see Figure 9B-31). Look into bushing locating pin (09) and align the hole in the spool with the center of the bushing locating pin.

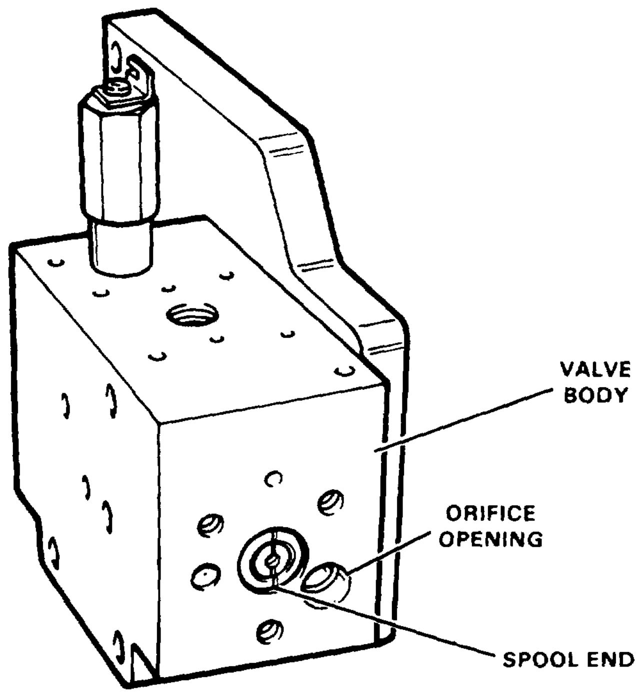


Figure 9B-31. Spool installation

10. With the mounting face of the valve body oriented away from the assembler and the leadwires of the hydraulic amplifier extending to the right, hand install four capscrews (25) and lockwashers (26) to hold the hydraulic amplifier assembly in place on the body. *Do not tighten the screws at this time.*

11. Carefully insert the feedback wire into the hole in bushing locating pin (09). Using extreme care, engage the feedback wire ball in spool (30) hole.

12. Slide the torque motor along the spool centerline and watch for spool motion. If longitudinal spool motion occurs, engagement was properly completed.

NOTE

The ball must engage the hole in the spool before proceeding with the control valve assembly. Carefully repeat steps 9 through 12, as necessary, to achieve the above condition.

13. Tighten down four capscrews (25) using a 3/32 inch Allen wrench. Torque the screws to 9-1/2 to 10-1/2 inch-lbs.

14. Grasp the flapper extension between the forefinger and thumb and move the flapper toward the end of the valve body. Observe for spool motion to ensure that engagement has not been lost.

15. If the feedback wire ball has become disengaged from the hole in the spool, repeat steps 9 through 14.

16. Set the controller on one end. Install O-ring (11) on inlet orifice assembly (12) and carefully insert the assembly into controller body (27) Unless they are new, inlet orifice assemblies should be discarded and replaced each time they are removed.

CAUTION

Apply force only around the edge of the inlet orifice assembly, or the filter may become damaged and result in controller malfunction.

17. Place seal plate (15) on a flat clean surface. Install O-ring (16) in the seal plate It may be necessary to work the O-ring into the seal plate with a finger.

18. Install the seal plate and O-ring assembly. Install end plate (14) on controller body (27). Using a 3/16 inch Allen wrench, install screws (28) and lockwashers (29). Torque the screws to 80-90 Inch-lbs.

19. Repeat steps 16 through 18 for the opposite end of the controller.

20. Install the tension spring having the end loops of approximately equal length by attaching them from the groove on the flapper extension to the spring retainer on the tip of the barrel and shaft assembly. Install the tension spring having one longer end loop with its shorter loop engaged in the groove on the flapper tip, and the longer loop attached to the spring retainer on the torque motor bracket.

21. Install the teflon tubing on each coil leadwire. Solder the coil leadwires to electrical connector (01) pins as marked during disassembly. Slide the teflon tubing over the connector pins. Install motor cap gasket (06) on the controller body.

22. Install gasket (02) on electrical connector (01). Hold the electrical connector in position in motor cap (03). Using a 5/64 inch Allen wrench, install screws (22) and torque to a snug condition.

23. Install gasket (06) and motor cap (03) on the controller body. Using a 9/64 inch Allen wrench, install two socket

head capscrews (23) and lockwashers (24). Torque the screws to 30 inch-lbs. Replace the nameplate if it was removed.

24. Install pan head screw (04) and O-ring (05).

25. Install the controller on the propel pump but do not connect the electrical lead.

26. Start the engine and visually examine for evidence of external leakage. If leakage is present and cannot be corrected by replacing O-rings and/or seal plates, replace the leaking components.

27. Adjust the mechanical null of the controller as described in the following topic, Null Adjustment.

28. Rotate the manual override lever and observe pump output flow. Motor output should be the same in both directions.

29. If a noticeable variance in pump output exists, remove the motor cap assembly and carefully align the mating surfaces of the motor cap assembly and controller body.

30. Repeat steps 27 and 28 as required to achieve near equilibrium of pump flow.

INSTALLATION

To install a controller on the pump, proceed as follows (see Figure 9B-27):

1. Place a new gasket on the pump case.

2. Connect the linkage from the pump to the controller.

3. Install the controller capscrews and finger tighten.

4. Install the pressure override valve and gasket and tighten all capscrews securely.

5. Connect the electrical lead to the controller.

ADJUSTMENT

Adjustment consists of adjusting the flow null of the controller. This is normally done when a new valve is installed or if the machine propels when the operator's controller is in neutral. To adjust the controller, proceed as follows (see Figure 9B-32):

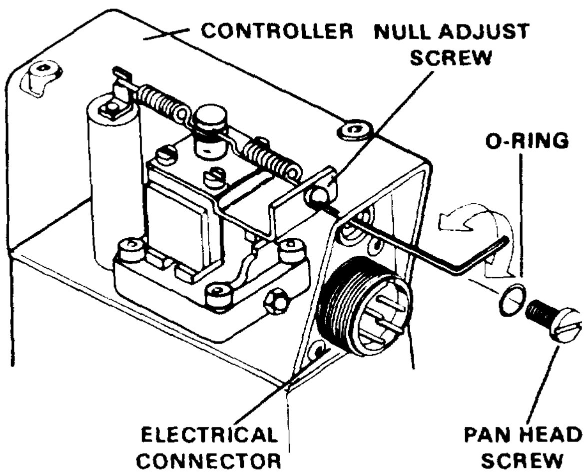


Figure 9B-32. Controller Null Adjustment

1. Ensure that zero electrical signal is applied to the controller by disconnecting the electrical lead to the controller.

2. Using a blade screwdriver, remove the pan head screw and O-ring to permit access to the null adjust screw.

3. With the pump running, use a 2-1/2 inch long, 1/8 inch Allen wrench to slowly rotate the null adjust screw in each direction (clockwise and counterclockwise), in turn. Note the relative position of the null adjust screw at the moment the machine begins to propel, for each direction of null adjust screw rotation.

4. Position the null adjust screw at a position approximately centered within the "deadband" between the two positions noted in step 3. Normal adjustment should require less than ± one-quarter turn.

5. After the desired flow null has been obtained, reinstall the pan head screw and O-ring.

6. Connect the electrical lead to the connector.

PRESSURE OVERRIDE VALVE

DESCRIPTION. The pressure override valve is mounted on the electric controller on the side of the pump. The override will automatically destroke the pump once the desired maximum system pressure (load) is reached. It will maintain that system pressure so the load can be held. This prevents operation of the system relief valves for prolonged periods and helps reduce heat build-up in the transmission.

The valve pressure is set at the factory, however, this setting can be checked and adjusted when a new valve is installed or if the pressure setting is requied for troubleshooting purposes.

REMOVAL. To remove the valve, proceed as follows (see Figure 9B-33):

1. Stop the engine and disconnect the battery cable.

2. Remove the two hydraulic lines from the valve.

3. Remove the capscrews securing the valve to the electric controller and lift the valve away from the controller.

INSTALLATION. To install a new override valve on the pump, proceed as follows (see Figure 98-33):

1. Place a new gasket on the controller.

2. Install the override valve to the controller and secure with capscrews.

3. Connect the two hydraulic lines to the valve.

ADJUSTMENT. To adjust the pressure override valve, proceed as follows (see Figure 9B-33):

1. Check the controller null adjustment as described previously in this subsection.

2. Disconnect the electrical wire at the controller to assure that the controller is in neutral.

3. Inspect the main relief valves to determine the factory setting. These valves are located in the manifold on the end of the propel motors and are stamped with a two digit number that is the main relief setting multiplied by 100 (55 is a 5500 psi relief setting).

4. Place the propel brake switch in the ON position to set the propel brakes.

5. Install pressure gauges (10,000 psi) at gauge port C on the pressure override valves of both pumps.

6. Loosen locknuts A on the pressure override valves and back out setscrews B three to five turns on both pumps

7. Disconnect the signal wires from the controller on the pump which is not being adjusted and tape the ends of the wires.

8. Start the engine and run it at 1500 rpm.

9. Bring the pump to be adjusted on stroke by turning the mechanical actuator on the controller.

10. While the pump IS on stroke, slowly turn setscrew B on the pressure override valve in until the pressure gauge Installed in gauge port C reads approximately 2000 psi. Return the pump to the neutral stroke position and shut off the engine.

11. Deadhead the flow from the pump pressure ports to the motor pressure ports. This must be done to provide a resistance to flow necessary to develop the high pressure.

12. Start the engine and run it at 1500 rpm.

CAUTION

Bring the pump on stroke with extreme caution since no reliefs other than the pressure override valves are in the system.

13. Slowly bring the pump being adjusted on stroke by turning the manual actuator on the controller. Watch the pressure gauge installed in port C and return the pump to neutral if the pressure exceeds 5000 psi.

14. With the engine running and the pump on stroke, slowly turn setscrew B on the override valve in until the pressure gauge installed in port C reads *5500 psi or 500 psi less than the main relief setting, whichever is less.* Tighten locknut A. If the pressure reading fluctuates set the pressure at mid-range of the fluctuation.

15. Return the pump to neutral stroke, shut off the engine, and connect the main lines to the motor. Connect the wires to the controller of the other pump.

16. Repeat steps 6 through 14 for the remaining pump.

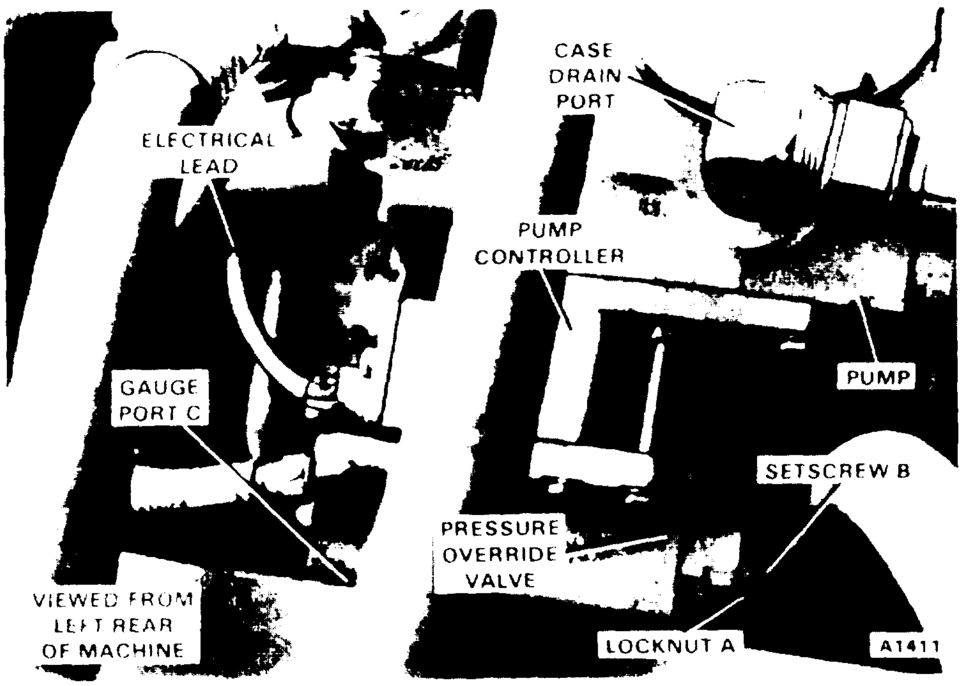


Figure 9B-33. Pressure Override Valve

SUBSECTION 9C

PROPEL BRAKES

GENERAL

The information in this subsection covers the removal, repair, and installation of the propel brakes used on this machine.

PROPEL BRAKES (15Z499)

DESCRIPTION

The propel brakes are of the spring set, hydraulically released disc type. One brake is bolted to each propel gear case with the brake shaft splined into the gear case input shaft. The propel motor output shaft is splined onto the brake shaft.

The brake consists of a housing, piston, springs, friction discs and disc separators. The friction discs are splined to the brake shaft, and the disc separators are pinned to the brake housing.

ADJUSTMENT

There are no propel brake adjustments. It is only required that the hydraulic system be maintained properly, and that the brake seals and discs are replaced when required. All air must be bled from the brakes after servicing.

OVERHAUL

It should be kept in mind that the propel brakes are meant only as parking brakes and are not intended to stop the machine from traveling. This being the case, the friction discs and disc separators will wear very little. When the brakes wear to the point that they do not hold the machine when parked, the discs must be replaced. Any time leakage at the brake is noticed the brake must be removed from the machine and the seals replaced.

REMOVAL. To remove a propel brake, proceed as follows (see Figure 9C-1):

1. Locate the machine on a firm level surface so the machine will not move when the brake is removed. Engage the swing brake and block the crawlers.

2. Release all pressure in the brake circuit, and disconnect the brake hydraulic line. Open the bleed screw to allow any fluid to escape. Close the bleed screw.

3. Mark the brake housing and the transmission case so the brake can be reinstalled in the same position. Remove the capscrews which secure the brake and motor to the gear case. Remove the brake and motor from the gear case

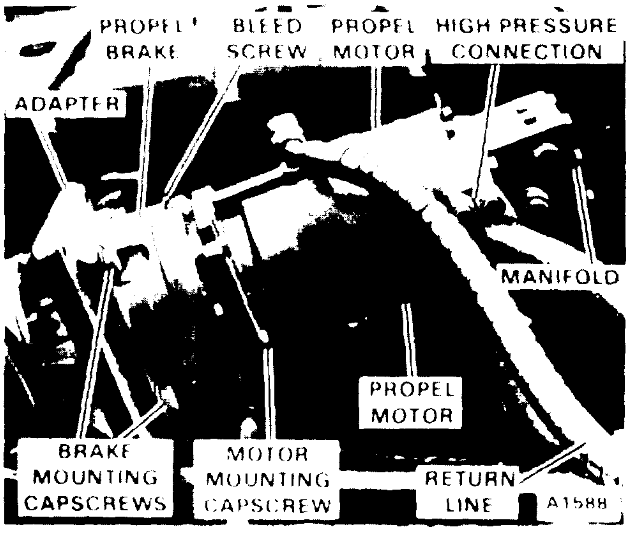


Figure 9C-1. Propel Brake Location

with a sling and proper lifting device. The brake and motor weigh approximately 225 lbs.

DISASSEMBLY. To disassemble the propel brake, proceed as follows (see Figure 9C-2):

1. Place the brake on blocking with the shaft end down.

2. Alternately remove capscrews (23) to release plate (19).

3. Pull packing (05), and all discs, springs, and pins from housing (04).

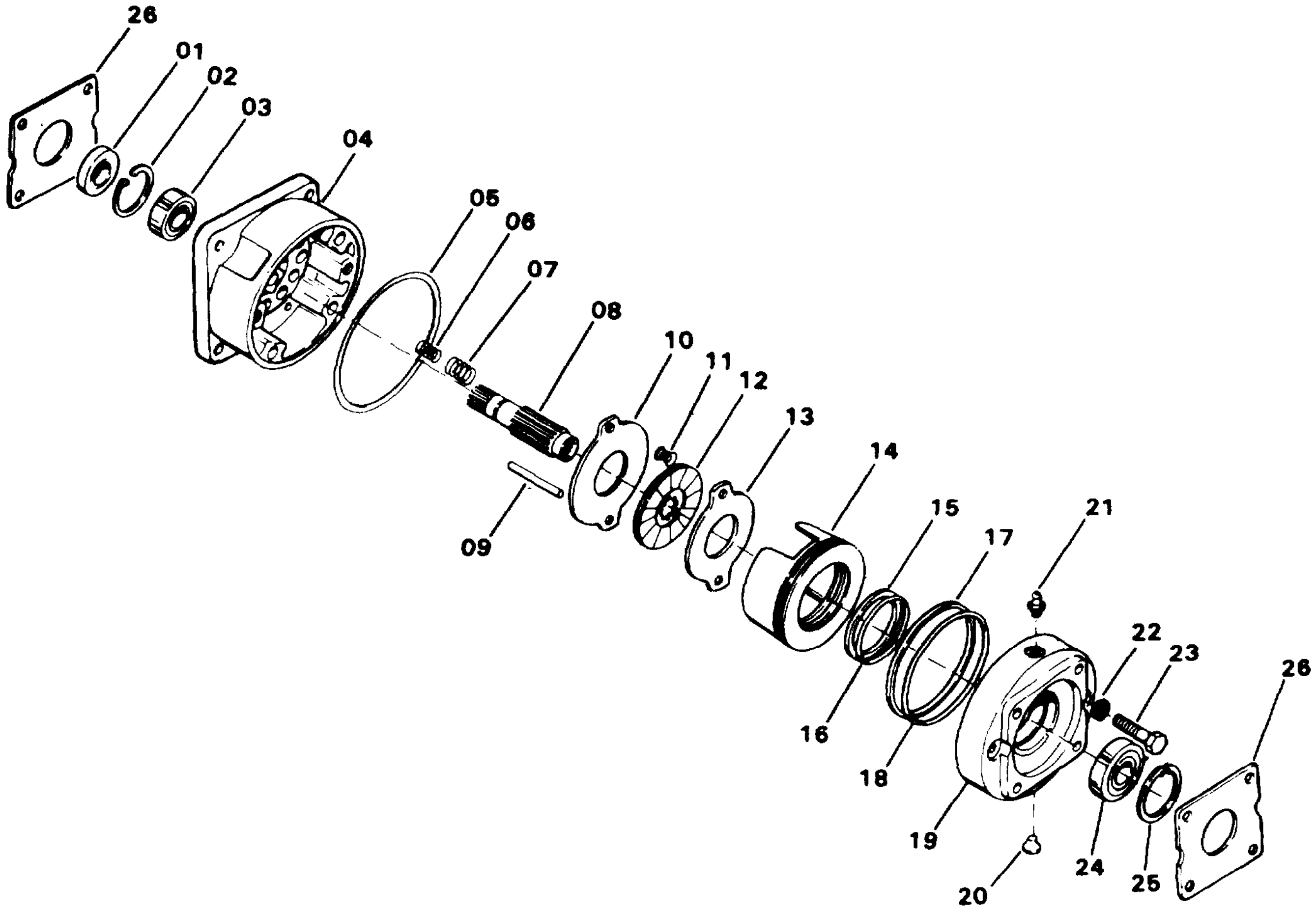
NOTE

> Further disassembly of the housing is usually unnecessary, and should not be attempted unless a specific component must be replaced. If more complete disassembly of the housing is necessary, complete steps 4, 5 and 6.

4. Pull seal (01) out of housing (04) taking care not to damage the seal in bearing (03).

5. Remove snap ring (02), then shaft (08) with bearing (03) by lightly tapping the shaft with a plastic mallet.

6. Press the bearing off of the shaft by supporting the inner race of the bearing and applying pressure to the shaft.



01. SEAL
02. RETAINING RING
03. BEARING
04. HOUSING
05. PACKING
06. SPRINGS
07. SPRINGS
08. SHAFT
09. PIN
10. PRIMARY DISC
11. SPRING
12. ROTATING DISC
13. STATIONARY DISC
14. PISTON
15. BACK-UP RING
16. O-RING
17. BACK-UP RING
18. O-RING
19. PLATE
20. PLUG
21. BLEEDER SCREW
22. LOCKWASHER
23. CAPSCREW
24. BEARING
25. RETAINING RING
26. GASKET

Figure 9C-2. Propel Brake (15Z499)

7. Remove piston (14) from plate (19) by introducing low pressure air (15 psi) into the hydraulic inlet. Make sure the piston is directed away from all personnel.

8. Slide O-rings (16 and 18) and back-up rings (15 and 17) from the piston grooves. The back-up rings will be damaged during removal and should not be removed if replacement is not planned.

9. Remove retaining ring (25) and tap bearing (24) out of plate (19).

CLEANING. INSPECTION AND REPAIR. Prior to assembly, perform the following procedures:

1. Clean all components in a suitable cleaning solvent and dry thoroughly. Do not clean the discs or plates in solvent.

2. Inspect the piston and housing for excessive wear or deep scratches.

3. Rotating discs should be clean and dry. There should be no presence of oil on any lining material on mating surfaces of the stationary discs. Worn or heavily scored lining material must be replaced.

4. Inspect the springs for cracks or distortion and make sure they are all the same length.

5. Inspect the shaft for cracks or other damage.

6. Replace all seals, O-rings, and back-up rings that have been removed. If the brake has been disassembled to replace O-rings, it is recommended that the discs also be replaced.

ASSEMBLY. To assemble the propel brake, proceed as follows (see Figure 9C-2):

1. Lubricate the piston, O-rings, back-up rings and the cylinder of plate (19) with fluid from the propel brake system.

2. Install new back-up rings (15 and 17) and O-rings (16 and 18) on piston (14).

CAUTION

Be careful not to damage O-rings or back-up rings during piston installation.

3. Visually align the center of the cutouts in piston (14) with pin (09) holes in plate (19). Using a shop press, install the piston into the plate. The depth of the piston installation into the plate is critical, do not exceed 0.120 inch for piston surface below plate (19) surface (see Figure 9C-3).

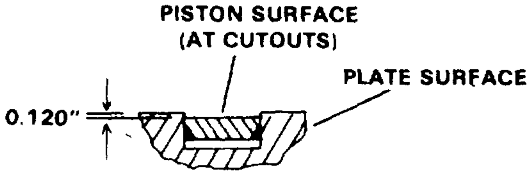


Figure 9C-3. Piston Installation

4. Install bearing (24) into plate (19) and secure with ring (25).

5. Press bearing (03) on shaft (08) and secure the assembly in housing (04) with ring (02).

6. Lubricate the lips of seal (01) and press into housing (04).

7. Assemble the springs, discs, separators and pins into housing (04).

NOTE

The rotating discs must be clean and dry. There should be no presence of oil on any lining material or mating surfaces of the stationary discs. Worn or heavily scored rotating discs must be replaced.

8. Install packing (05) and plate (19) to housing (04). Secure the assembly by torquingcapscrews (23) alternately to 75-85 ft-lbs.

INSTALLATION. To install the brake assembly, proceed as follows (see Figure 9C-1):

1. Place a gasket (26) on each end of the brake assembly and align the brake output shaft with the gear case input shaft. Be sure the bleeder screw is in the vertical position.

2. Insert the four lubricated capscrews (3/4 inch) into brake flange (04) and torque to 230 ft-lbs.

3. Insert the four lubricated capscrews (1/2 inch) through the motor flange, the gasket, and into plate (19). Alternately tighten the capscrews and torque to 65 ft-lbs.

4. Attach the brake line and start the machine. Open the bleed screw and operate the brake several times to allow any trapped air to escape. Tighten the bleed screw after all air has escaped.

SUBSECTION 9D

PROPEL GEAR CASE

GENERAL

This subsection covers the removal, repair, and installation of the propel gear case.

GEAR CASE (14Q121)

DESCRIPTION

A propel gear case is attached at the rear of each crawler frame (see Figure 9D-1). The gear case transmits propel motor rotation to the propel driveshaft. The gear case consists of an input section, center planetary section and output section.

REMOVAL

To remove the propel gear case, proceed as follows (see Figure 9D-1):

1. Refer to Subsection 9B and remove the propel motor and brake.

2. Remove the gear case oil drain plug and drain the oil into a container. Install the drain plug after all the oil has been drained.

3. Remove the shaft assembly oil drain plug and drain the oil into a container. Install the drain plug after all the oil has been drained.

4. Attach lifting slings to the gear case and attach the slings to a suitable hoist. The gear case weighs approximately 1000 lbs.

5. Remove the sixteen capscrews which secure the propel gear case to the side frame Pull and lift the gear case from the mounting.

DISASSEMBLY

GENERAL. The propel gear case is disassembled by section. Each section is listed separately and the complete disassembly procedure for the section is given.

OUTPUT SECTION. To disassemble the output section, proceed as follows (see Figure 9D-12):

1 Remove capscrews (02), holding cover (04) to the body of the drive.

2. Lift the cover assembly straight up from the unit, allowing the pilot of the cover to slide straight out of the counterbore in ring gear (13).

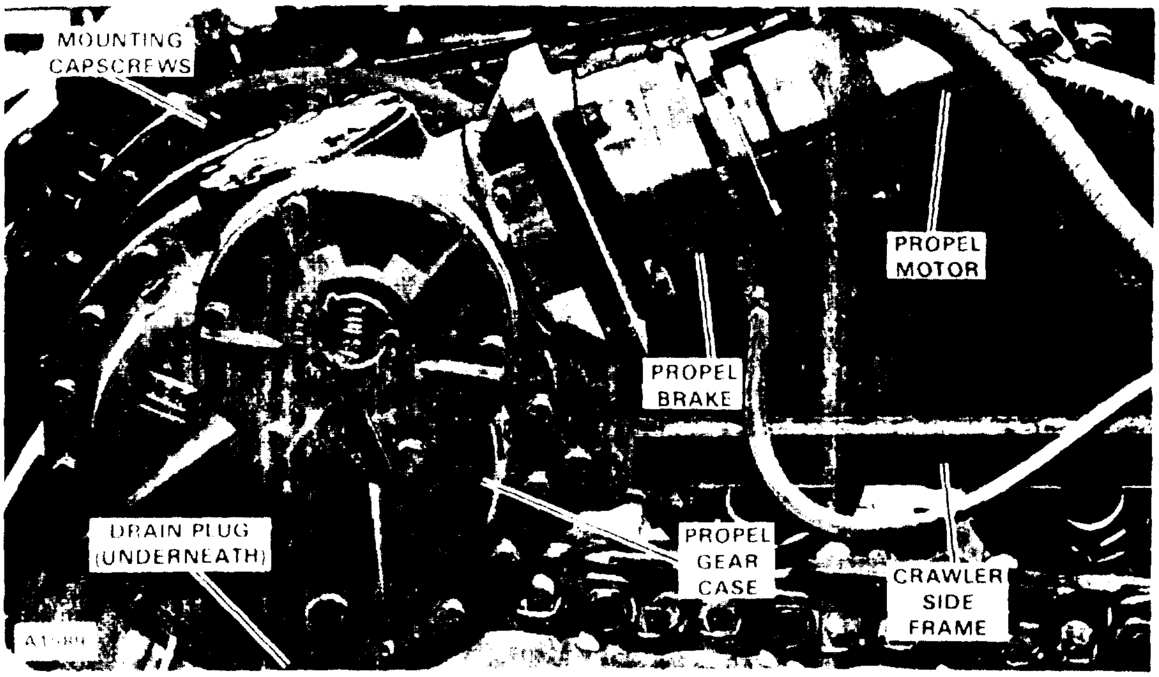


Figure 9D-1. Propel Gear Case

3. Lift output shaft (06) out of output carrier (08).

4. Remove seal (01) and discard.

CENTER SECTION. To disassemble the center section, proceed as follows (see Figure 9D-12):

1. Place the center housing assembly so that it is resting on the input side.

2. Remove the output gear set using eyebolts in the holes provided in carrier (08).

NOTE

Shafts and gears should be marked to insure that each shaft and gear set is located in its original bore with care taken that the shafts are not rotated.

3. Drive roll pins (07) into shafts (10) so that they will clear the carrier. Bronze shafts (10) may now be driven out.

4. Lift input gear set (16) straight up to remove it from the housing.

NOTE

Care should be taken to mark shafts, gears, and bearings such that all are kept in their original locations in the carrier.

5. Drive roll pin (23) into shaft (22) enough to clear the carrier allowing the shaft to be driven out.

6. With gears (20) removed, output sun gear (15) maybe removed from carrier (16) by removing snap ring (17).

7. Remove all roll pins (07 and 23) from shafts (10 and 22).

INPUT SECTION. To disassemble the input section, proceed as follows (see Figure 9D-12):

1. Lift out input sun gear (18).

2. Set ring gear (13) on the output end and remove capscrews (59).

3. Input housing (57) may then be lifted straight up to clear the pilot of the ring gear.

4. Remove tie wire (46) from capscrews (47) and remove the capscrews.

5. Lift bull gear (49) straight up and tilt it away from the smaller gear (see Figure 9D-2).

6. Drive shaft (62) out of the case.

NOTE

Bearing assembly (43,50,51,54 and 55) is a matched set and care must be taken that all components in this assembly remain in their original position.

7. Remove capscrews (75) and cover (73) from the input housing.

NOTE

Spacer shims (72) should be retained as a set. If no gears or bearings are replaced, these shims can be reused

8. Remove cone (69) from shaft (67).

9. Remove gear (68). shaft (67), and cone (66) from the input housing.

Figure 9D-2. Bull Gear Removal

10. Remove capscrews (30) and lockwashers (31).

11. Remove adapter assembly (32) from housing (57).

12. Slide coupler (24) out of gear (37).

13. Straighten the tong on washer (26) and remove nut (25).

14. Washer (27) and cone (28) can now be removed from the top of the adapter and cone (35) and gear (37) can be removed from the bottom.

CLEANING AND INSPECTION

Clean and Inspect all gear case components as follows (see Figure 9D-12):

1. Clean all components with solvent and air dry.

2. Inspect bushing (05). If it is scored or worn, press it out and replace.

3. Shafts (10) should be inspected to see that the gearing surface is smooth. There will be a slight step on each shaft; this is normal seating-in wear. If the shafts are badly worn (more than 0.040 inch wear), all four shafts must be replaced.

4. All gears should be inspected to see that the bores are smooth and that all teeth are in good condition, free from cracks and pitting. A smooth polished surface IS normal in the bore of the planet gears.

NOTE

Spiral bevel gears (37 and 68) are a matched set. If one needs. replacement, a complete set must be ordered.

5. Bearings and shafts should show no scoring or other signs of distress or abnormal wear.

6. Carrier spacer (12) should be inspected. If the thickness is less than 0.060 inches or it IS scored it should be replaced.

7. Check the outer end of sun gear (15). If it is scored, replace it.

ASSEMBLY

GENERAL. The propel gear case is assembled by section. Each section is listed and the complete assembly procedure for that section is given.

INPUT SECTION. To assemble the input section, proceedas follows (see Figure 9D-12):

NOTE

If no gears or bearings are replaced, shim sets may be used in the exact order in which they were removed. If gears or bushings are replaced or if shim sets are lost or damaged, the procedures listed below for determining shim requirements must be followed exactly.

1. Place bearing cone (66) and cup (65) on a surface plate (see Figure 9D-3).

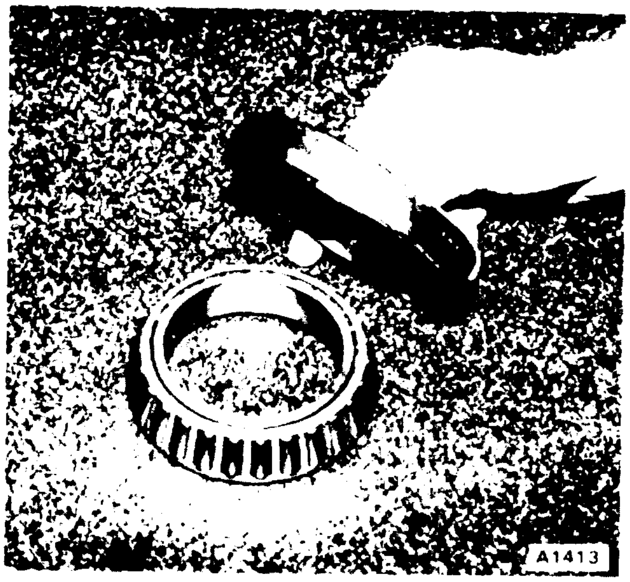


Figure 9D-3. Bearing Measurement

2. Measure the thickness of the bearing using a height gauge or depth micrometer (see Figure 9D-4 and 9D-5).

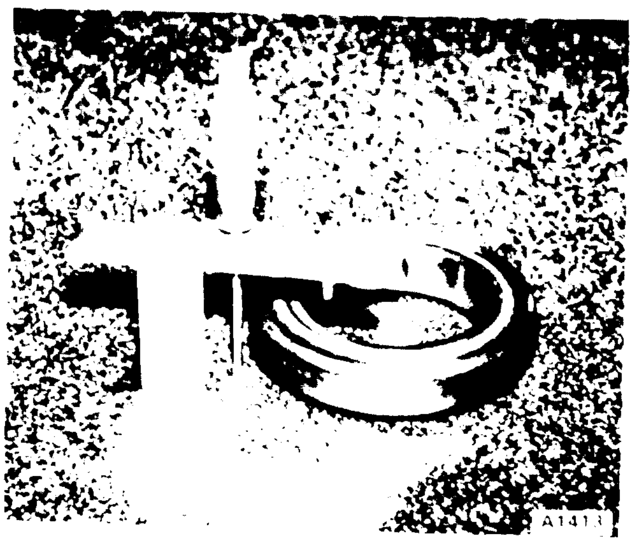


Figure 9D-4. Height Micrometer

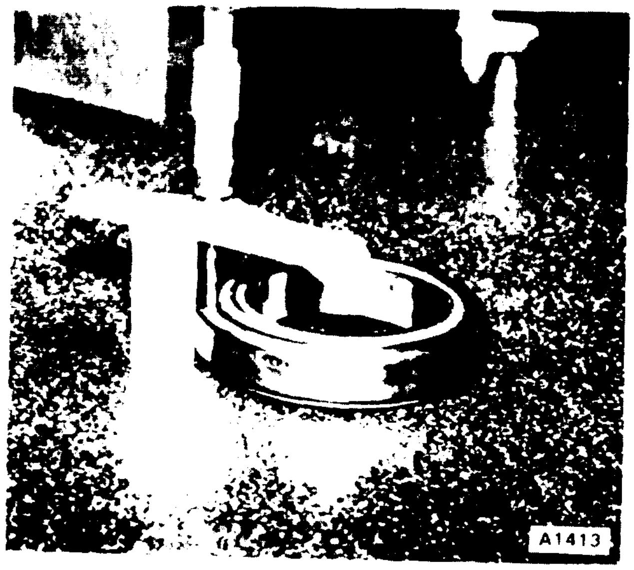


Figure 9D-5. Depth Gauge

3. Determine the housing dimension from input housing (57). This number is stamped on the mounting face (see Figure 9D-6).

4. Refer to Table 9D-1 and, using the housing dimension and bearing dimension previously obtained, determine the shim column number.

Table 9D-1. Shim Column Determination

Housing Dimension	Bearing Dimension	Shim Column
3.807/3.808	1.008/1.007	1
	1.006/1.005	2
	1.004/1.003	3
	1.002/1.000	4
3.809/3.810	1.008/1.007	2
	1.006/1.005	3
	1.004/1.003	4
	1.002/1.000	5
3.811/3.812	1.008/1.007	3
	1.006/1.005	4
	1.004/1.003	5
	1.002/1.000	6
3.813/3.814	1.008/1.007	4
	1.006/1.005	5
	1.004/1.003	6
	1.002/1.000	7

5. Determine the gear mounting dimension by inspecting gear (68) as shown in Figure 9D-7.

6. Refer to Table 9D-2 and, using the gear mounting dimension and shim column number, determine the total amount of shim distance required.

Figure 9D-6. Housing Dimension Location

NOTE

For housing dimensions less than 3.807, use 3.807/3.808 and subtract a shim thickness equal to the difference between the actual housing dimension and 3.807. For housing dimensions greater than 3.814, use 3.813/3.814 and add a shim thickness equal to the difference between actual housing dimensions and 3.814.

Table 9D-2. Shim Distance

Gear Mounting Dimension	Shim Columns						
	1	2	3	4	5	6	7
1.495/1.496	.008	.010	.013	.015	.017	.019	.021
1.497/1.498	.010	.013	.015	.017	.019	.021	.023
1.499/1.500	.013	.015	.017	.019	.020	.023	.025
1.501/1.502	.015	.017	.019	.021	.023	.025	.027
1.503/1.504	.017	.019	.021	.023	.025	.027	.029
1.505/1.506	.019	.021	.023	.025	.027	.029	.031

7. Construct a shim set to obtain the shim distance determined in step 6.

8. Install shim set (64) into the bore of input housing (57).

9. Press bearing cup (65) into the bore of the input housing with the thin edge out.

10. Press cone (66) onto the end of shaft (67) and install this assembly into the input housing.

11. Slide gear (68) onto shaft (67) and then press cone (69) onto the shaft with the thin edge out.

12. Press cup (70) into cover (73).

13. Place the cover on the input housing and install two capscrews (75) 180° apart.

14. Tighten the capscrews down evenly and gradually while turning shaft (67).

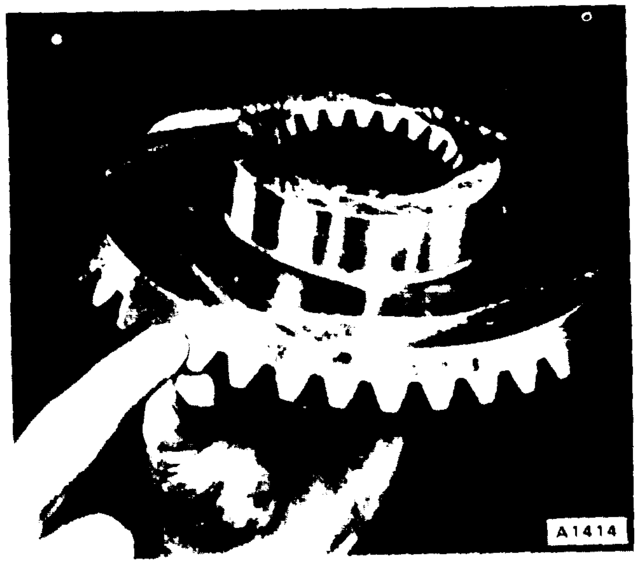


Figure 9D-7 Gear Mounting Dimension

15. When all end play is taken out of the bearings, measure the space beween the cover and input housing in three places with a feeler gauge.

16. Take the average of the three readings and install shims (72) to equal this average Shim color codes are shown in Table 9D-3.

Table 9D-3. Shim Color Codes

SHIM COLOR CODE
.003 Thick — Green
.005 Thick — Blue
.010 Thick — Brown

17. Coat O-ring (71) with grease and install on the cover.

18. Install all capscrews (75) and lockwashers (74) and tighten to 80-90 ft-lbs.

19. Determine the gear mounting dimension from gear (37) and record for future use (see Figure 9D-8).

Figure 9D-8 Gear Mounting Dimension

20. Press bearing cups (29 and 34) in adapter (32) with the thin edges out.

21. Press cone (35) onto gear (37).

22. Install gear (37) into adapter (32)

23. Install cone (28), washer (27), lockwasher (26) and nut (25) onto the gear.

24. Tighten the nut until all end play is removed from the bearings.

25. Using a height gauge, measure the distance between the face of the spiral bevel gear and the face of the adapter (see Figure 9D-9).

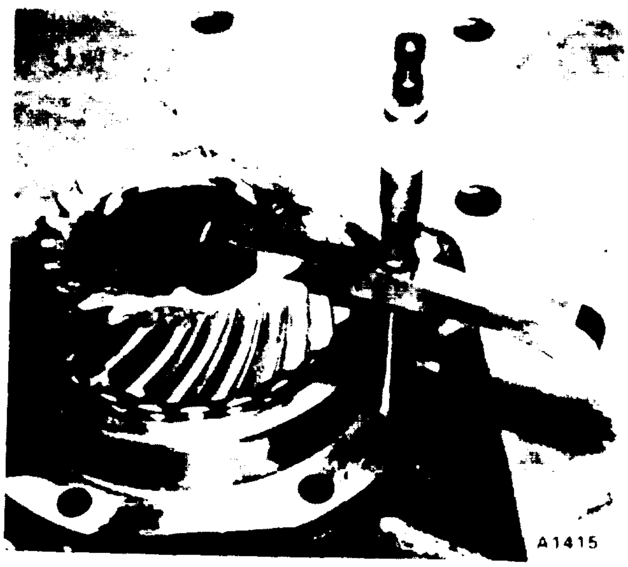


Figure 9D-9. Gear Adapter Assemblv Dimension

26. Determine the housing dimension by examining the input housing (see Figure 9D-10).

27. Using the dimensions found in steps 25 and 26, find the proper shim column from Table 9D-4.

NOTE

For housing dimensions greater than 5.357, use 5.357/5.356 to find the shims required and remove a shim thickness equal to the difference between the actual housing dimension and 5.357. For housing dimensions less than 5.352, use 5.353/5.352 to find the shims required and add a shim thickness equal to the difference between the actual housing dimension and 5.352.

28. Using the proper shim column number and the gear mounting dimension from step 19, refer to Table 9D-5 to determine the shim spacing required.

29. Make up shim set (33) from Table 9D-3 and install it on the input housing.

30. Coat O-ring (38) with grease and install adapter assembly (32).

Figure 9D-10. Housing Dimension

31. Place the adapter assembly on the input housing

Table 9D-4. Shim Column Determination

Housing Dimension	Gear Adapter Assy. Dimension	Shim Column
5.357/5.356	2.406/2.409	8
	2.410/2.413	10
	2.414/2.415	11
	2.417/2.419	12
	2.420/2.422	14
	2.423/2.426	15
	2.427/2.430	17
5.355/5.354	2.406/2.409	9
	2.410/2.413	11
	2.414/2.415	12
	2.417/2.419	13
	2.420/2.422	15
	2.423/2.426	16
	2.427/2.430	18
5.353/5.352	2.406/2.409	10
	2.410/2.413	11
	2.414/2.415	13
	2.417/2.419	14
	2.420/2.422	15
	2.423/2.426	17
	2.427/2.430	19

32. Install lockwasher (31) and capscrews (30) and tighten to 75 ft-lbs (lubricated).

33. Install coupler (24) into gear (37).

34. Remove capscrews (39) and lockwashers (40) from cover (41).

35. Remove cover (41) from the input housing and visually inspect the spiral bevel gear set for correct alignment.

Table 9D-5. Shim Spacing

Gear Mounting Dimension	Shim Columns											
	8	9	10	11	12	13	14	15	16	17	18	19
2.954/2.956	.006	.008	.010	.013	.016	.018	.020	.023	.025	.027	.029	.031
2.957/2.959	.009	.011	.013	.016	.019	.021	.023	.026	.028	.030	.032	.034
2.960/2.962	.012	.014	.016	.019	.022	.024	.028	.029	.031	.033	.035	.037
2.963/2.965	.015	.017	.019	.022	.025	.027	.029	.032	.034	.036	.038	.040
2.966/2.968	.018	.020	.022	.025	.028	.030	.032	.035	.037	.039	.041	.043
2.969/2.971	.021	.023	.025	.028	.031	.033	.035	.038	.040	.042	.044	.046

36. Install the cover, capscrews, and lockwashers and tighten to 80-90 ft-lbs.

37. Coat O-ring (61) with grease and install it on shaft (62).

38. Install the shaft and O-ring into the input housing.

39. Install the bearings and bull gear on shaft (62) as follows:

A. Press bearing cone (55) with the small diameter out onto shaft (62).

B. Press bearing cups (51) into the bore of bull gear (49)

C. Place spacers (43 and 52) into the bore of the bull gear

D. Press the remaining bearing cup into the bore of the bull gear.

E. Install cone spacer (53) onto shaft (62)

F. Install the bull gear over the bearing cone on the shaft [see Figure 9D-11).

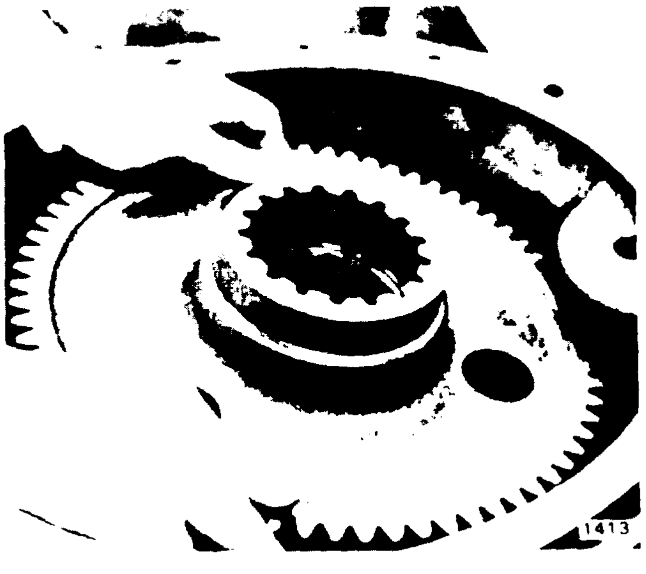


Figure 9D-11 Bull Gear Installation

G. Press the remaining bearing cone onto shaft (62) with the small drameter down.

40. Place cap (48) behind the bearing cone.

41. Secure with three capscrews (47) torqued to 80-90 ft-lbs Lockwire the capscrews.

42. Coat O-ring (14) with grease and install it on the input housing.

43. Place the input housing on ring gear (13) making sure that the pilot of the input housing seats in the counterbore of the ring gear.

44. Install capscrews (59) and lockwashers (58) and tighten to 160-180 ft-lbs.

CENTER SECTION. To assemble the center section, proceed as follows (see Figure 9D-12):

1. Install sun gear (15) and snap ring (17) into input planet carrier (16). Install input planet gears (20), washers (19). shafts (22). and bearings (21) into the input carrier.

NOTE

It is important that these items be installed in their original positron and location.

2. Drive steel roll pins (23) flush with the carrrer, locking the shafts in place.

3. Install the planet assembly into the gear case with sun gear (15) up.

4. Install carrrer spacer (12) onto planet carrier (16)

5. Install planet gears (09) and bronze shafts (10) into output planet carrier (08).

NOTE

It is important that the pins and gears be installed in their original positions and locations.

6. Drive roll pins (07) into the carrier and shafts.

7. Use the tapped holes in the carrier and install the carrier assembly into ring gear (13).

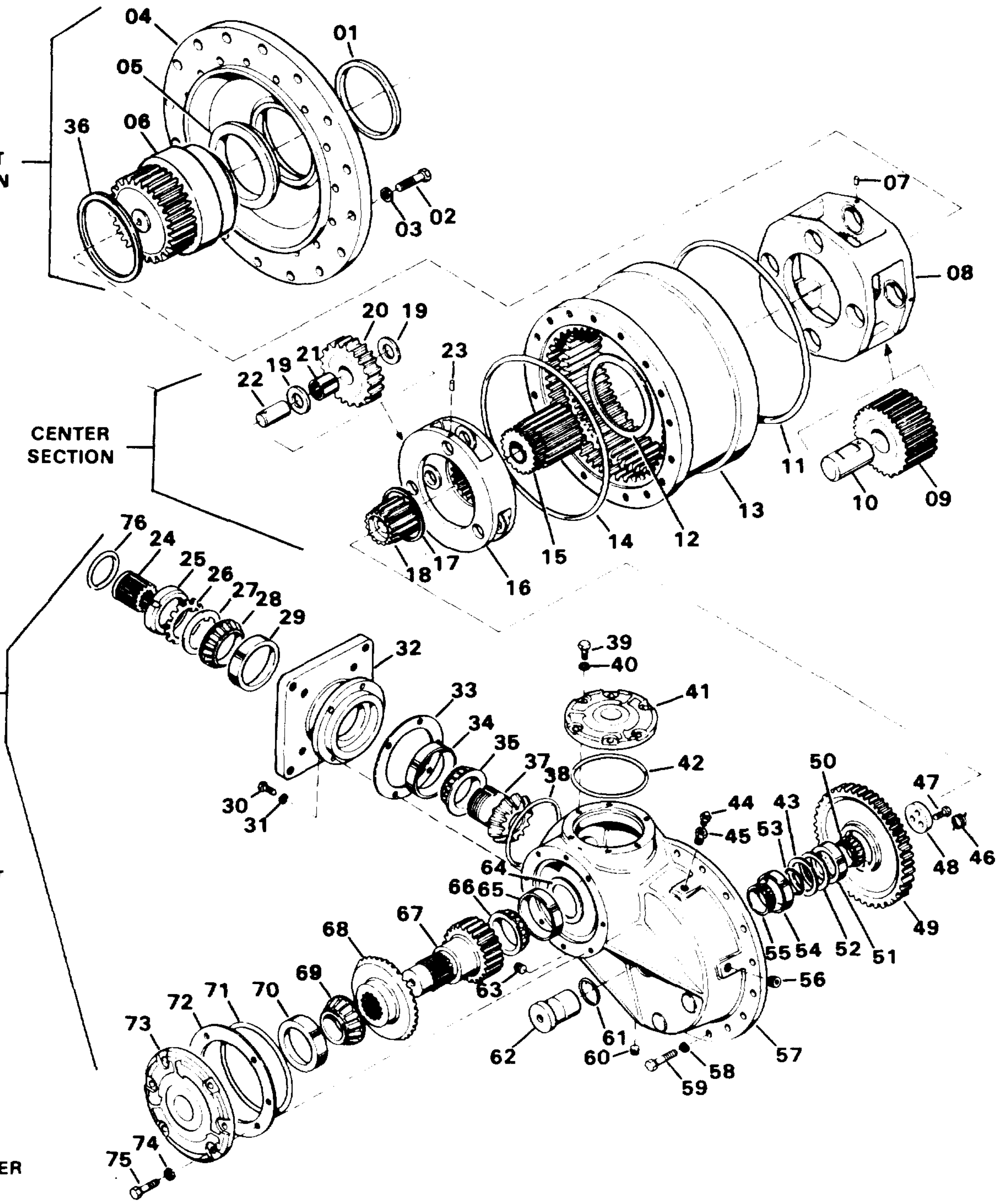
OUTPUT SECTION. To assemble the output section, proceed as follows (see Figure 9D-12):

1. Install seal (01) into the front of cover (04).

2. With the center section resting on the input side, place output shaft (06). with spacer (36) adjacent to collar, into the spline in output carrier (08).

3. Place the cover assembly over the output shaft, being careful not to damage seal (01). Check to insure that the pilot of the cover has sealed properly into the ring gear bore.

4. Install capscrews and lockwashers (02 and 03) and torque to 160-180 ft-lbs.



01. SEAL
02. CAPSCREW
03. LOCKWASHER
04. COVER
05. BUSHING
06. OUTPUT SHAFT
07. ROLL PIN
08. CARRIER
09. GEAR
10. SHAFT
11. O-RING
12. SPACER
13. RING GEAR
14. O-RING
15. GEAR
16. CARRIER
17. SNAP RING
18. GEAR
19. THRUST WASHER
20. GEAR
21. BEARING
22. SHAFT
23. ROLL PIN
24. COUPLER
25. LOCKNUT
26. LOCKWASHER
27. WASHER
28. CONE
29. CUP
30. CAPSCREW
31. LOCKWASHER
32. ADAPTER
33. SHIM SET
34. CUP
35. CONE
36. SPACER
37. GEAR
38. O-RING
39. CAPSCREW
40. LOCKWASHER
41. COVER
42. O-RING
43. CUP SPACER
44. BREATHER
45. BUSHING
46. TIE WIRE
47. CAPSCREW
48. CAP
49. GEAR
50. CONE
51. CUP
52. CUP SPACER
53. CONE SPACER
54. CUP
55. CONE
56. PLUG
57. HOUSING
58. LOCKWASHER
59. CAPSCREW
60. PLUG
61. O-RING
62. SHAFT
63. PLUG
64. SHIM SET
65. CUP
66. CONE
67. SHAFT
68. GEAR
69. CONE
70. CUP
71. O-RING
72. SHIM SET
73. COVER
74. LOCKWASHER
75. CAPSCREW
76. O-RING

Figure 9D-12. Propel Gear Case (14Q121)

INSTALLATION

To install the propel gear case on the crawler frame, proceed as follows (see Figure 9D-13):

1. Wipe mating surfaces on the crawler frame and propel gear case clean.

2. Place sealant (21Z587.D8) on the crawler frame and gear case.

3. Attach suitable lifting slings to the gear case and position the gear case next to the crawler frame. Start the output shaft into the propel driveshaft. It may be necessary to rotate the gear case input shaft to engage the splines of the driveshaft.

4. Secure the gear case to the crawler frame using lubricated capscrews. Torque the mounting capscrews to 330ft-lbs.

NOTE

Use a diametrically opposite pattern for torquing the mounting capscrews which hold the gear case to the carbody.

5. Fill the gear case and driveshaft assembly case with the proper quality and amount of lubricant See Section Ill.

6. Refer to Subsection 9C and install the propel brake and motor.

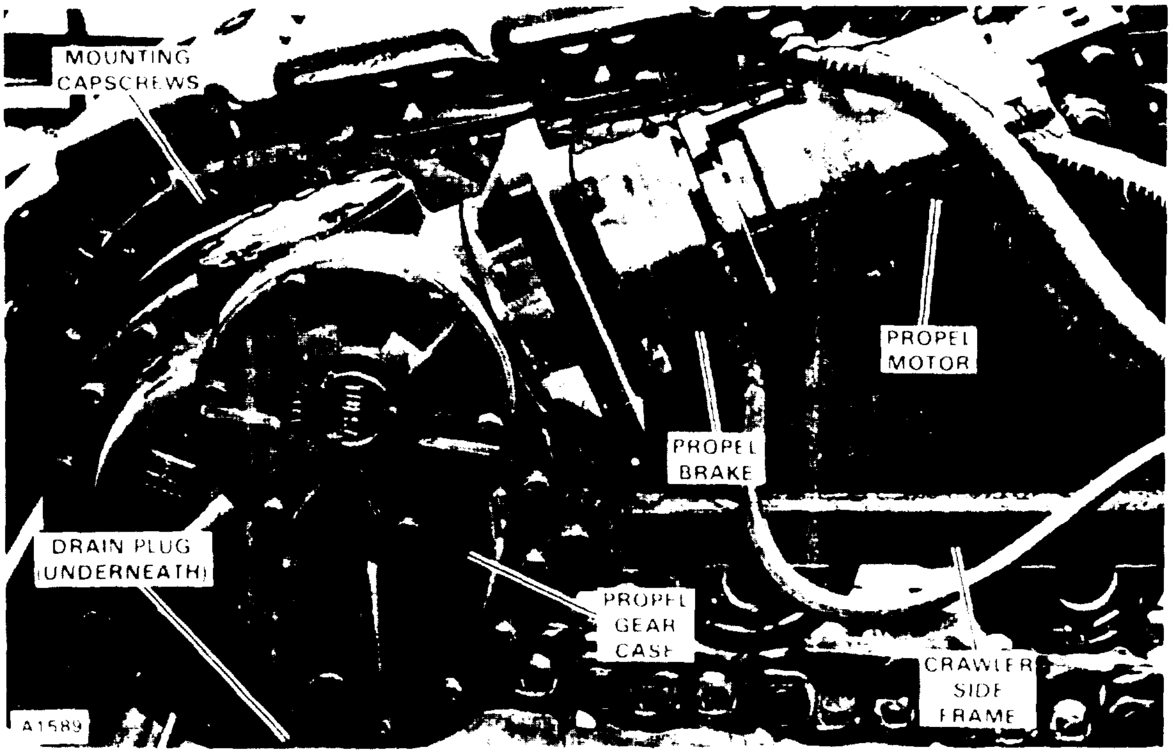


Figure 9D-13. Propel Gear Case

SUBSECTION 9E

CRAWLER COMPONENTS

GENERAL

This subsection covers the maintenance and repair of the crawler components.

MAINTENANCE

Crawler component wear cannot be prevented completely, but the rate at which parts wear can be decreased through preventative maintenance as follows:

1. Check the propel drive components and the crawler rollers and idler often and lubricate them in accordance with the lubrication charts in Section III.

2. Keep crawler parts tight. Check the torque of the components in Table 9E-1, and maintain the torque specifications

Table 9E-1. Crawler Component Torques

Component	Torque (Ft-Lbs)
Brake Mounting Bolts	230
Motor Mounting Bolts	65
Gear Case Mounting Bolts	330
Drive Tumbler Bearing Retainer Bolts	330
Axle to Carbody Mounting Bolts	2800
Track Roller Retaining Bolts	345

3. Maintain proper track adjustment (see Crawler Adjustment in this subsection).

4. Check the crawler components daily for leaks. Repair or replace parts as required.

5. Clean mud and debris from the crawler components daily.

CRAWLER TRACK TENSION ADJUSTMENT

Adjust crawler track tension, as follows (see Figure 9E-1).

1. Propel the machine so that any sag will appear at the front of the track (the end where the adjustment is made).

2. Remove the capscrews holding the keeper plates to expose the shims.

3. Remove the shims found in front of the bearing blocks.

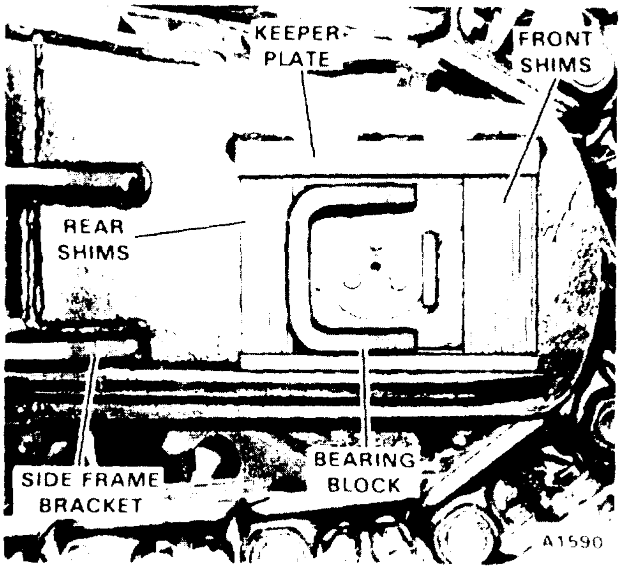


Figure 9E-1. Crawler Track Adjustment

4. Using a hydraulic power unit, placed between the side frame bracket and the bearing block, force the idler sprocket forward to remove the slack from the track.

5. Place the shims behind the bearing block, in the slot opening, to take up the space.

6. Repeat steps 4 and 5 on the inside.

NOTE

An even thickness of shims in the inside and outside packs is required to maintain parallel alignment of the idler sprocket to the track.

7. Place the remainder of the shims in the slot in front of the bearing block to hold it firmly in place.

8. When the track has been properly adjusted, install the keeper plates.

9. Eventually. after an extended period of operation, crawler track wear will reach the point where all the shims are on the inside of the bearing block. When this occurs, remove all shims, break the crawler track and remove one crawler shoe. Then, reconnect the track and adjust the desired track tension by rebuilding the shim pack to whatever arrangement is required.

CRAWLER TRACK REMOVAL AND INSTALLATION

REMOVAL. To remove the track, proceed as follows:

1. Propel the machine to place the master track link (the one with the longer pin) in position above the vertical centerline of the idler shaft (see Figure 9E-2).

2. Loosen the track tension by removing the shims behind the bearing block of the idler shaft.

3. Drive out the master link pin in the track shoe and propel the machine to the rear until the track is laid out flat. Do not propel the machine forward, since the crawler track will bunch up and may cause damage to the machine. Propel backwards until the track is free of the crawler tumbler on the rear. Then jack up the carbody and pull the track out from under the crawler side frame.

TRACK REPAIRS. Repairs are limited to the replacement of individual parts. If the crawler has been adjusted to the point where no more slack can be taken up, a crawler shoe will have to be removed. If this is the case, it is important that this is done to both crawlers or there will be uneven propel motion.

INSTALLATION. To install the track, proceed as follows:

1. Place the track under the crawler side frame and lower the machine onto the track. Insert a bar through the holes in the shoe and attach a cable to each end of the bar. Run the cable over the top of the crawler side frame and attach it to a pulling device. Propel the machine forward while keeping the cable taut. Make sure the shoe engages the rollers.

2. Continue this operation until the shoe is over the top of the idler shaft. Remove the bar and cables.

3. Using a suitable lifting device, lift the lower shoe portion and align the holes in the two shoes.

4. Drive the master pin into the two shoes until the pin is centered.

5. Adjust the track tension.

IDLER SPROCKET ASSEMBLY (2100J968)

REMOVAL AND DISASSEMBLY. If it is necessary to remove the idler sprocket assembly, proceed as follows (see Figure 9E-3):

1. Remove the crawler track as explained earlier in this subsection.

2. Place a jack beneath the axle at the corner of the carbody nearest the idler shaft to be removed. Use suitable blocking beneath the jack to support the weight of the machine on the jack.

3. Remove the keeper plate, shims and end cap.

4. Support the sprocket with a suitable lifting device (the sprocket weighs approximately 600 pounds) and drive the shaft out. Lift the sprocket out of the side frame.

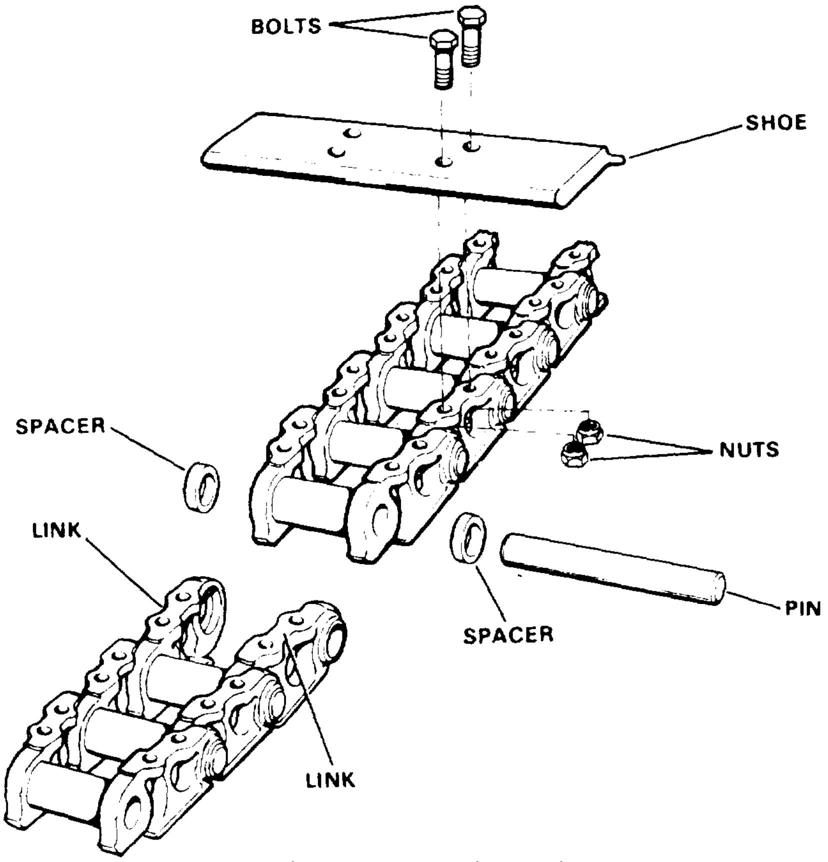


Figure 9E-2. Crawler Track

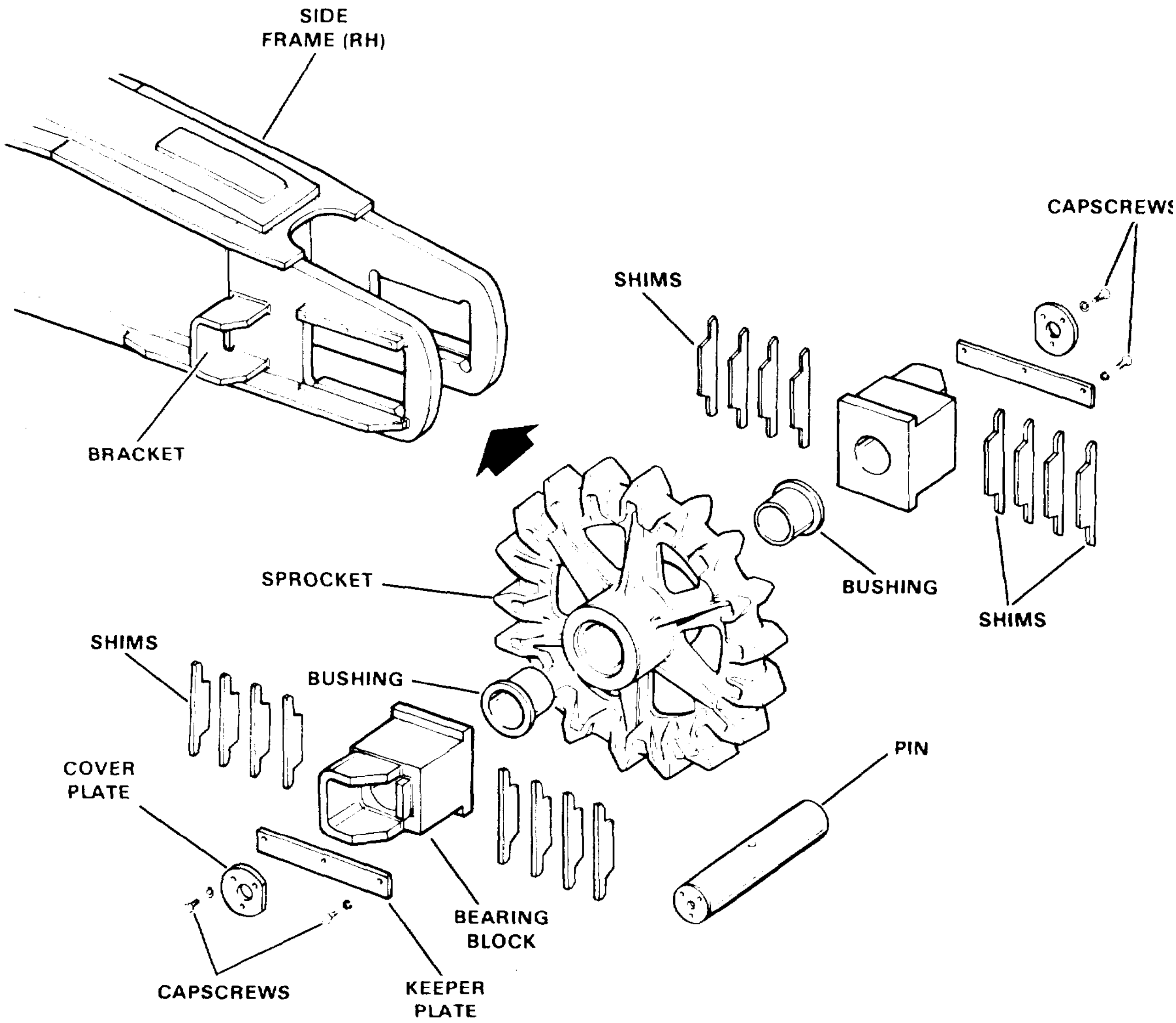


Figure 9E-3. Idler Sprocket (2100J968)

5. Remove the bearing block from the side frame and inspect for wear or damage.

6. Remove the bushings if bushing replacement is necessary. The bushings should be replaced if worn excessively or deeply scratched.

ASSEMBLY AND INSTALLATION. To install the crawler idler shaft, reverse the above procedure and adjust the crawler track as explained earlier. When assembling, pay particular attention to the bushings to see that they are properly installed. Lubricate all parts during assembly.

DRIVE SPROCKET ASSEMBLY (2100J969)

REMOVAL AND DISASSEMBLY To remove and disassemble the drive sprocket assembly, proceed as follows (see Figure 9E-4):

1. Remove the track as described earlier in this subsection.

2. Drain the oil from the propel driveshaft. Replace the drain plug.

3. Remove the propel gear case. See Subsection 9D.

4. Jack the machine at the corner of the carbody nearest the drive sprocket to be removed. Use suitable blocking beneath the jacks to support the weight of the machine on the jack.

5. Block the sprocket to prevent it from falling while the driveshaft is being removed. The sprocket weighs about 430 lbs.

6. Remove capscrews (01 and 16) and retainer (15). Also, remove capscrews (19) and end plate (18).

7. Drive or press shaft (17) out of the sprocket toward the inboard side of the side frame. Bearing (02). carrier (03), spacer (05) and seal (06) wilI come out with the shaft.

8. Pull carrier (12), bearing (14), shims (10 and 11), spacer (09). and seal (08) out. Remove the bearing frorn the carrier.

NOTE

Keep the shim sets intact as the same shim sets are used for assembly.

9. Remove the sprocket from the side frame.

CLEANING AND INSPECTION Clean and inspect all components as follows:

1. Clean all parts in solvent and dry with compressed air. Do not spin the bearings with compressed air.

2. Inspect the bearings for pitted or spalled areas. Replace the bearings if necessary.

3. Check all parts for cracks, breaks or unusual wear.

4. Replace both seals and O-rings.

5. Check the oil grooves inside the hub of the sprocket. The grooves must be open to allow the free flow of oil to the outboard bearing.

ASSEMBLY AND INSTALLATION To assemble and install the drive sprocket assembly, proceed as follows (see Figure 9E-4):

1. Support sprocket (07) between the side frames

2. Heat bearing (02) to 300°F and press it up against the shoulder on shaft (17).

3. Install carrier (03) into the side frame with the break edge lip up.

4. Install the bearing and shaft assembly into carrier (03). Slide spacer (05) and seal (06) over the shaft. When installing seals (06 and 08) use the following procedure:

A Be sure the sprocket and other seal bores are absolutely clean prior to seal installation by cleaning with solvent and drying with compressed air.

B. Wipe the lapped faces of the metal sealing rings clean.

C. Snug the bellville washer of each seal half up against the seal ring flange shoulder around the full circumference of the washer. (See insert in Figure 9E-4.)

D. Insert each seal half into the seal receiving bore.

E. Again wipe the lapped sealing ring faces clean, then, apply a light film of oil to one of the sealing ring lapped faces.

F. For much of the assembly the seal is visible. Any popping out of the seal so that the retainer barb loses contact with the bore wall will require backing up and starting over.

5. Place lubricated O-ring (04) in the carrier groove and start the shaft into the sprocket.

6. As the shaft comes through the sprocket, add spacer (09), shim sets (10 and 11), carrier (12), and assembly spacer (218T1178) in place of bearing (14). If the assembly spacer is not available, one can be fabricated as shown in Figure 9E-5. Carrier (12) must be installed wrth break edge lips up.

7. Install end plate (18), capscrews (01 and 19). retainer (15), and capscrews (16). Torque capscrews (01) to 230 ft-lbs.

8. Check gap “A” first. This gap must measure 0.106 to 0.126 inch. Add shims (10) to increase the gap, remove shims (10) to decrease the gap.

NOTE

Gaps “A” and “B” provide the correct pressure on seals (06 and 08). Incorrect gaps could cause oil leakage or excessive seal wear.

9. With the correct amount of shims (10) installed and the assembly spacer, end cap, carrier, shims and retainer in place, measure the gap at point “B”. This gap must measure 0.106 to 0.126 inch also. If the gap is incorrect, add shims (11) to increase the gap, or remove shims (11) to decrease the gap.

10. After gap “B” is attained, remove the assembly spacer. Install seal (08), shims (11), and carrier (12). Do not change the position of carrier (12).

11. Install bearing (14) tight against shims (10). Secure the bearing in place with end plate (18) and capscrews (19) torqued to 130 ft-lbs.

12. Install lubricated O-ring (13) into carrier (12). Place retainer (15) in position and secure the entire assembly with capscrews (16) torqued to 330 ft-lbs.

13. Remove level plug (20) and fill the driveshaft through the filler hole with the lubricant specified in Section III. When the lubricant begins to run out of the level hole, install the level plug.

14. Install the propel gear case and fill with the lubricant specified in Section III.

15. Remove the blocking and jacks from the sprocket and carbody.

16. Install the track as described earlier in this subsection.

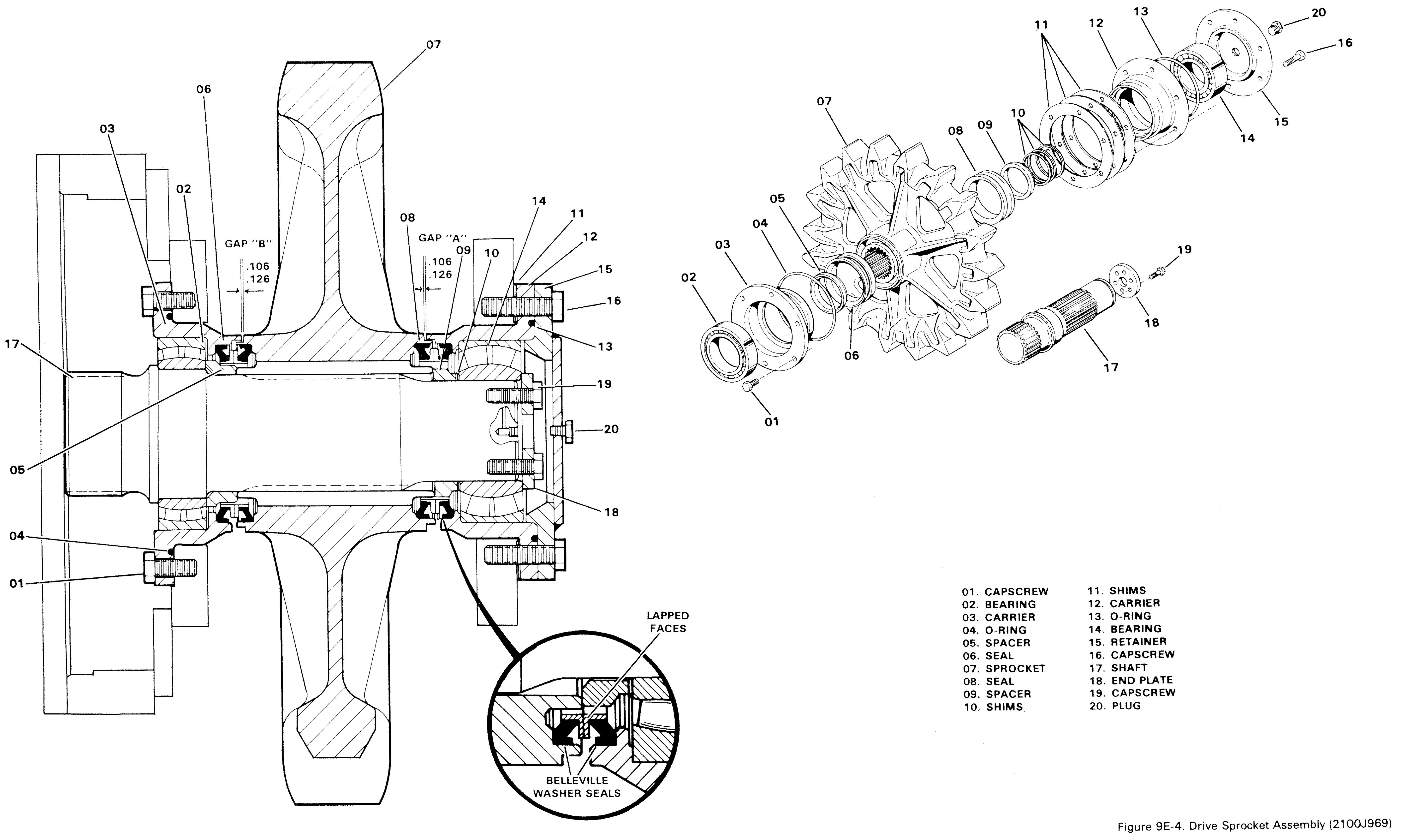
SIDE FRAMES AND AXLES (2100J949)

SIDE FRAME REMOVAL. To remove a side frame, proceed as follows (see Figure 9E-6 and 9E-7):

1. Choose firm, level ground or a level “lowboy” platform on which to work. Install the basic boom on the machine. Remove the counterweight (see the Operator’s Manual).

WARNING

The weight of the block and sling must equal 1500 lbs. to prevent backward tipping with one side frame removed and one side frame installed. Proceed slowly and exercise caution throughout this procedure.



01. CAPSCREW	11. SHIMS
02. BEARING	12. CARRIER
03. CARRIER	13. O-RING
04. O-RING	14. BEARING
05. SPACER	15. RETAINER
06. SEAL	16. CAPSCREW
07. SPROCKET	17. SHAFT
08. SEAL	18. END PLATE
09. SPACER	19. CAPSCREW
10. SHIMS	20. PLUG

Figure 9E-4. Drive Sprocket Assembly (2100J969)

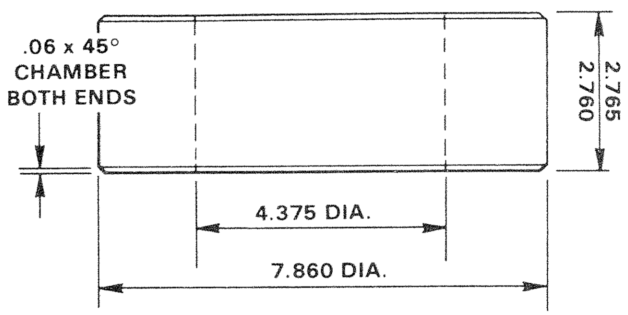


Figure 9E-5. Assembly Spacer (218T1178)

2. Jack up and block the carbody at the four axle housing flanges to a height where the crawler tracks just clear the ground. The centerline of these blocks must be a minimum of 40 inches from both the lateral and longitudinal centerline of the crawler lower.

3. Place both side frames in the extended position and lock the axles using the axle locking pin. With the gantry in the raised position, raise the boom until the bottom block is at a 12 foot operating radius.

4. Disconnect the hydraulic lines from the propel motors and brakes. If equipped, disconnect the extend cylinder from the side frame.

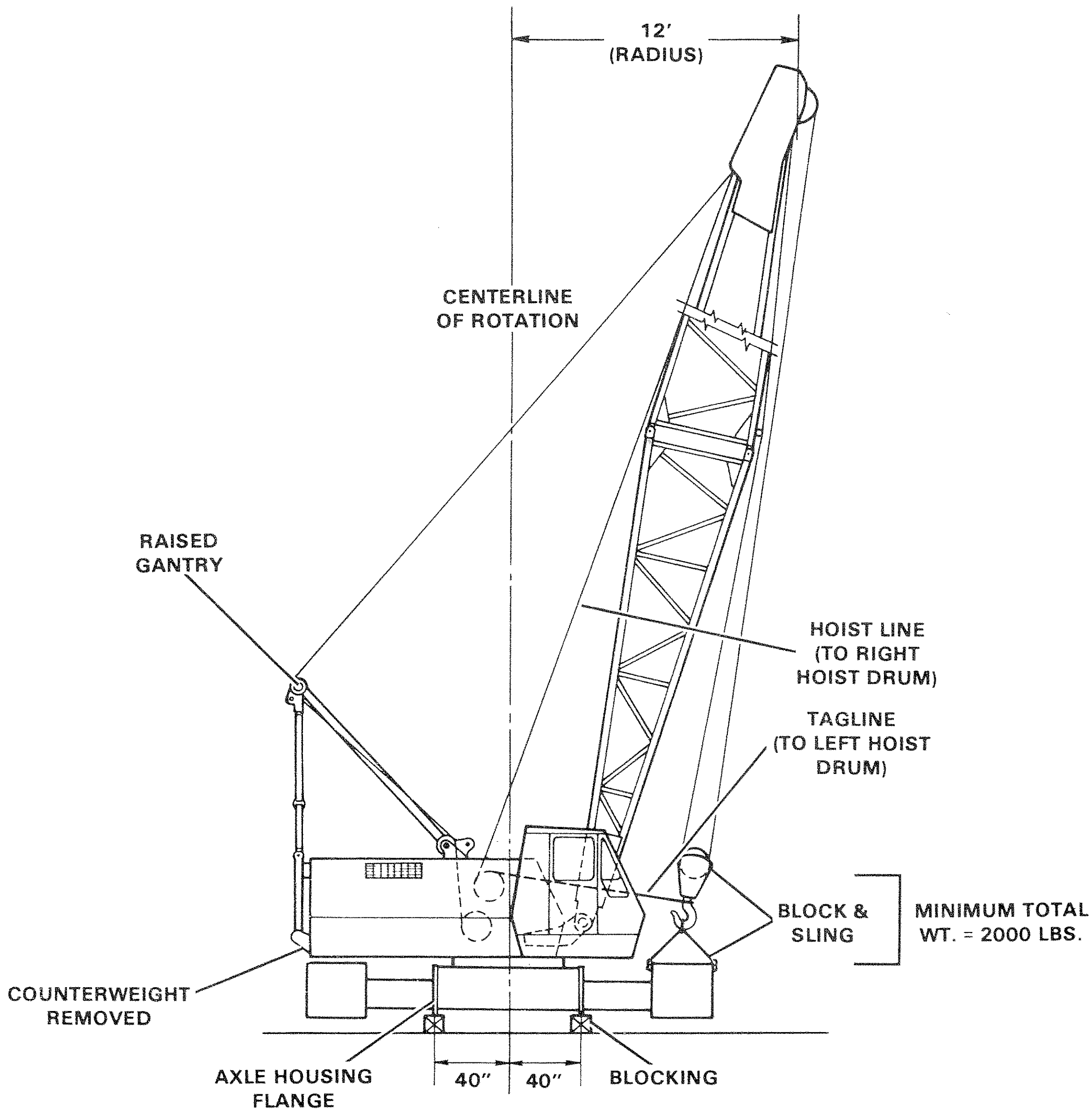


Figure 9E-6. Side Frame Removal

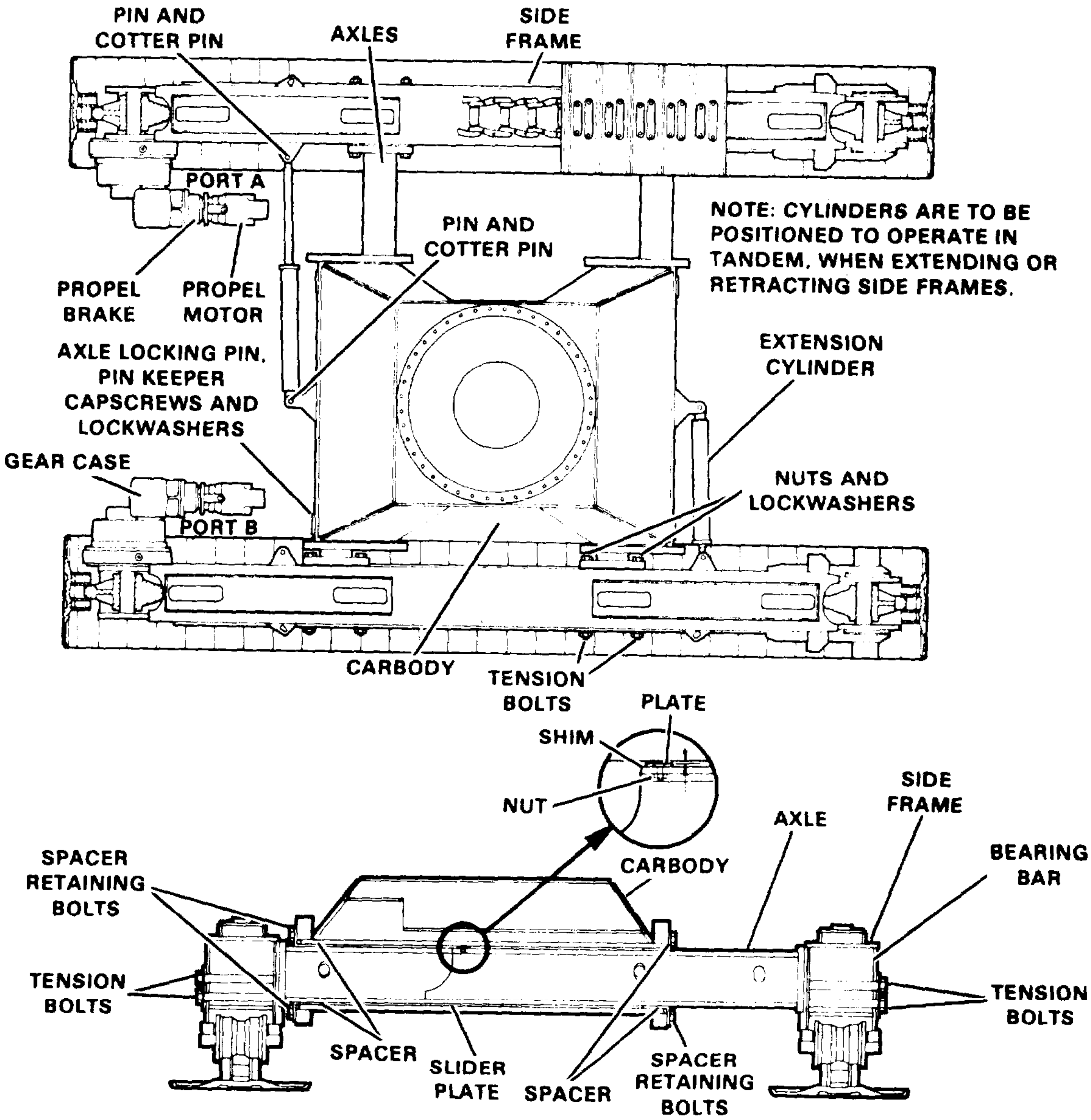


Figure 9E-7. Crawler and Axle Assembly (2100J949)

5. Position a sling onto the crawler shoes so that the entire side frame assembly will balance. Hook a tagline from the left hoist drum and the side frame removal sling into the bottom block as shown in Figure 9E-6.

6. Lift the sling with the right hoistdrum and take in on the tagline to remove any slack in the lines. Remove the large tension bolts and nuts that secure the side frames (see Figure 9E-7).

7. Slack off on the tagline. The side frame will swing outward from the carbody. It may be necessary to take up on the hoist line slightly to provide clearance between the crawler track and the ground, since the side frame will swing outward on a downward arc.

8. If loading the side frame on a lowboy, park it 12 inches from the side frame. Take up on the hoist line enough to clear the lowboy. Let out on the tagline and position the side frame on the farside of the lowboy.

CAUTION

Do not let the hook block EXCEED A RADIUS OF 15 FEET, OR A TIPPING CONDITION COULD RESULT.

9. Lower the side frame to the ground or onto a lowboy.

10. Retract the axles and pin them in place.

11. Swing the machine upper through 180° to remove the opposite side frame, using the procedure in steps 4 through 7.

12. When loading onto a lowboy, keep the centerline of the side frame at 6-1/2 feet radius and *swing slowly towards the lowboy.* Place the side frame next to the other side frame on the lowboy.

CAUTION

Do not let the hook block EXCEED A RADIUS OF 12 FEET, OR A TIPPING CONDITION COULD RESULT.

13. After removal of the side frame, lower the block to the ground. The axles may be retracted and locked in position with the locking pin, if necessary.

AXLE REMOVAL. To remove an Individual axle, proceed as follows (see Figure 9E-7):

1. Remove the appropriate side frame as indicated above.

2. Fully extend the axle to be removed.

3. Attach a sling around the axle frame and then attach the sling to the hook block. Lift the sling with the hoist drum and take in on the tagline to remove all the slack. Remove the spacers from the axle housing.

4. Slowly pull the axle out of the carbody a short distance. Reposition the sling until the axle is almost out of the carbody. Place blocking at the end of the axle and reposition the sling at two points that will balance the axle. Remove the axle from the carbody.

AXLE INSTALLATION To install an axle, proceed as follows (see Figure 9E-7):

1. Attach a sling to the axle at points that will balance the axle. Lift the axle and insert it into the carbody until the shim plate lines up with the edge of the axle housing.

2. Check the clearance between the axle and the housing. It should be 0.060 inch at this point. If not, proceed as follows to adjust this clearance (see insert in Figure 9E-7).

A. Remove the nuts from the inside of the axle frame and raise the plate.

B. Insert the shims under the plate to obtain the necessary clearance.

C. Install and tighten the nuts that hold the plate and the shims in place.

3. Insert the axle, along with a pair of spacers, into the axle housing.

4. Check the clearance between the axle and the housing after adding spacers, one in the top and one in the bottom (the thickest spacer goes in the bottom). This clearance should be 0.125 inch. If not, add a thicker spacer at the top to arrive at this setting.

5. Insert the capscrews and washers through the holes in the spacers and tighten to the axle housing securely.

SIDE FRAME INSTALLATION. To install a side frame, proceed as follows (see Figure 9E-6):

WARNING

The weight of the block and sling must equal 1500 lbs. to prevent backward tipping with one side frame removed and one side frame installed. Proceed slowly and exercise caution throughout this procedure.

1. Attach a sling to the crawler shoes so that the entire side frame assembly will balance. Hook a tagline from the left hand hoist drum and the side frame removal sling into the bottom block.

NOTE

The side frame should be installed using the basic boom only.

2. Place both axles in the extended position and lock the axles with the locking pins. With the gantry in the raised position, raise the boom.

3. Lift the sling with the right hoist drum and take in on the tagline to bring the side frame to the axles. Work the hoist line and tagline to engage the side frame with the axles.

4. When the side frame is positioned against the shear ledges, install the large tension bolts and nuts. Torque the bolts to 2800 ft-lbs.

5. Install the opposite side frame as explained in steps 1.

6. After installation of the side frames, lower the block to the ground, and jack up the carbody to remove the blocking. Lower the carbody and test the machine.

CRAWLER ROLLER (13Q18D1)

DESCRIPTION. The crawler rollers guide the track rail in a straight line as it rotates around the crawler side frame. Wear of the rollers is a result of contact between the track rail links and the outside surfaces of the rollers. These surfaces, called rolling diameters, can be expected to decrease as the machine is propelled. As the outside diameter of the rollers becomes smaller, the flange height of the rollers will increase to a point where the rollers will begin to contact the bosses on the track links. This should never be allowed to occur; the crawler rollers must be replaced prior to reaching this point.

REMOVAL. To remove a crawler roller, proceed as follows:

1. Jack up thecarbody enough to allow the roller to drop out of the crawler frame. Fully support the carbody at the axle housing flanges. Remove all tension from the track rail by removing the shims at the idler sprocket as previously described in this subsection.

NOTE

The crawler rollers can be removed without disconnecting the track rail. The nearer the roller is to the end of the crawler the less clearance there will be between the roller and track rail, however. It will be necessary to start in the middle and remove each roller until the faulty roller can be removed.

2. The crawler roller weighs approximately 160 pounds Support the roller so that it will not fall, and remove the capscrews which secure the roller end collars to the crawler side frame. Remove the roller from the side frame.

DISASSEMBLY AND REPAIR. It is recommended that all seals be replaced whenever a roller is disassembled. To repair a crawler roller, proceed as follows (see Figure 9E-8):

1. Remove plug (13) from the end of shaft (02) and drain the oil from the roller.

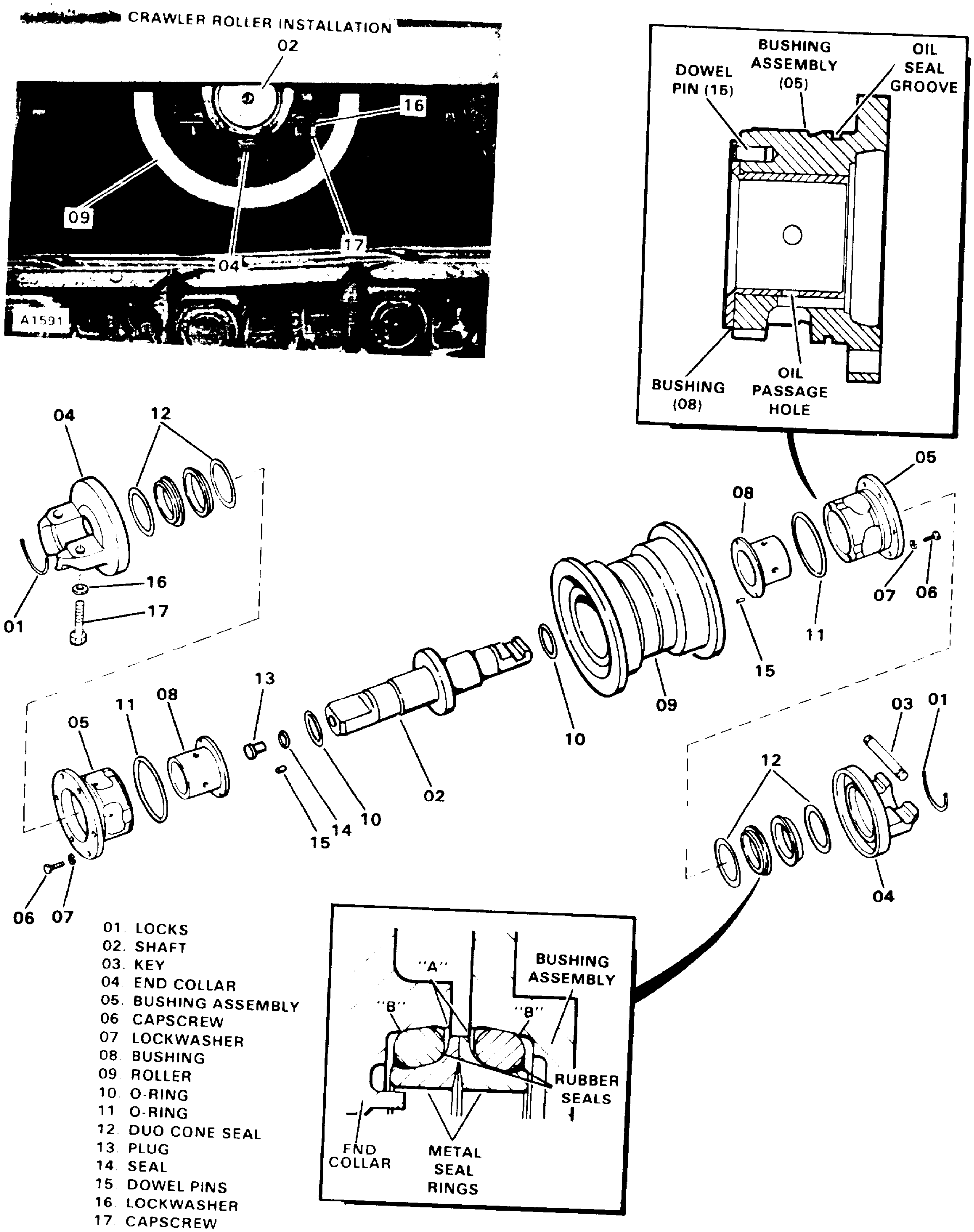


Figure 9E-8, Crawler Roller (13Q18D1)

2. Remove locks (01) from each end of shaft (02) and remove key (03).

3. Pull end collars (04) off of each end of shaft (02).

4. Remove bushing assembly (05) from each end of roller (09). Press shaft (02) out of the roller. Then remove bushings (08) by pressing them out of bushing assemblies (05); see insert view in Figure 9E-8.

5. Remove an O-ring (10) from each end of shaft (02). Remove O-ring (11) from the groove in each bushing assembly (05).

6. Remove one half of duo cone seal (12) from each end collar (04) and another half of duo cone seal (12) from each bushing assembly (05).

7. Thoroughly wash all parts in solvent and dry. Inspect all metal parts for excessive wear, cracks or distortion. Replace parts as required.

8. To replace bushing (08) in the bushing assembly as shown in the insert of Figure 9E-8, proceed as follows:

A. Remove pins (15) from the bushing assembly and discard.

B. Install a new bushing in the bushing assembly with the oil holes in alignment.

C. Drill two holes (9/32 inch) through the bushing and into the bushing assembly being careful not to drill into the oil grooves. Make the holes 3/4 inch deep.

D. Ream the holes to a diameter of 0.3052 inch to the same depth.

E. Ream the holes to a diameter of 0.308 *but only to a depth of 1/4 inch.*

F. Install two new pins (15) into these holes to a depth of 0.030 inch below the outside surface of bushing (08). Clean the bushing assembly thoroughly of any metal filings or chips.

ASSEMBLY. To assemble the crawler roller, proceed as follows:

1. Install seal (11) in grooves on the bushing assemblies. Apply a light coating of oil to the seals, the groove of the bushing assembly, and the inside of the roller.

2. Install one bushmg assembly into the track roller with a press.

3. Install the six capscrews that hold the bushing assembly to the roller and torque to 25 ft-lbs

4. Insert the shaft into the roller and press the other bushing assembly into the roller

5. Install the other capscrews and torque to 25 ft-lbs.

6. Install duo cone seals (12) as follows (see insert view in Figure 9E-8):

A. Remove all oil and any protective coating from the metal seal rings and seal seat ("B") on the roller and retainer, using a cleaning solvent and making sure all surfaces are dry.

B. Check retaining lips ("A") and seal seats ("B") for rough tool marks or nicks. Smooth any nicks and reclean. Also make sure that the sealing face of the metal seal rings is free of nicks.

C. Wipe all seal faces to remove any foreign material. Place a few drops of clean gear oil (see Lube Chart) on a cleaning tissue and completely coat the sealing faces of the seals to assure corrosion protection and initial lubrication. Install a rubber seal on each metal seal ring so they seat uniformly on the metal rings. Be sure the rubber seals are not twisted and are resting uniformly against the lip that prevents them from falling off the metal seal rings.

D. Install one half of a duo cone seal in each end collar (04) and in the end of each bushing assembly (05). Press the rubber seal into the seal seat making sure that it is straight in the bore and inside retaining lips ("A"). *Do not use a screwdriver or any sharp instrument to seat the rubber rings.*

7. Install a new O-ring (10) in the groove on each end of shaft (02). Install end collar (04), with the keyway, over the keyway end of shaft (02). Install key (03) and lock (01). Install the other end collar (04) over the other end of shaft (02). Align the mounting holes and install lock (01).

8. Fill the crawler roller with gear oil (see Lube Chart) through the hole in shaft (02). Install a new O-ring (14) on plug (13) and torque the plug to 125 ft-lbs.

INSTALLATION. To install a new or repaired crawler roller, proceed as follows:

1. Position the roller below the crawler side frame and align the mounting holes. Block the roller in position.

2. Lubricate the mounting screws with SAE 30 oil, install the screws with flat washers, and torque the screws to 345 ft-lbs.

3. Install all other crawler rollers that were removed.

4. Remove the blocking from the rollers and adjust track tension. Raise the crawler with the jack and remove the blocking from the carbody. Lower the crawler onto the ground.

SECTION X

ELECTRICAL SYSTEM

SUBSECTION 1OA

ELECTRICAL SYSTEMS

GENERAL

This subsection contains schematics of the power plant, floodlights, mark-load system, and the main machinery (see Figures 10A-1 and 10A-2). These schematics should be helpful in determining the cause of an electrical malfunction. Table 10A-1 lists the circuit breakers and the circuits that are controlled by them. There is one circuit breaker located at the right rear side of the engine, the other circuit breakers are located in the operator's module.

Table 10A-1. Circuit Breakers

BREAKER	CIRCUITS CONTROLLED
CB-1 (Engine)	Engine
CB-1	Clutch, boom hoist, start aid, horn
CB-2	Main drum pawls, swing brake, gauges, lights
CB-3	Windshield wipers
CB-4	Heater, defogger
CB-5	Drum turn indicator, load monitoring
CB-6	Engine warning,.spares
CB-7	Propel, swing
CB-8	Spare

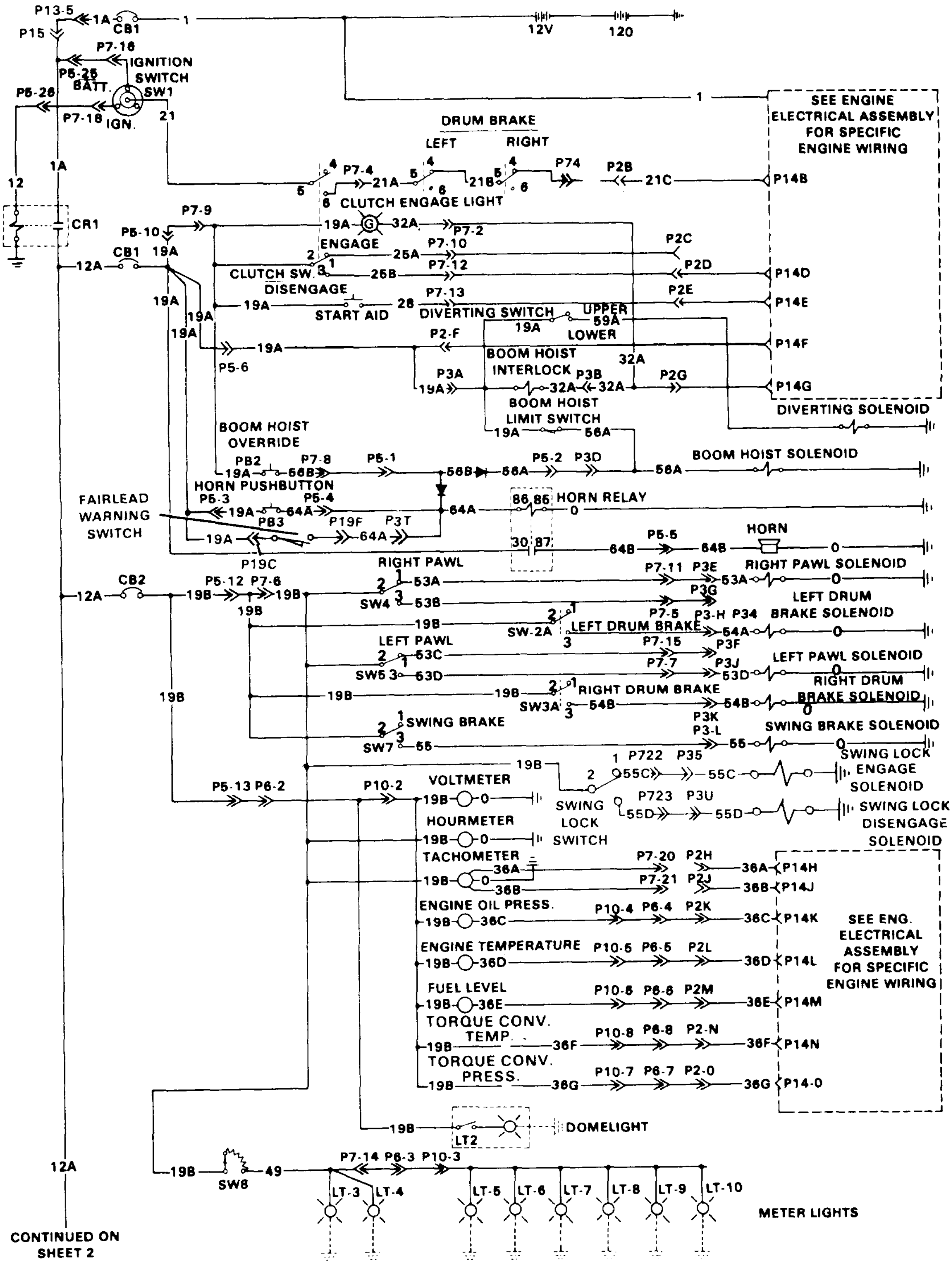


Figure 10A-1 Machinery ElectrIcal SchematIc (2101J44 – 1 of 2)

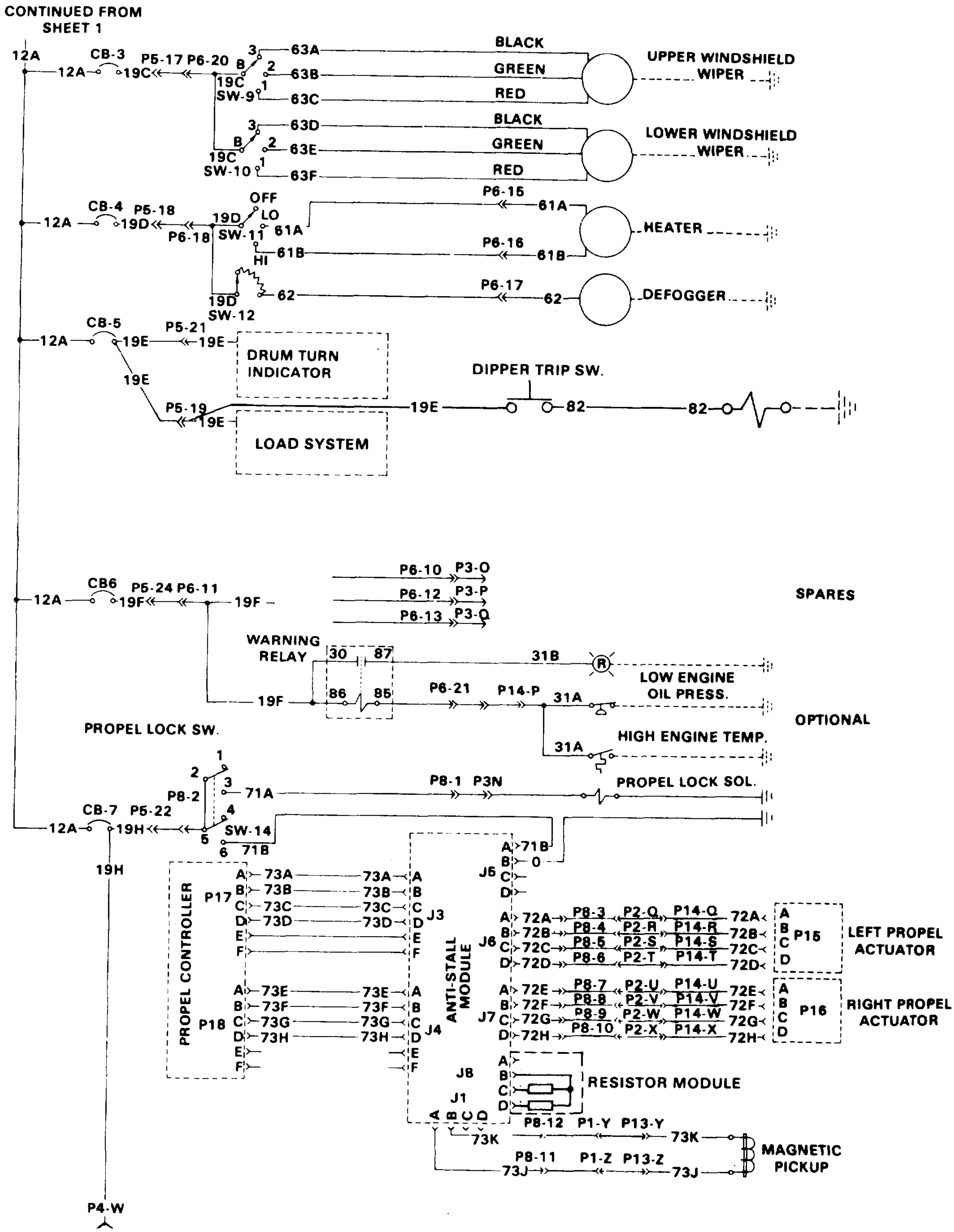


Figure 10A-1. Machinery Electrical Schematic (2101J44 – 2 of 2)

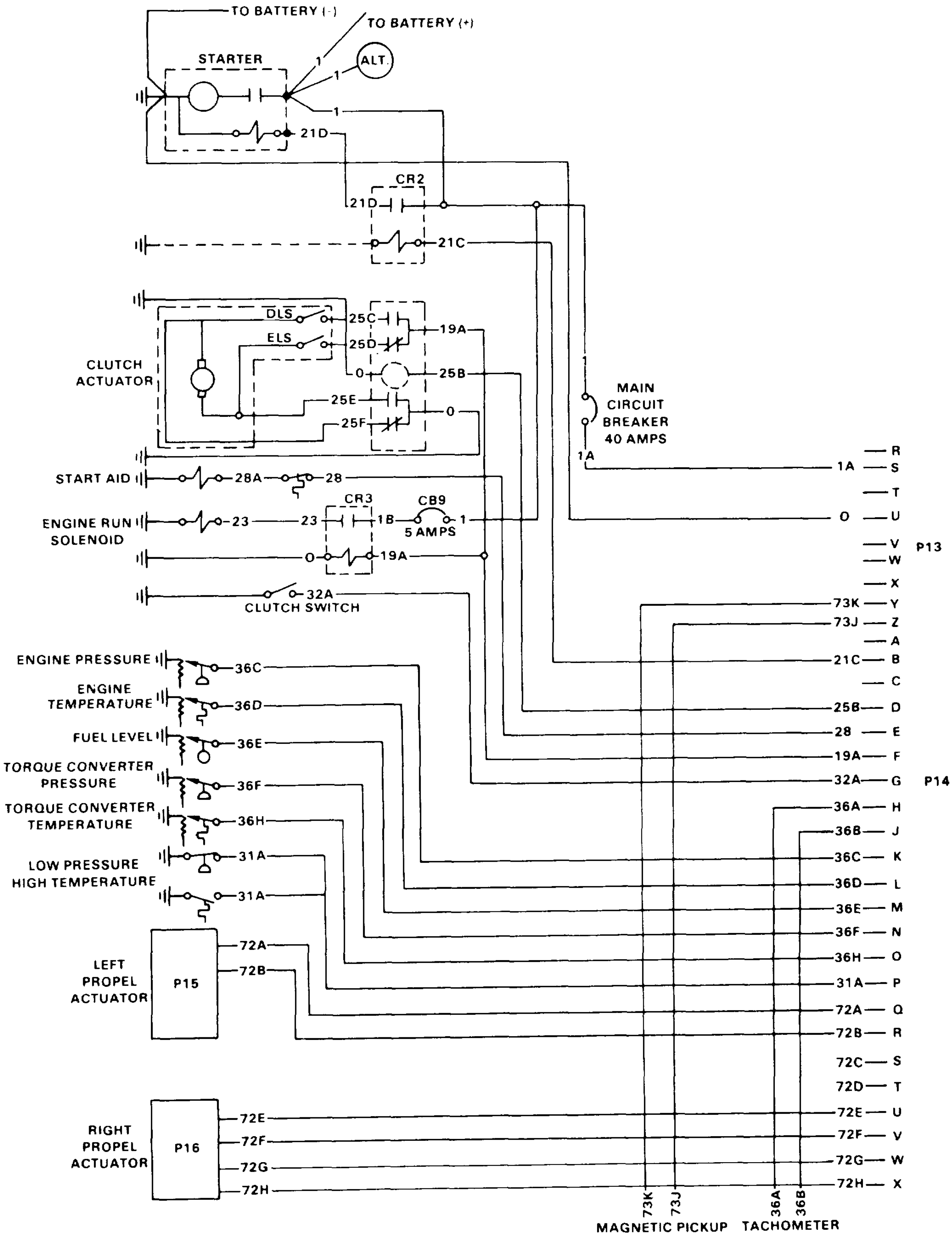


Figure 1OA-2. Engine Electrical Schematlc (2100J1165-1) DDA4-71T

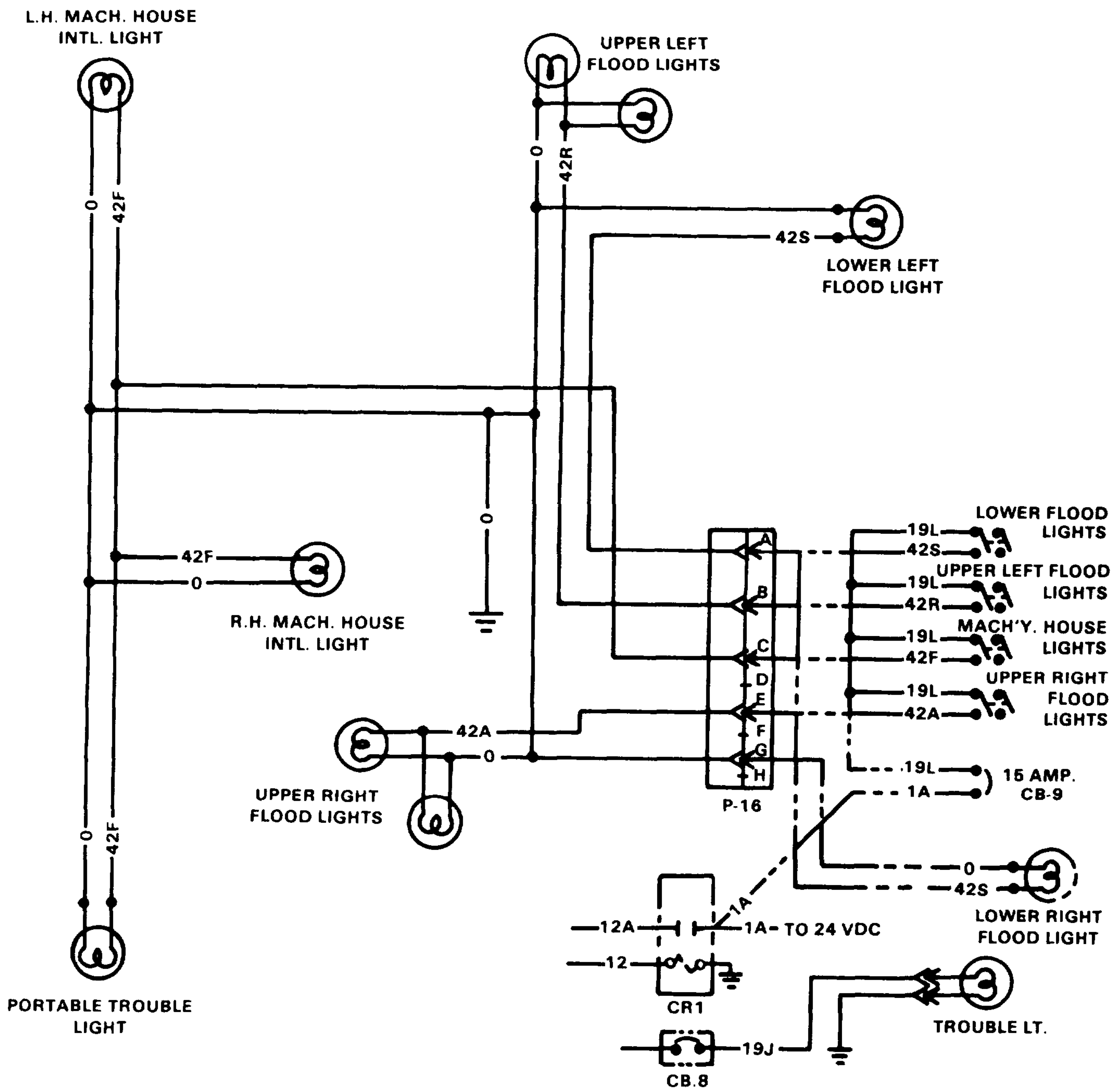


Figure 10A-3. Floodlight Electrical Schematic (2105J235)

SUBSECTION 1OB

OPERATIONAL AIDS

GENERAL

This subsection covers any necessary adjustments to the operational aids.

BOOM HOIST LIMIT DEVICE (2100J1005)

DESCRIPTION. The boom hoist limit device is used to set the maximum angle of the boom. When the boom stop block, mounted on the boom base contacts the limit switch it shifts the boom hoist limit solenoid. At this point, pulling the boom hoist control lever back will direct hydraulic oil back to tank and will not release the boom hoist brake or engage the boom hoist clutch to raise the boom.

ADJUSTMENT. Whenever a boom hoist limit switch has been replaced or disturbed the maximum angle that the boom is allowed to reach should be checked. To set the boom limit for the proper maximum angle, proceed as follows (see Figure 10B-1):

1. Elevate the boom to an angle of 80°.
2. Loosen the screw which secures the trip lever to the limit switch and adjust the trip lever as required to open the switch contacts. The switch contacts will make a click to indicate when they are open.

NOTE

When the switch is in proper adjustment the switch will move 12° before shut-off.

3. Tighten the screw in the trip lever.
4. Raise and lower the boom slowly several times to check the adjustment. Repeat the procedure as necessary to achieve the proper adjustment.

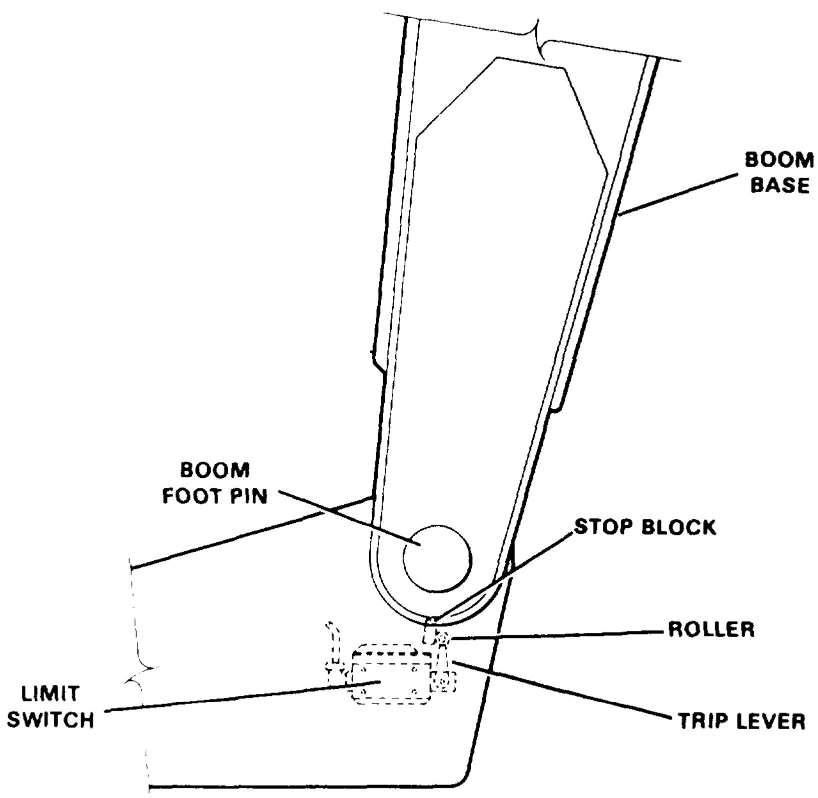


Figure 10B-1. Boom Hoist Limit Switch Adjustment (2100J1005)

KRUEGER LOAD SYSTEM

GENERAL

The information below is intended as a calibration and troubleshooting guide for the Krueger Load computer system.

The rating of any crane is limited by two factors, namely, the strength of its structural members, and the stability of the crane. The purpose of the load moment system is to give the operator an indication when the load on the machine is approaching or has reached the limits shown on the capacitv chart.

When properly calibrated, as described below the load system will give visual and audible indications when the load on the machine reaches 90% and 100% of machine capacity.

The system consists of a central unit, remote Indicators (meters), angle sender, preampirfier. load cell and connecting cables.

WARNING

This unit is an operating aid and cannot be used as a substitute for the rating plate. The system should be inspected on a weekly basis for pinched, loose or cracked cables. Also check for proper sealing of the central unit and meters to keep out water and dust and to insure proper operation of the unit.

CALIBRATION

INITIAL TESTING. Initially test the units as follows:

1. Check all cable routing and all connections. Also check the load cell mounting (5).
2. Check the angle transducer and load cell for damage
3. Set up the load weighing system as outlined in Section II.
4. If the unit does not perform as outlined in Section II, then contact the manufacturer:

Krueger Crane Systems Inc.
4904 Cold Road
Rockford, Ill. 61109-2609

SUBSECTION 1OC

PROPEL ANTI-STALL CONTROL SYSTEM

GENERAL

This subsection provides the information necessary for troubleshooting the propel anti-stall control system used on this machine. Troubleshooting instructions are outlined to permit isolation of the specific component(s) which may have failed. Individual components of this system are not field serviceable: if a component is faulty it must be replaced.

The information in this subsection pertains only to the electrical components in the propel anti-stall system. Refer to Subsection 9A for propel hydraulic system troubleshooting information.

DESCRIPTION

The anti-stall control system automatically destrokes the propel pumps to prevent engine stalling when the machine is propelled. In addition to the pump/motor hydrostatic transmissions, the propel system includes an electronic anti-stall module, an engine speed potentiometer, two pump controllers, a magnetic engine speed pickup and a propel control station (see Figure 10C-1).

This machine is equipped with two propel motors and two propel pumps. One pump/motor transmission drives the right side of the machine while the other pump/motor transmission drives the left side of the machine. One propel pump controller is located on the side of each pump. The pump controllers provide flow to the pump swashplate control pistons and respond to displacement of the swashplate through a feedback linkage and spring followup.

Electrical current input into the pump controllers is provided by a dual axis propel control station located in the operator's module. The control station outputs current proportional to input voltage and the lever position selected by the operator. The pump controller positions the swashplate proportional to input current. Therefore, the input voltage to the control station and lever position determine the displacement of the pump.

An engine speed potentiometer is used to sense the throttle setting. The potentiometer is connected to the throttle linkage located below the circuit breaker panel at the rear of the operator's module. A magnetic pulse pickup is used to sense engine speed. The pulse pickup is fastened to the lower left hand side of the engine flywheel housing. Whenever engine speed falls below the rpm expected at a given throttle setting, the anti-stall module electronics will automatically reduce the input voltage to the control station. The reduced input voltage proportionally destrokes the pumps, thereby preventing the engine from stalling. A switch on the anti-stall module can be used to bypass the anti-stall electronics. Switching into the manual mode supplies the control station with constant battery voltage.

TROUBLESHOOTING

GENERAL. Before any service is performed on this system, this subsection and Subsection 9A should be thoroughly reviewed. Adequate servicing depends upon a good understanding of the control system. To perform the tests and minor repairs described in this subsection, the following tools are required: a 25-50 watt soldering iron, a volt-ohm-ammeter, a blade screwdriver and a 1/8 inch Allen wrench (2-1/2 inches long).

Table 10C-1 is provided to assist in isolating and correcting problems that may occur in the propel anti-stall control system. The tests listed in the troubleshooting chart are described in detail in the paragraphs following the chart.

Table 10C-1. Propel Anti-Stall Control Troubleshooting

Problem	Possible Cause	Test	Remedy
Complete loss of control	Anti-stall module does not function properly.	Electrical Power to Anti-Stall Module Electrical Power to Controller	Replace anti-stall module.
	Magnetic pickup not functioning properly.	Magnetic Pulse Pickup	Adjust or replace the magnetic pickup.
	Propel control station does not function.	Propel Control Station	Replace the propel control station.
	Pump controller does not function properly.	Pump Controller Manual Input	Replace the pump controller.
	Open or short circuit in cables		Repair or replace cable.
Loss of only one axis of control.	A single axis of the propel control station does not function	Propel Control Station	Replace the propel control station.
	Open coil or open coil lead of the pump controller.	Pump Controller Manual Input	Replace the pump controller.
	Anti-stall module does not function.	Electrical Power to Pump Controller	Replace the anti-stall module.
	Open or short circuit in cables.		Repair or replace cable.
Machine rotates with forward or reverse command.	One of the pump controllers does not function.	Electrical Power to Pump Controller and Pump Controller Manual input.	Replace the faulty pump controller.
Engine stalls	Anti-stall module does not function.	Electrical Power to Anti-Stall Module	Replace the anti-stall module.
	Engine speed potentiometer does not function.	Engine Speed Potentiometer	Replace the engine speed potentiometer.
	Open or short circuit in cables.		Repair or replace cables.
Transmission output in one direction only. Limited or no response to command signal.	Pump controller not functioning properly.	Pump Controller Manual Input.	Replace pump controller.
	Short circuit in cables.		Repair or replace cables.
	Short circuit in control station.	Control Station	Replace the control station.
Transmission slowly rotates when the propel control station is returned to neutral.	Pump controller not properly nulled.	See Subsection 9B.	Null or replace the pump actuator.
	Short circuit in propel control station	Propel Control Station	Replace the propel control station.

Table 1OC-1. Propel Anti-Stall Control Troubleshooting (Cont.)

Problem	Possible Cause	Test	Remedy
Poor response, pump delays in returning to neutral after the propel control station is returned to neutral.	Pump controller not functioning properly,	Pump Controller Manual Input	Replace pump controller.
	Pump controller not properly nulled.	See Subsection 9B.	Null or replace pump controller.
Non-repeatability (pump fails to return to neutral each time the propel control station is returned to neutral).	Propel controller not functioning properly.	Propel Control Station	Replace propel control station.
	Pump controller not functioning properly,	Pump Controller Manual Input	Replace faulty pump actuator.

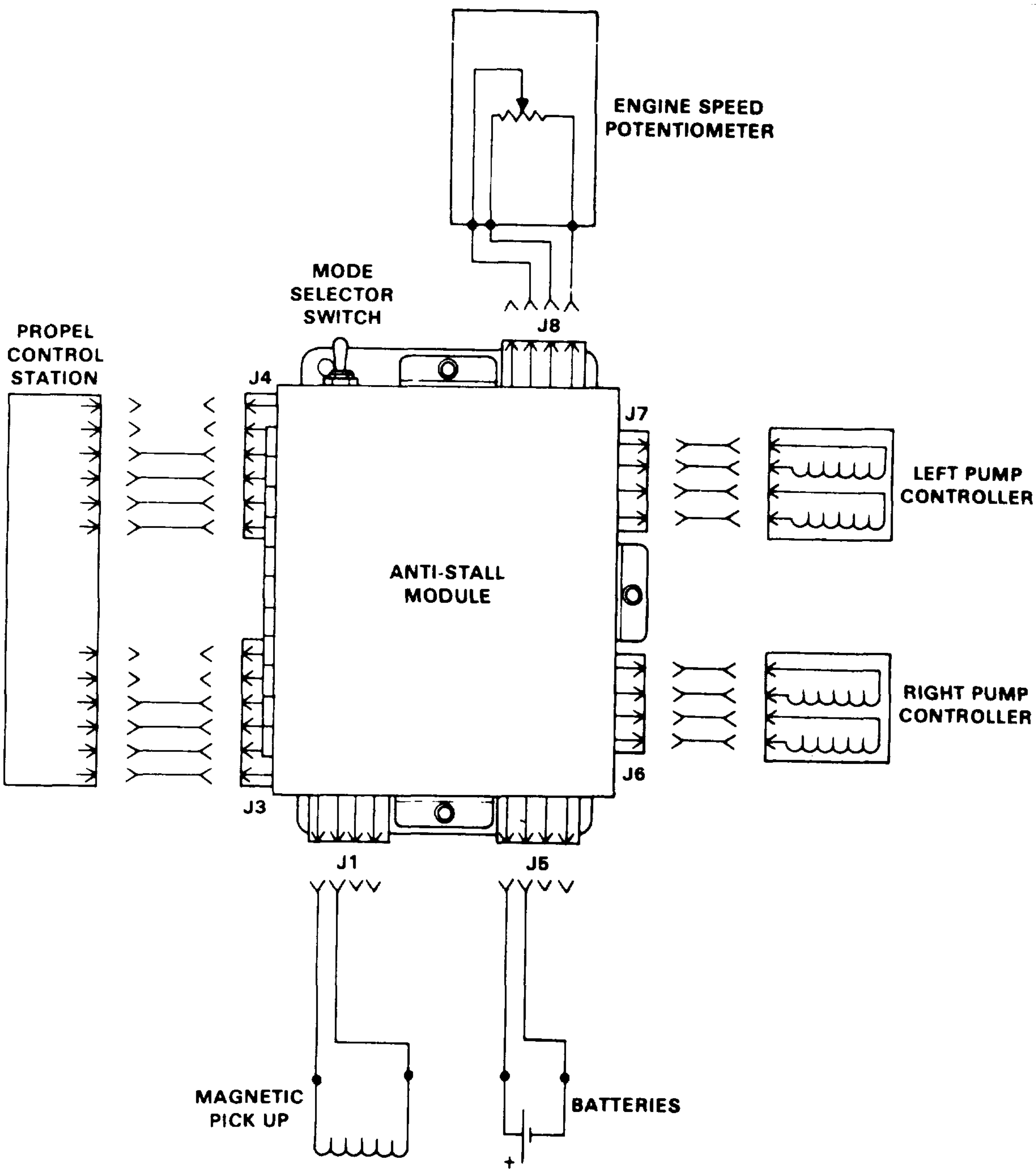


Figure 10C-1. Anti-Stall Control Electrical Schematic

ELECTRICAL POWER TO ANTI-STALL MODULE TEST. The anti-stall module is located under the gauge panel at the left of the operator's seat. Access to the module is gained by removing the gauge console side panel. A manual override switch is located on top of the module. The manual mode of operation is used during specific test procedures. To place the module in the manual mode, move the switch away from the operator. Move the switch back toward the operator to return the module to the anti-stall mode.

The anti-stall module contains solid state electronics, therefore, servicing is limited to voltage checks at key pins on the electrical connectors. The module is non-repairable and should be replaced if it malfunctions. To test the electrical power to the anti-stall module, proceed as follows:

1. Disconnect the electrical cables from the pump controllers.

2. Disconnect the cables to the propel control station.

3. Connect and verify battery power (24 to 28 volts) to the anti-stall module junction J2, pins A (+), B (GND).

4. Using a voltmeter, measure the voltage across the specified electrical connector pins of the anti-stall module. The voltage must be within the specification tolerances given in Table 1OC-2 with the engine running at approximately full throttle and no load attached

Table 10C-2. Anti-Stall Module Voltages

Connector On Anti-Stall Module	Voltmeter Across Pins	Voltage Specification	Switch Mode
J3	D(+) C(-)	+24 to 28 VDC	Anti-Stall
J3	D(+) C(-)	+24 to 28 VDC	Manual
J4	D(+) Ct-)	+24 to 28 VDC	Manual
J4	D(+) C(-1	+24 to 28 VDC	Anti-Stall

5. If in the manual mode the voltage is not within the specified tolerance, the anti-stall module must be replaced.

6. If in the anti-stall mode the voltage is not withm the specified tolerance, the magnetic pulse pickup must be checked.

7. If all voltages check within specifications, proceed to the Propel Controller Test.

MAGNETIC PULSE PICK-UP TEST. To test the magnetic pulse pick-up, proceed as follows.

1. Disconnect the cable which connects the magnetic pulse pickup to the anti-stall module at junchon J1.

2. Using an ac voltmeter, measure the ac voltage across pins A and B of the cable connected to the magnetic pulse pickup.

3. With the engine running at full speed, the voltage reading must be 15 volts minimum or proceed as follows:

A. Check the continuity of the cable, inspect and repair any damaged cable or solder the joints.

B. If a low voltage is present, turn off the engine and inspect to be sure that the spacing between the magnetic pulse pickup and the gear teeth is 0.010 ± 0.005 inches.

C. If the low voltage condition continues, replace the magnetic pulse pickup.

PROPEL CONTROL STATION TEST. The servicing of the propel control station is limited to a resistance check of the electrical connector assembly. To test the propel control station, proceed as follows:

NOTE

Do not attempt to remove the cover or reposition the control lever

1. Turn off or otherwise remove the power to the propel control station.

2. Disconnect the electrical cables from the propel control station

3. Establish the test setup shown in Figure 10C-2.

4. Set the meter to the R x 1 scale, short the meter leads together and adjust the meter to zero ohms to insure that the meter IS reading the correct resistance

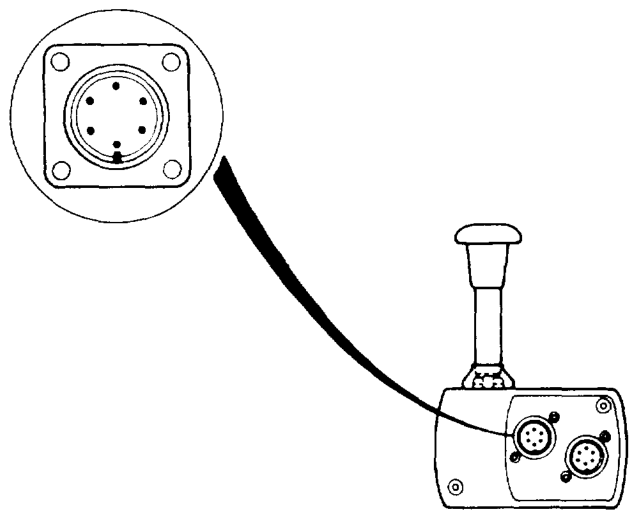


Figure 10C-2 Propel Control Station

Perform the resistance checks per Table 10C-2

NOTE

When connecting the test leads to the electrical connector pins, care should be taken not to deflect or deform the electrical connector pins.

Table 10C-3. Propel Control Station Tests

Check	Condition	Approximate Resistance (Ohms)
Pin C to D	Lever at center positron Lever approximately 2° forward Lever approximately 2° reverse	 120 120
Pin C to B	*Lever at center position *Lever full forward *Lever full reverse	80 0 120
Pin C to E	Lever at center position	120
Pin F to B	Lever at center position	13

"Meter indication should denote smooth action when traveling between control lever Iimits.

6. The propel control station is non-repairable, if the resistance check is not satisfied in every respect, the unit should be replaced.

ELECTRICAL POWER TO PUMP CONTROLLER TEST. To check the electrical power to the pump actuators, proceed as follows.

1. Disconnect the cables connecting the pump controllers, junctrons J6 and J7 at the anti-stall module.

2. With electrical power on and the anti-stall module switch in the manual mode, run voltage checks at junctions J6 and J7 of the anti-stall module per Table 10C-4. Make the check with the engine at idle and again at full speed A dc voltmeter should be used for voltage sensing.

Table 10C-4. Electric Power to Pump Controller Test

Check	Condition	Approximate Voltage (VDC)
Pin J6-A to J7-A	Lever at center position Lever approximately 2° forward Lever approximately 2° reverse Lever full forward Lever full reverse	0 + .4 - .4 +5.4 -5.4
Pin J6-C to J7-D	Lever at center position Lever approximately 2° left Lever approximately 2° right Lever full left Lever full right	0 + .4 - .4 +5.4 -5.4

3. If the voltage checks are not satisfied, check the cables between the anti-stall module and the pump controllers. If the problem still exists, test the throttle setting potentiometer. If the potentiometer tests satisfactory, replace the anti-stall module.

ENGINE SPEED POTENTIOMETER TEST. To test the engine speed potentiometer, proceed as follows:

1. Turn the engine off and disconnect the electrical power at junction J1 of the anti-stall module.

2. Disconnect the cable running to the engine speed potentiometer at junction J8 of the anti-stall module.

3. Using an ohmmeter, measure the resistance across pins B and D of the cable running to the throttle setting potentiometer.

4. With the throttle set at idle, resistance should measure approximately 10,000 ohms.

5. With the throttle set at full speed, resistance should measure approximately 0 ohms.

6. If the resistance tests are not satisfied, after the cable running to the engine speed potentiometer has been checked, replace the engine speed potentiometer.

PUMP CONTROLLER MANUAL INPUT TEST. To manually test the pump controller, proceed as follows (see Figure 10C-3):

NOTE

> The manual input lever can be used for emergency operation of the machine in case of loss of electrical power. Rotation of the manual input lever causes displacement of the swashplate, the same as an electrical input.

1. With the engine running at approximately 1/2 throttle, slowly rotate the manual input lever until motion of the machine is sensed.

2. In the case of no motion with manual input lever rotation, a problem exists in the pump controller, hydrostatic transmission, or the drive mechanism (see Subsection 9A).

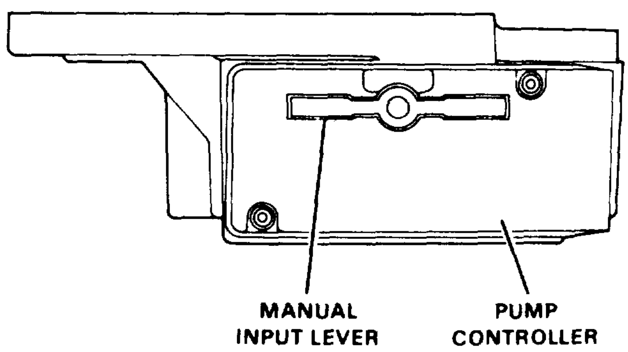


Figure 10C-3. Pump Controller

TABLE OF CONTENTS

SUBSECTION 10D

ELECTRICAL COMPONENTS

GENERAL

This subsection contains information on testing, maintenance and repair of electrical components such as the starting motor, alternator, regulator/rectifier and solenoid.

STARTING MOTOR

Operation

When the start switch is closed, battery current flows through the solenoid winding and the built-in thermostat to ground (see Figure 10D-1).

NOTE

The motor has a built-in thermostat to protect against damage due to overcranking for excessively long periods of time.

The magnetic switch closes, connecting the motor solenoid "S" terminal to the battery. The solenoid windings are energized and the plunger and shift lever movement causes the pinion to engage the engine flywheel ring gear and the solenoid main contacts close, and cranking takes place.

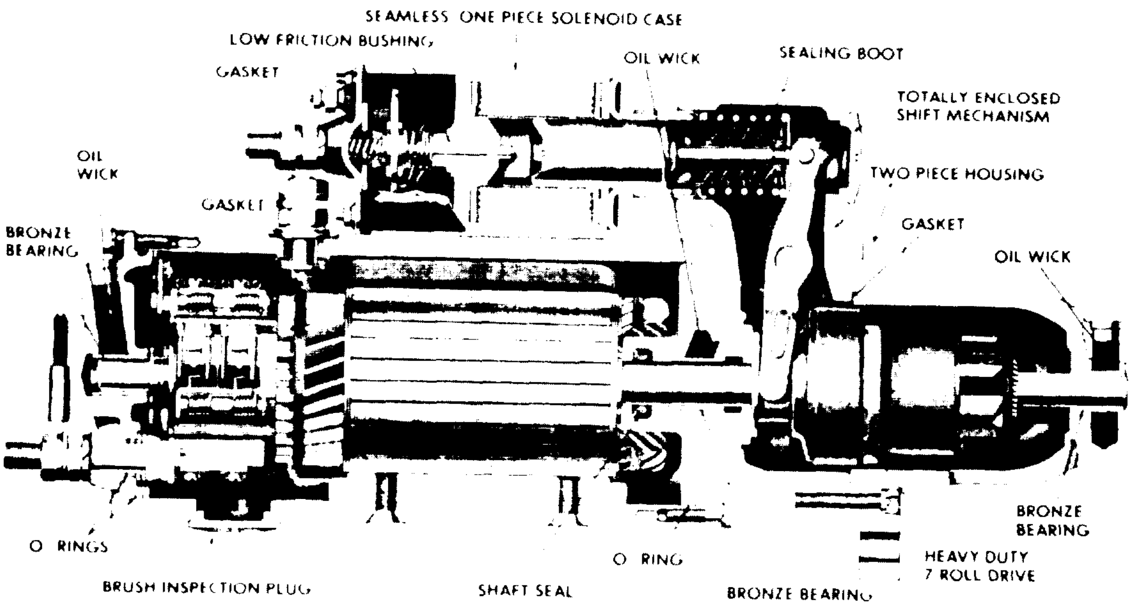


Figure 10D-1. Starting Motor Cross-sectional View

When the engine starts, pinion overrun protects the armature from excessive speed until the switch is opened, at which time the return spring causes the pinion to disengage.

A cranking period for all types of starting motors should never exceed 30 seconds without stopping to allow the motor to cool. If over-cranking should occur, the thermostat will open and the cranking cycle will stop to protect the motor. After the cranking motor cools (usually 1 to 6 minutes) the thermostat will close and then a new starting attempt can be made.

Troubleshooting

If the cranking system is not performing properly, make the following checks to determine which part of the circuit is at fault.

1. BATTERY: Using a voltmeter and hydrometer check the condition of the battery. Make sure the battery is fully charged. The wiring, switches, and cranking motor cannot be checked if the battery is defective or discharged.

2. WIRING: Inspect the wiring for damage. Inspect all connections to the cranking motor, solenoid, magnetic switch, starter switch and battery, including all ground connections. Clean and tighten all connections as required. The cranking system cannot operate properly with excessive resistance in the circuit.

3. MAGNETIC SWITCH, SOLENOID AND CONTROL SWITCHES: Inspect all switches to determine their condition. From the machine wiring diagram (Figure 10A-1 and 10A-2), determine which circuits should be energized with the starting switch closed. Use a voltmeter to detect any open circuits.

4. THERMOSTAT, OR OVERCRANK PROTECTION: To check the thermostat for continuity, detach wiring harness connector and connect an ohmmeter to the two thermostat terminals on the motor (see Figure 10D-2 on page 10D-3). The ohmmeter should read zero. If not, thermostat is open circuit. DO NOT check thermostat hot, since it is supposed to be open-circuit above certain temperatures.

5. MOTOR: If the battery, wiring and switches are in satisfactory condition, and the engine is known to be functioning properly, remove the motor and follow the test procedures outlined below.

A cranking motor is designed for intermittent duty only, and should never be operated for more than 30 seconds at a time. After 30 seconds, the cranking must be stopped for at least two minutes to allow the motor to cool. The same rule applies to a motor with a thermostat. The thermostat is an added protection against damage from overcranking.

With the cranking motor removed from the engine, the armature should be checked for freedom of rotation by prying the pinion with a screwdriver. Tight bearings, a bent armature shaft, or a loose pole shoe screw will cause the armature to not turn freely. If the armature does not turn freely, the motor should be disassembled immediately. However, if the armature does rotate freely, the motor should be given a no load test before disassembly.

No Load Test

Connect a voltmeter from the motor terminal to the motor frame, and use a RPM indicator to measure armature speed (see Figure 10D-3 on page 10D-4). Connect the motor and an ammeter in series with a fully charged battery of the specified voltage, and a switch in the open position from the solenoid battery terminal to the solenoid switch terminal. Close the switch and compare the RPM, current and voltage reading with the specifications shown in Table 10D-1 on page 10D-3. It is not necessary to obtain the exact voltage specified as an accurate interpretation can be made by recognizing that if the voltage is slightly higher the RPM wilt be proportionately higher, with current remaining essentially unchanged. However, if the exact voltage is desired, a carbon pile connected across the battery can be used to reduce the voltage to the specified value. Connect the carbon pile to only one of the 12 volt batteries. If the specified current draw does not include the solenoid, deduct from the ammeter reading the specified current draw of the solenoid hold-in winding. Make disconnection only with the switch open. Interpret the test results as follows :

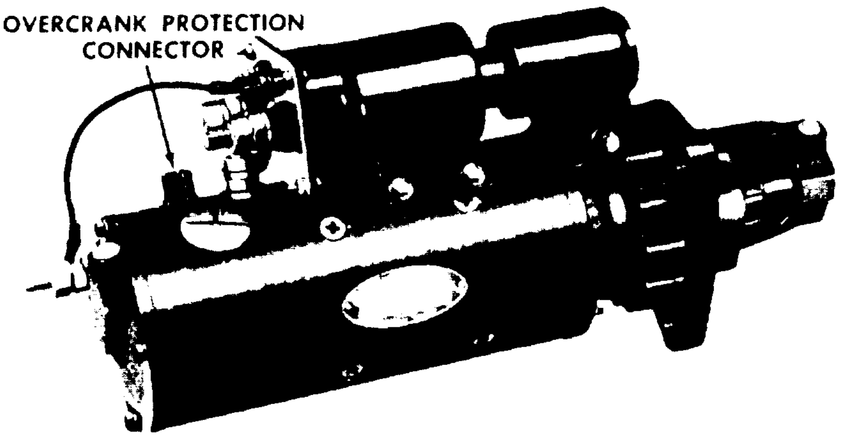


Figure 10D-2. Starting Motor Overcrank Protection

VOLTS	MIN. AMPS	MAX. AMPS	MIN RPM	MAX RPM
20	70	110	5500	9000

Table 10D-1. Starter Motor No Load Specifications

Interpreting Results of Tests

1. Rated current draw and no load speed indicates normal condition of the crank motor.

2. Low free speed and high current draw indicates:

A. Too much friction-tight, dirty, or worn bearings, bent armature shaft or loose pole shoes allowing the armature to drag.

B. Shorted armature. This can be further checked on a growler after disassembly.

C. Grounded armature or fields. Check further after disassembly.

3. Failure to operate with high current draw indicates:

A. A direct ground in the terminal or fields .

B. "Frozen bearings (this should have been determined by turning the armature by hand).

4. Failure to operate with no current draw indicates:

A. Open field circuit. This can be checked after disassembly by inspecting internal connections and tracing circuit with a test lamp.

B. Open armature coils. Inspect the commutator for badly burned bars after disassembly.

C. Broken brush springs, worn brushes, high insulation between the commutator bars or other causes which would prevent good contact between the brushes and commutator.

5. Low no load speed and low current draw indicates-High internal resistance due to poor connections, defective leads, dirty commutator and causes listed above.

6. High free speed and high current draw indicates shorted fields. If shorted fields are suspected, replace the field coil assembly and check for improved performance.

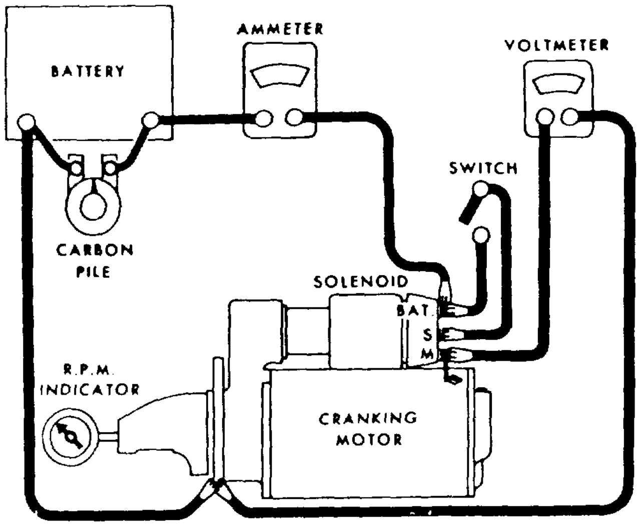


Figure 10D-3. No Load Test Circuit

Removal

To remove the starter motor, proceed as follows:

1. Disconnect the battery ground cable.

2. Disconnect the cable at the starter motor.

3. Support the motor and remove the bolts and lockwashers which secure the starter motor to the flywheel housing.

4. Pull the motor forward to remove it from the flywheel assembly.

Disassembly

Normally the cranking motor should be disassembled only so far as is necessary to make repair or replacement of the defective parts. As precaution, it is suggested that safety glasses be worn when disassembling or assembling the cranking motor.

1. Note the relative position of the solenoid, lever housing, and nose housing so the motor can be reassembled in the same manner.

2. Disconnect field coil connector from solenoid motor terminal, and lead from the solenoid ground terminal.

3. Remove the brush inspection plate and remove the brush lead screw. This will disconnect the field leads from the brush holders.

4. Remove the attaching bolts and separate the commutator end frame from the field frame.

5. Separate the nose housing and field frame from lever housing by removing attaching bolts.

6. Remove armature and clutch assembly from lever housing.

7. Separate solenoid from lever housing by pulling apart.

Cleaning

The drive, armature and field should not be cleaned in any degreasing tank, or with grease dissolving solvents, since these would dissolve the lubricant in the drive and damage the insulation in the armature and field coils. All parts except the drive should be cleaned with mineral spirits and a brush. The drive can be wiped with a clean cloth.

If the commutator is dirty it may be cleaned with No. 00 sandpaper. NEVER USE EMERY CLOTH TO CLEAN A COMMUTATOR.

BRUSHES AND HOLDERS. Inspect the brushes for wear. If they are worn excessively when compared to a new brush, they should be replaced. Make sure the brush holders are clean and the brushes are not binding in the holders. The full brush surface should ride on the commutator to give proper performance. Check by hand to insure that the brush springs are giving firm contact between the brushes and commutator. If the springs are distorted or discolored they should be replaced.

Armature Servicing

If the armature commutator is worn, dirty, out of round, or has high insulation, the armature should be put in a lathe so the commutator can be turned down. The insulation should then be undercut 1/32 of an inch wide and 1/32 of an inch deep, and the slots cleaned out to remove any -trace of dirt or copper dust. As a final step in this procedure, the commutator should be sanded lightly with No. 00 sandpaper to remove any burrs left as a result of the undercutting procedure.

The armature should be checked for opens, short circuits and grounds as follows:

1. OPENS-Opens are usually caused by excessively long cranking periods, The most likely place for an open to occur is at the commutator riser bars. Inspect the points where the conductors are joined to the commutator bars for loose connections. Poor connections cause arcing and burning of the commutator bars as the cranking motor is used. If the bars are not too badly burned, repair can be effected by resoldering or welding the leads in the riser bars (using rosin flux), and turning down the commutator in a lathe to remove the burned material. The insulation should then be undercut except as noted above.

2. SHORT CIRCUITS-Short circuits in the armature are located by use of a growler. When the armature is revolved in a growler with a steel strip such as a hacksaw blade held above it, the blade will vibrate above the area of the armature core in which the short circuit is located. Shorts between bars are sometimes produced by brush dust or copper between the bars. These shorts can be eliminated by cleaning out the slots.

3. GROUNDS-Grounds in the armature can be detected by the use of a 110 volt test lamp and test points. If the lamp lights when one test point is placed on the commutator with the other point on the core or shaft, the armature is grounded. Grounds occur as a result of insulation failure which is often brought about by overheating of the cranking motor produced by excessively long cranking periods or by accumulation of brush dust between the commutator bars and the steel commutator ring.

Field Coil Checks

The internal circuit of the field coil is shown in Figure 10D-4. The field coils can be checked for grounds and opens by using a test lamp.

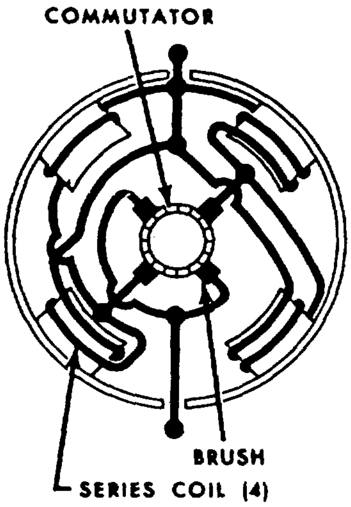


Figure 10D-4. Internal Motor Circuit

GROUNDS-If the motor has one or more coils normally connected to ground, the ground connections must be disconnected during this check. Connect one lead of the, 110 volt test lamp to the field frame and the other lead to the field connector. If the lamp lights, at least one field coil is grounded, which must be repaired or replaced. This check cannot be made if the ground connection cannot be disconnected.

OPENS-Connect test lamp leads to ends of field coils. If lamp does not light, the field coils are open.

Field Coil Removal

Field coils can be removed from the field frame assembly by using a pole shoe screwdriver. A pole shoe spreader, should also be used to prevent distortion of the field frame. Careful installation of the field coils is necessary to prevent shorting or grounding of the field coils as the pole shoes are tightened into place. Where the pole has a long lip on one side and a short lip on the other, the long lip should be assembled in the direction of armature rotation so it becomes the trailing edge of the pole shoe.

Solenoid Checks

A basic solenoid circuit is shown in Figure 10D-5. Solenoids may differ in appearance but can be checked electrically by connecting a battery of the specified voltage, a switch and an ammeter to the two solenoid windings.

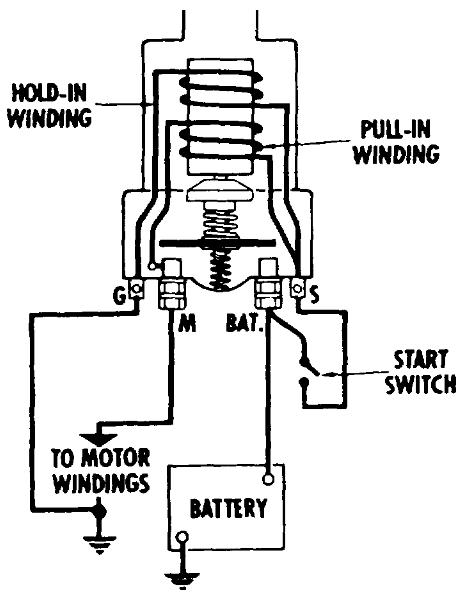


Figure 10D-5. Internal Solenoid Circuit

With all leads disconnected from the solenoid, make test connections as shown to the solenoid switch terminal and to the second switch terminal (G), to check the hold-in winding (see Figure 10D-6).

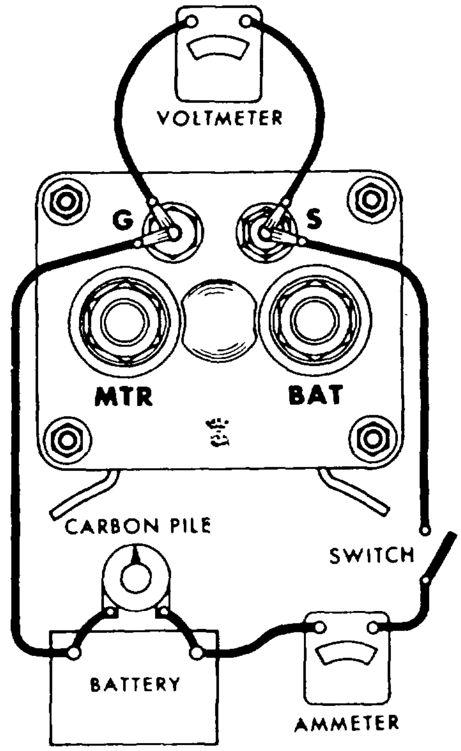


Figure 10D-6. Checking Solenoid Hold-in Winding

Use a carbon pile to decrease the battery voltage to the value specified in Table 10D-2 and compare the ammeter reading with specifications. A high reading indicates a shorted hold-in winding, and a low reading excessive resistance. To check the pull-in winding connect from the solenoid switch terminal (S) to the solenoid motor (M or MTR) terminal (see Figure 10D-7 on page 10D-7).

To check for grounds, move batter lead from (G, Fi gure 10D-6) and from (MTR, Figure 10D-7 on page 10D-7) to solenoid case. Ammeter should read zero. If not winding is grounded.

RATED VOLTAGE	PULL-IN WINDING CURRENT	HOLD-IN WINDING CURRENT
24	9 to 11.5 Amps 5 Volts	6.8 Amps Max. 20 Volts

Table 10D-2. Solenoid Specifications

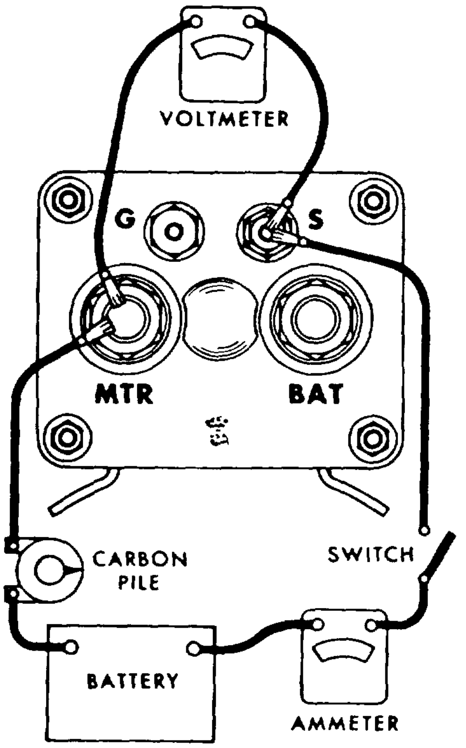


Figure 10D-7. Checking Solenoid Pull-in Winding

NOTE

If needed to reduce the voltage to the specified value, connect the carbon pile between the battery and the (MTR) terminal as shown. If the carbon pile is not needed, connect a jumper directly from the battery to the (MTR) terminal.

CAUTION

To prevent overheating do not leave the pull-in winding energized more than 15 seconds. The current draw will decrease as the winding temperature increases.

A magnetic switch can be checked in the same manner by connecting across its winding.

Reassembly

To reassemble the end frame with brushes onto the field frame, pull the armature out of the field frame just far enough to permit the brushes to be placed over the commutator. Then push the commutator end frame and the armature back against the field frame.

Lubrication

All bearings, wicks and oil reservoirs should be saturated with SAE No. 20 oil. Place a light coat of lubricant, Delco Remy No. 1960954, on the washer located on the shaft between the armature and shift lever housing.

Sintered bronze bearings used in these motors have a dull finish, as compared to the early type machined, cast bronze bearings which had a shiny finish.

Before pressing the bearing into place, dip it in SAE No. 20 oil. Also, tangent wicks, if present, should be soaked with SAE No. 20 oil. Insert the wick into place first, and press in the bearing.

DO NOT DRILL, REAM OR MACHINE sintered bearing in any way. These bearing are supplied to size. If drilled or reamed, the I.D. will be too large, also the bearing pores will be sealed over.

It is not necessary to cross-drill a sintered bearing when used with a tangent wick. Because the bearing is so highly porous, oil from the wick touching the outside bearing surface will bleed through and lubricate the shaft.

Middle bearings are support bearings and prevent armature deflection during cranking. As compared to end frame bearings, the clearance between middle bearing and shaft is large and the clearance provides a loose fit when assembled.

Pinion Clearance

To check pinion or drive clearance, proceed as follows:

1. Make connections as shown in Figure 10D-8 on page 10D-8.

2. Momentarily flash a jumper lead from terminal (G) to terminal (MTR). The drive will now shift into cranking position and remain so until the battery is disconnected.

3. Measure the distance between drive and housing (see Figure 10D-9 on page 10D-8).

4. Adjust clearance by removing plug and turning shaft nut.

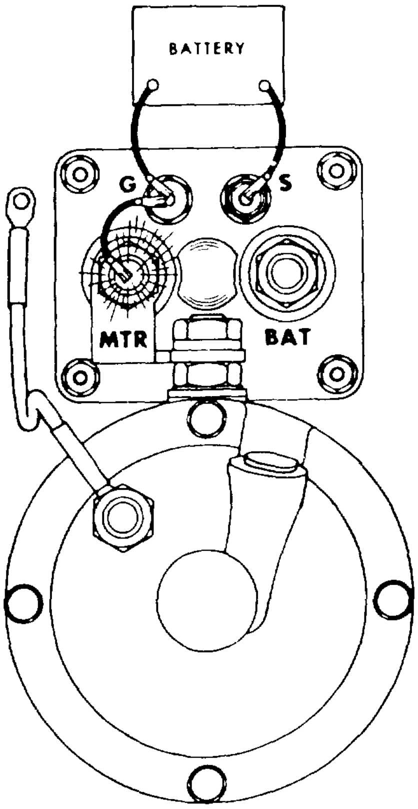


Figure 10D-8. Checking Pinion Clearance Circuit

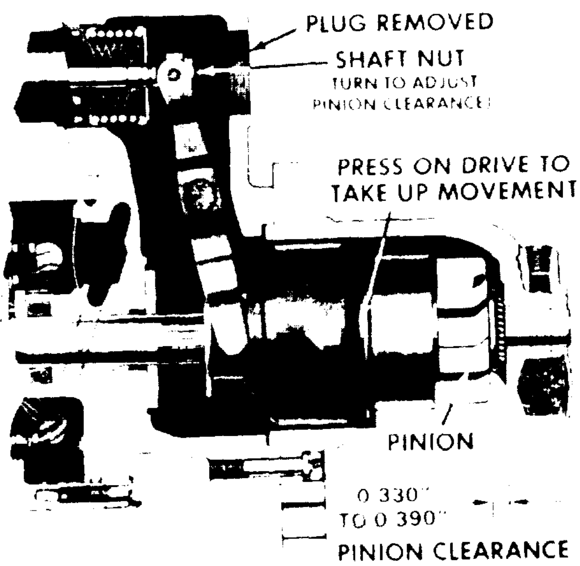


Figure 10D-9. Measuring Pinion Clearance

Installation

To install the starter, proceed as follows:

1. Set the motor into the flywheel housing.

2. Support the motor and install the bolts and lockwashers used to secure the motor to the flywheel housing. Tighten the attaching bolts to 137-147 ft-lbs torque.

3. Make sure electrical connections are clean. Install wires as marked earlier and tighten hardware.

ALTERNATOR

Description

The integral charging system is a self-rectifying, brushless unit wit a built in regulator. The only moveable part is the rotor which is mounted on a ball bearing on the drive end, and a roller bearing at the rectifier end. All current carrying conductors are stationary. These conductors are the field winding, the stator windings, the six rectifying diodes, and the regulator circuit components. The regulator and diodes are enclosed in a sealed compartment.

A fan located on the drive end provides airflow for cooling. Extra large grease reservoirs contain an adequate supply of lubricant so that no periodic maintenance is required. Only one wire is needed to connect the charging system (alternator) to the battery, along with an adequate ground return. The output terminal is connected directly to the battery positive terminal.

The hex head bolt on the output terminal is electrically insulated; no voltage reading can be obtained by connecting to the hex head bolt.

Operation

The basic operating principles are explained below and shown in Figure 10D-10 on page 10D-9.

As the rotor begins to turn, the permanent magnetism therein induces voltages

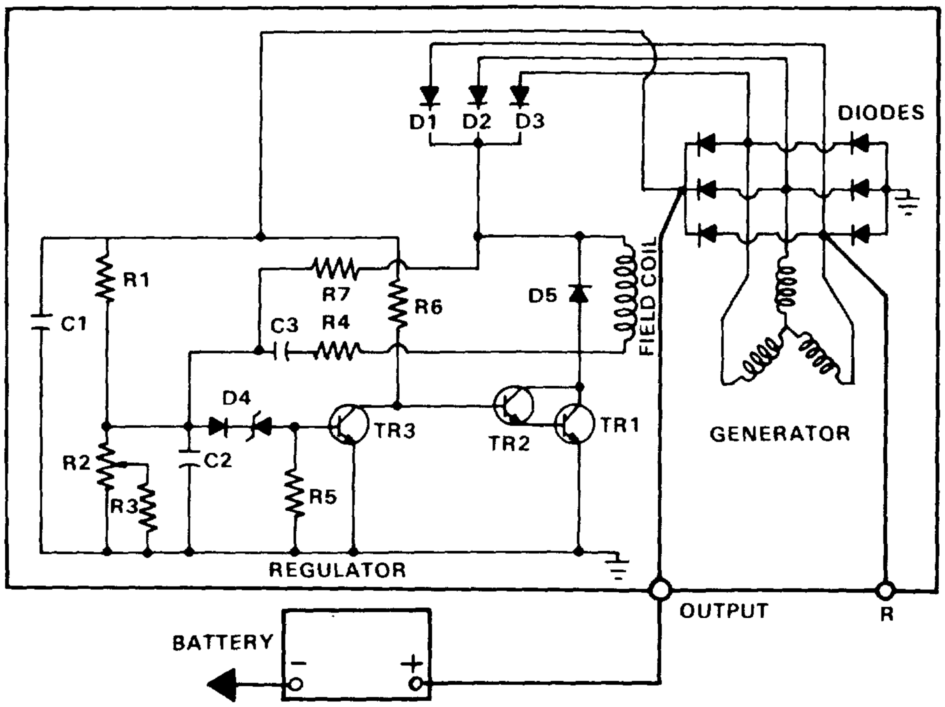


Figure 10D-10. Alternator Wiring

in the stator windings. The voltages across the six diodes cause current to flow to charge the battery.

Current from the stator flows through the three diodes to resistor R6 and the base-emitter of TR2 and TR1 to turn these transistors on. Current also flows from the stator through the diode trio 01, 02, and 03, the field coil and transistor TR1, returning to the stator through the other three diodes. All stator current, except through the diode trio D1, D2, and D3, flows through the six diodes connected to the stator.

Current flow through R1, R2, and R3 causes a voltage to appear at zener diode D4. When the voltage becomes high enough due to increasing alternator speed, D4 and the base-emitter or TR3 conduct current and TR3 turns on. TR2 and TR1 then turn off, decreasing the field current and the system voltage decrease. The voltage at D4 decreases, D4 and TR3 turn off, TR2 and TR1 turn back on and the system voltage increases. This cycle then repeats many time per second to limit the system voltage as determined by the setting of the potentiometer R2, R3.

Capacitor C1 protects the alternator diodes from high transient voltages and suppresses radio interference.

Resistor R5 prevents current leakage through TR3 at high temperatures.

Diode D5 prevents high transient voltages in the field coil when the field current is decreasing.

Resistor R7, capacitor C3 and resistor R4 all act to cause transistor TR2 and TR1 to turn on and off more quickly.

Troubleshooting

DEFINITIONS. The following points should be kept in mind while troubleshooting the alternator.

The energizing speed is the RPM at which the regulator turns on to energize the field coil. This speed is higher than some speeds at which output can be obtained. Therefore, when checking output at low speeds, increase the speed until the regulator turns on, then reduce the speed to check the output. No output can be obtained until the regulator turns on. Once the regulator turns on, it will remain turned on until the engine is stopped.

The integral charging system output preferably should be checked at the “Rated Voltage” given.

However, it is permissible to check the output in amperes at any voltage within the “Operating Range” listed, since the current output will be quite close to the value that would be obtained at “Rated Voltage”. The voltage should never be allowed to rise above the "Operating Range" for any length of time.

It should be noted that the voltage may be below the "Operating Range" if the battery is in a low state of charge. However, as the battery receives a charge, the voltage will rise to some value within the "Operating Range".

SYSTEM VOLTAGE	RATED VOLTAGE	OPERATING RANGE
24	28.0	26.0-30.0

The rotor normally retains magnetism to provide voltage build-up when the engine is started. After disassembly or servicing, however, it may be necessary to reestablish the magnetism. To magnetize the rotor connect the integral charging system to the battery in a normal manner, then momentarily connect a jumper lead from the battery positive post to the integral charging system relay terminal, identified in Figure 10D-11. This procedure applies to both negative and positive ground systems, and will restore the normal residual magnetism in the rotor.

PROCEDURES. Trouble in the crane charging will be indicated by one of two conditions:

1. An undercharged battery as evidenced by low specific gravity reading and slow cranking.

2. An overcharged battery as evidenced by excessive battery water usage.

The conditions can be caused by (1) a defective battery, (2) poor circuit connections and (3) defective alternator.

BATTERY. Since the battery may have an internal defect, it must be checked to determine its condition. Use a voltmeter and hydrometer to check the condition of the battery. Make sure the battery is fully charged.

CIRCUIT CONNECTIONS. Poor connections in the alternator can cause an undercharged condition only. Carefully inspect all connections including grounds between the alternator and battery for cleanliness and tighteness. insure that the battery cable clamps are clean and tight, and that the battery is dry and clean.

ALTERNATOR. If the battery and circuit connection checks are satisfactory, the alternator may be checked either on or off the crane by making connections as shown in Figure 10D-12 on page 10D-11. Assemble a closed end terminal clip with 1/2 inch hole to output terminal, then connect ammeter lead clip to this terminal clip.

1. With all accessories and carbon pile turned off, increase engine speed as required to obtain maximum voltage reading.

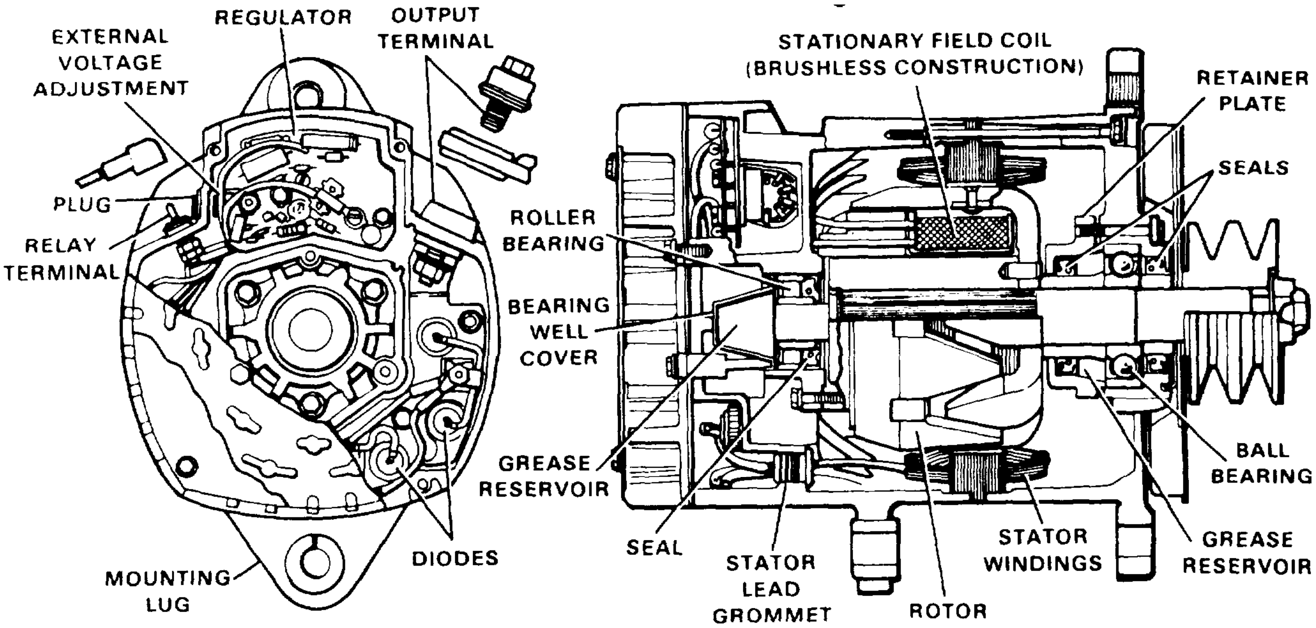


Figure 10D-11. Alternator

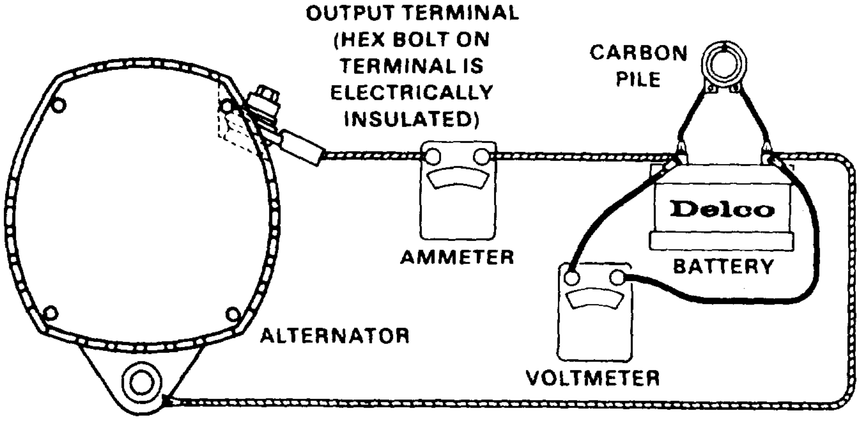


Figure 10D-12. Output Check

2. If voltage exceeds 30 volts, remove the alternator for repair.

3. If voltage does not exceed these values, proceed as follows:

A. Insure that accessories have not been left on for extended periods.

B. Check the drive belt for proper tension.

C. Inspect the wiring for defects Check all connections for tightness and cleanliness, including the cable clamps and battery posts.

Connect a voltmeter from output terminal on the alternator to ground. A zero reading indicates an open between voltmeter connection and battery.

If previous steps check satisfactorily, check the alternator as follows:

1. Disconnect the battery ground cable.

2. Connect an ammeter in the circuit at the output terminal of the alternator.

3. Reconnect the battery ground cable.

4. Turn on accessories. Connect carbon pile across the battery.

5. Operate the engine at moderate speed as required, usually 4000 alternator RPM or more, and adjust the carbon pile as required, to obtain maximum current output.

NOTE

Initial voltage build-up is by residual magnetism in the rotor. Increase the speed as required to obtain maximum current output.

6. If ampere output is not within 10 amperes of rated output as stamped on the alternator frame, remove the alternator for repair. If ampere output is within 10 amperes of rated output as stamped on the alternator frame, the alternator is not defective. In this case, an adjustment of the voltage setting may correct the condition.

7. Adjust the voltage setting as follows:

A. Remove cover to expose potentiometer as shown in Figure 10D-13 on page 10D-12.

B. Turn potentiometer one or two notches clockwise to raise the voltage setting and one or two notches counterclockwise to lower the voltage setting.

C. Install cover.

After adjusting setting, check for an improved battery condition over a service period of reasonable length. If adjusting the setting does not correct the battery condition, remove the alternator for repair.

Remember that if the battery state of charge is low, the regulator may not be limiting the voltage, and turning the ad-

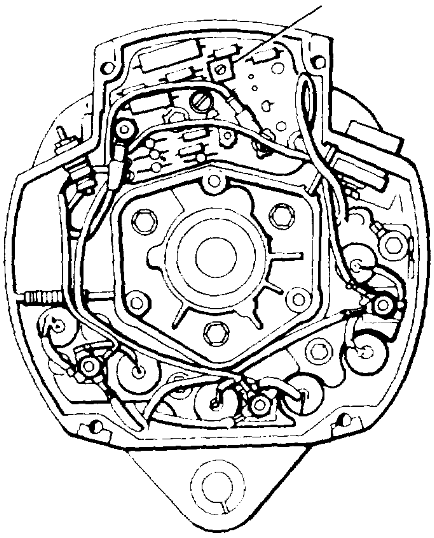


Figure 10D-13. Adjusting Voltage Setting

justing screw will show no change on the voltmeter. However, turning the adjusting screw will change the voltage setting to a new value, which will be indicated by the voltmeter when the battery state of charge increases.

Removal

To remove the alternator, proceed as follows:

1. Disconnect the battery cables. Remove the electrical lead at the alternator.

2. Loosen the mounting bolts and the adjusting strap bolt. Swing the alternator down and remove the drive belts.

3. Support the alternator and remove the adjusting strap bolt and washers. Remove the mounting bolts, washers and nuts. Remove the alternator.

4. Remove the pulley assembly from the alternator.

Repair and Test

DISASSEMBLY. To disassemble the alternator, proceed as follows:

1. Remove the cover plate, cover and gasket . With the cover off components look as shown in Figure 10D-14 on page 10D-13.

2. Note connections as shown. To make stator and diode checks, remove the three nuts, three regulator leads, three stator leads, six diode leads and the (R) terminal lead from the three studs.

3. To make field coil checks, disconnect the two field coil leads from the regulator.

4. See "Bearing Replacement" on page 10D-16 for information on separating the drive end frame assembly from the rectifier and frame assembly.

FIELD COIL CHECKS. To check for grounds, connect a test lamp, or an ohmmeter to one field coil lead and to the end frame as shown in Figure 10D-15 on page 10D-13. If the lamp lights, or if ohmmeter reading is low, the field coil is grounded.

To check for opens. connect a test lamp or an ohmmeter to the two field coil leads as shown. If the lamp fails to light, or if ohmmeter reading is high, the field coil is open.

The winding is checked for short-circuits by connecting a battery and ammeter in series with the field coil. Note the ammeter reading and the specifications stamped on the alternator frame. An ammeter reading above the specified value indicates shorted windings. An alternate method is to check the resistance of the field by connecting an ohmmeter to the field coil. If the resistance reading is below the specified value, the winding is shorted. The specified resistance value can be determined by dividing the voltage by the current.

To replace the field coil, separate drive end frame, remove field coil attaching screws and pull leads and grommet through end frame hole. Place grease on grommet and pull grommet into hole during assembly.

DIODE CHECKS. Check each of the six diodes by removing each diode lead from the stud and connecting an ohmmeter using the lowest range scale to the diode lead and case. Then reverse the ohmmeter lead connection to the diode lead and case. If both reading are the same, replace the diode. A good diode will give one high and one low reading.

WARNING

Do not use high voltage such as 110 volt test lamps, to check diodes.

Before replacing a diode in the rectifier end frame, the end frame must be separated from the drive end frame as described under the topic "Bearing Replacement" on page 10D-16. Also, before replacing a diode in the heat sink or end frame, it is necessary to remove the heat sink from the end frame by detaching from the heat sink the regulator lead, the heat sink mounting screws, and the alternator output terminal. Note the round insulators under the heat sink mounting screws, and the flat insulator located behind the heat sink. The silicone grease on both sides of the flat insulator provides the necessary heat transfer between heat sink and end frame. Reapply silicone grease during assembly, tighten the heat sink mounting screws loosely, securely tighten the output terminal, then securely tighten the heat sink screws.

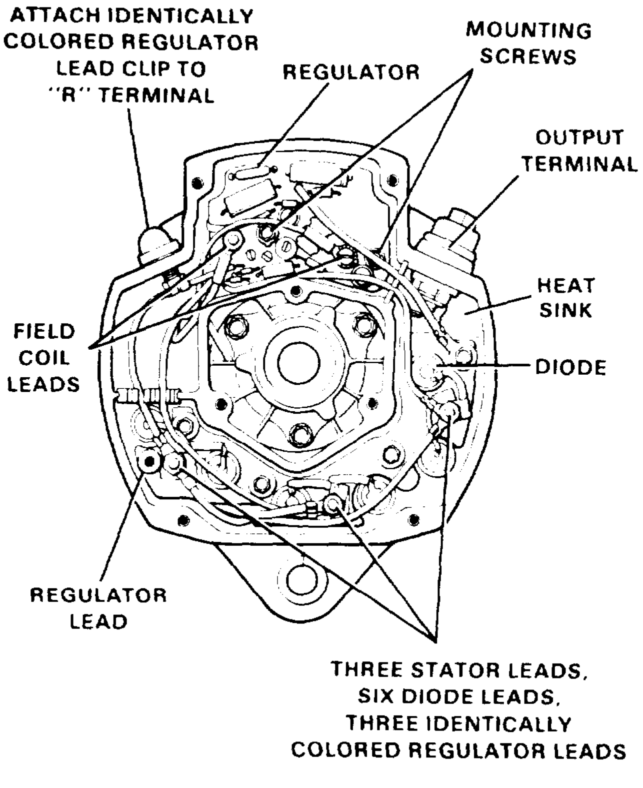


Figure 10D-14. End View, Cover Removed

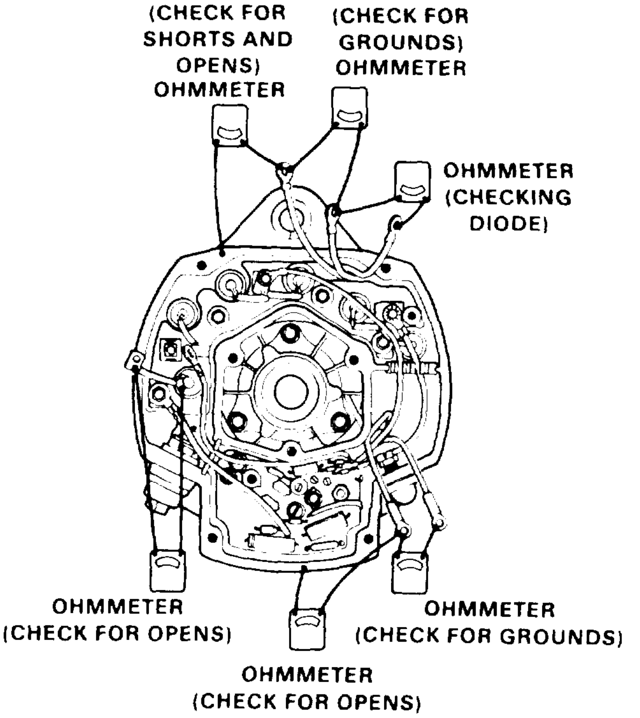


Figure 10D-15. Electrical Checks

To replace a diode in the heat sink, support the heat sink, and use an arbor press or vise to push the diode out. Use a suitable tool to pull the diode out of the end frame. Also use a suitable tool which fits over the outer diode edge to push the diode in, and support the heat sink or end frame with a suitable tool.

NOTE

Diode replacement tools are available from various manufacturers normally supplying tools and test equipment to the automotive industry.

CAUTION

Do not strike the diode, as the shock may damage it and the other diodes. Use only those diodes listed in the parts list for this unit. Never use substitutes.

STATOR CHECKS. The stator windings may be checked with a 110 volt test lamp or an ohmmeter. If the lamp lights, or if the meter reading is low when connected from any stator lead to the frame, the windings are grounded.

If the lamp fails to light, or if the meter reading is high when successively connected between each pair of stator leads, the windings are open.

A short circuit in the stator windings is difficult to locate without laboratory test equipment due to the low resistance of the windings. However, if all other electrical checks are normal, and the alternator fails to supply rated output, shorted stator windings are indicated.

To replace the stator drive end frame from rectifier end frame, refer to "Bearing Replacement" on page 10D-16, and pull leads and grommet through hole. Place grease. on grommet and pull into hole during assembly.

REGULATOR REPLACEMENT. After disconnecting the three identically colored regulator leads, the regulator may be replaced by removing the attaching screws and disconnecting the regulator lead from the heat sink.

If previous checks indicate the regulator should be repaired, proceed as follows:

1. The panel board is shown without the sealing compound so the seven (7) serviceable parts can be easily identified (see Figure 10D-16 on page 10D-15).

2. Remove screw, transistor TR1 and pry apart heat sink and panel board with screwdriver.

3. Carefully inspect printed circuit for poor solder joints.

4. Carefully inspect for broken parts.

5. Check components as follows (see Figure 10D-17 on page 10D-15): Use 1-1/2 volt ohmmeter on low scale. SCRATCH HARD WITH SHARP INSTRUMENT TO BREAK THROUGH TRANSPARENT COATING OVER SOLDER TO MAKE OHMMETER CONTACT. Use 50 watt soldering gun.

CAUTION

The ohmmeter polarity must be determined by connecting its leads to voltmeter leads. The voltmeter will read up scale when the negative leads are connected together and the positive leads are connected together. The polarity of the voltmeter leads can be determined by connecting the leads to the identified terminals of a battery .

6. Transistor TR2

A. Should read about 5-50 ohms, If zero or well above 50, replace transistor.

B. Should read very high, If not, replace transistor.

C. Repeat Step A.

7. Transistor TR3

A. Should read very high. If not, replace transistor.

B. Should read about 5-50 ohms. If zero or well above 50, replace transistor.

C. Repeat Step A.

8. Diode D5 should read 5-50 ohms. If zero or well above 50, replace transistor.

9. Diode trio D1, D2, and D3-Each diode should read 5-50 ohms. If zero or well above 50 ohms, replace diode being tested.

10. Capacitor C2 should read high. If zero, replace capacitor.

CAUTION

Change ohmmeter to X10 or middle scale.

11 . Potentiometer R2-With ohmmeter connected, turn potentiometer slotted screw (see Figure 10D-16 on page 10D-15). Ohmmeter needle should deflect slightly. If no deflection at all, replace R2.

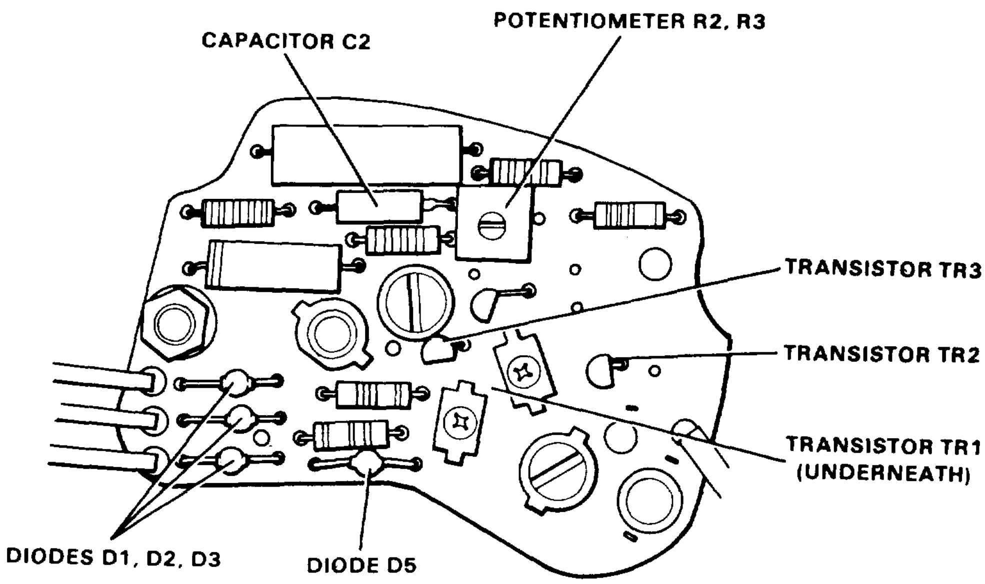


Figure 10D-16. Panel Board Assembly

CAUTION

Turn ohmmeter back to low or X1 scale.

12. Transistor TR1-Connect ohmmeter both ways in each step (see Figure 10D-18 on page 10D-16).

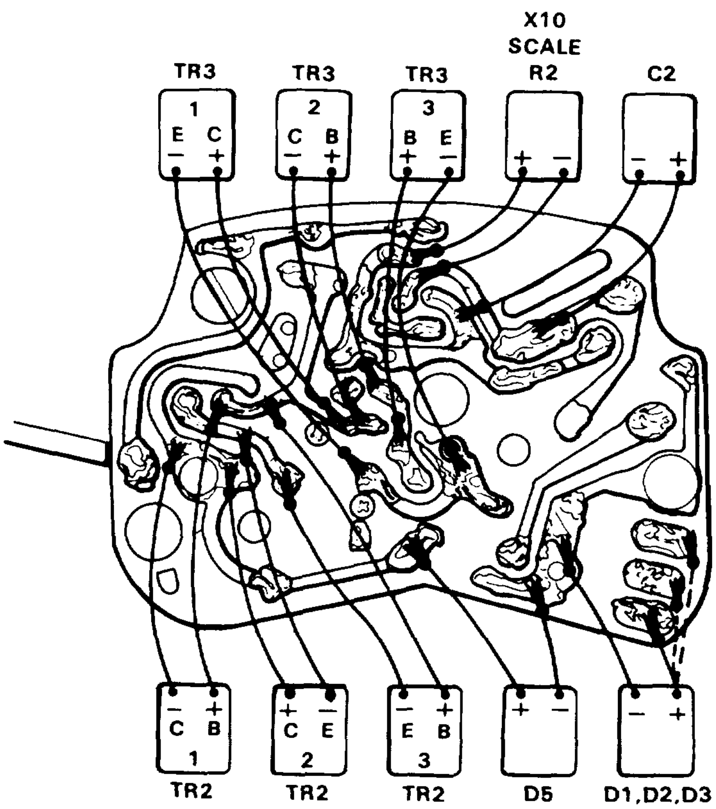


Figure 10D-17. Checking Regulator Components

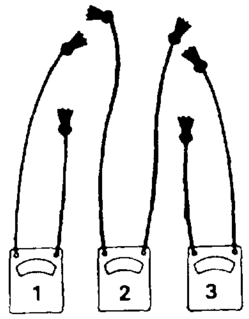


Figure 10D-18. Checking Transistor TR1

A. Both readings should be very high. If not, replace transistor.

B. Should read very high and low. If not, replace transistor.

C. Repeat Step B.

13. If no defects have been found, replace complete regulator assembly.

14. If regulator was repaired, reassemble, using silicone grease on both sides of mica under transistor TR1.

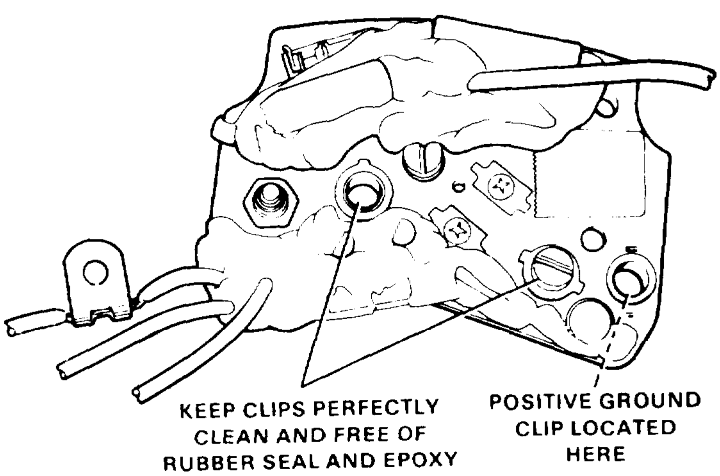


Figure 10D-19. Rubber Seal Applied to Regulator

15. Apply sealing compound as shown in Figure 10D-19 around components using Dow Chemical RTV Silastic 732 silicone rubber seal or equivalent, available at hardware stores. Keep metal clips perfectly clean and free of rubber seal.

16. Test regulator to see if it works. If okay, return to service. If defective, replace complete regulator assembly.

REASSEMBLY. To reassemble the alternator, proceed as follows:

1. Place over each stud IN THIS ORDER (see Figure 10D-14 on page 10D-13); the two diode leads, the stator lead, the (R) terminal lead on one stud only, the regulator lead and the nut.

2. Install the gasket, cover and cover plate.

Bearing Replacement

DRIVE END BEARING. To replace a drive end bearing, proceed as follows:

1. Remove shaft nut, washer, pulley, fan, slinger and the four retainer plate bolts, then remove the rotor and bearing assembly from the end frame.

2. Pull the bearing from the rotor shaft, separate retainer plate and collar from shaft, and discard seals in retainer plate and end frame.

3. Add Delco-Remy lubricant No. 1948791 so each reservoir between the bearing and seal after assembly will be only three quarters full. Arrange the lubricant so at least a portion will contact the bearing after reassembly. Otherwise the oil in the lubricant will not bleed to the bearing. Also add lubricant to each seal lip and fill the cavity with lubricant between the rubber lip and steel case of each seal. The seals must be assembled so the seal lip is toward or next to the bearing.

4. Lubricate collar, then install collar and retainer plate, then press against the inner race only to install the new bearing onto the shaft against the collar.

5. The remaining assembly procedure is the reverse of disassembly.

RECTIFIER END FRAME BEARING. To replace a rectifier end frame bearing, proceed as follows (see Figure 10D-20 on page 10D-17):

1. Pull inner race from shaft and bearing from end frame.

2. Assemble new inner race and bearing as shown. Assemble bearing toward drive end. Press against seal end of bearing to assemble into housing.

3. Use Delco-Remy lubricant No. 1948791 and fill reservoir half full. Arrange lubricant so a portion will touch bearing when assembled.

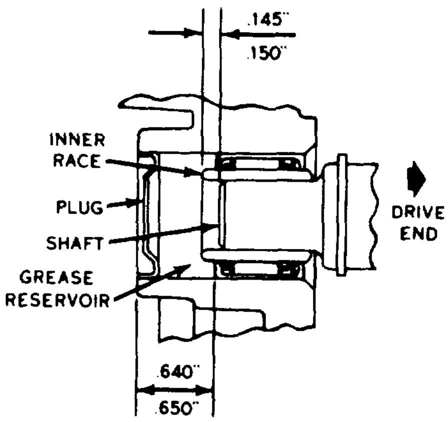


Figure 10D-20. Bearing Assembled Between Shaft and Housing

4. Reassemble the alternator in the reverse of disassembly. Torque the shaft nut to 70-80 ft-lbs. Torque the output terminal bolt to 100-110 inch lbs.

5. Magnetize the rotor as described in “Definitions” on page 10D-9.

Installation

To install the alternator, proceed as follows:

1. Install the drive pulley, if removed. Tighten pulley retaining nut to 50-60 ft-lbs torque.

NOTE

If the pulley was not removed, check the retaining nut for proper torque.

2. Position the alternator on the mounting brackets and 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 groove of the pulleys.

5. Adjust the belt tension so that a firm push with the thumb at a point midway between the two pulleys, will depress the belt 1/2” to 3/4”.

6. Check that alternator connection and electrical leads are clean. Install and tighten lead to alternator.

THROTTLE SOLENOID (81Z18)

DESCRIPTION. The throttle solenoid is used to shut down the fuel supply to the injectors when the ignition switch is in the OFF position.

ELECTRICAL TESTS. The DC throttle solenoid has a stroke of 1”, a pull current of 20 amperes and a holding current of 0.3 amperes.

PLUNGER BOTTOM TEST. Connect a voltmeter or light (24 volt) between the auxiliary and (+) terminals. When the solenoid is energized and the plunger bottoms, the voltmeter will indicate battery voltage or the light is on. If not, replace the solenoid.

VOLTAGE SUPPLY TEST. Connect a DC voltmeter across the solenoid terminals and manually hold the plunger so that it can not bottom. Energize the solenoid just long enough to obtain a voltmeter reading, then connect the same voltmeter across the power source and manually hold the plunger so that it cannot pull in just long enough to obtain a voltmeter reading. the difference between the two voltmeter readings is the voltage reduction due to wiring which should normally be less than 7% of rated voltage (24 volts).

REPAIRS. Repairs to the solenoid are limited to the plunger, dust boot, spring and jam nut. If the solenoid is not operating properly, replace it.

REPLACEMENT. To replace the shut down solenoid, proceed as follows (see Figure 10D-21 on page 10D-19).

1. Mark and disconnect the electrical leads from the shut down solenoid.

2. Disconnect the throttle solenoid clevis from the engine fuel shutdown lever.

3. Remove the capscrews, lock washers and nuts securing the throttle solenoid to the throttle bracket.

4. Remove the throttle solenoid. Remove the clevis from the solenoid actuating rod.

5. If the solenoid has not been operating properly, replace it.

6. Set the solenoid up to the solenoid bracket and secure it with the capscrews, lock washers and nuts.

7. Install the electrical leads to the solenoid.

8. Install the clevis on the solenoid actuating rod and adjust as indicated to give the 35° arc between STOP and RUN.

9. Check the operation of the solenoid. If the engine shut down mechanism needs adjusting see subsection 11D.

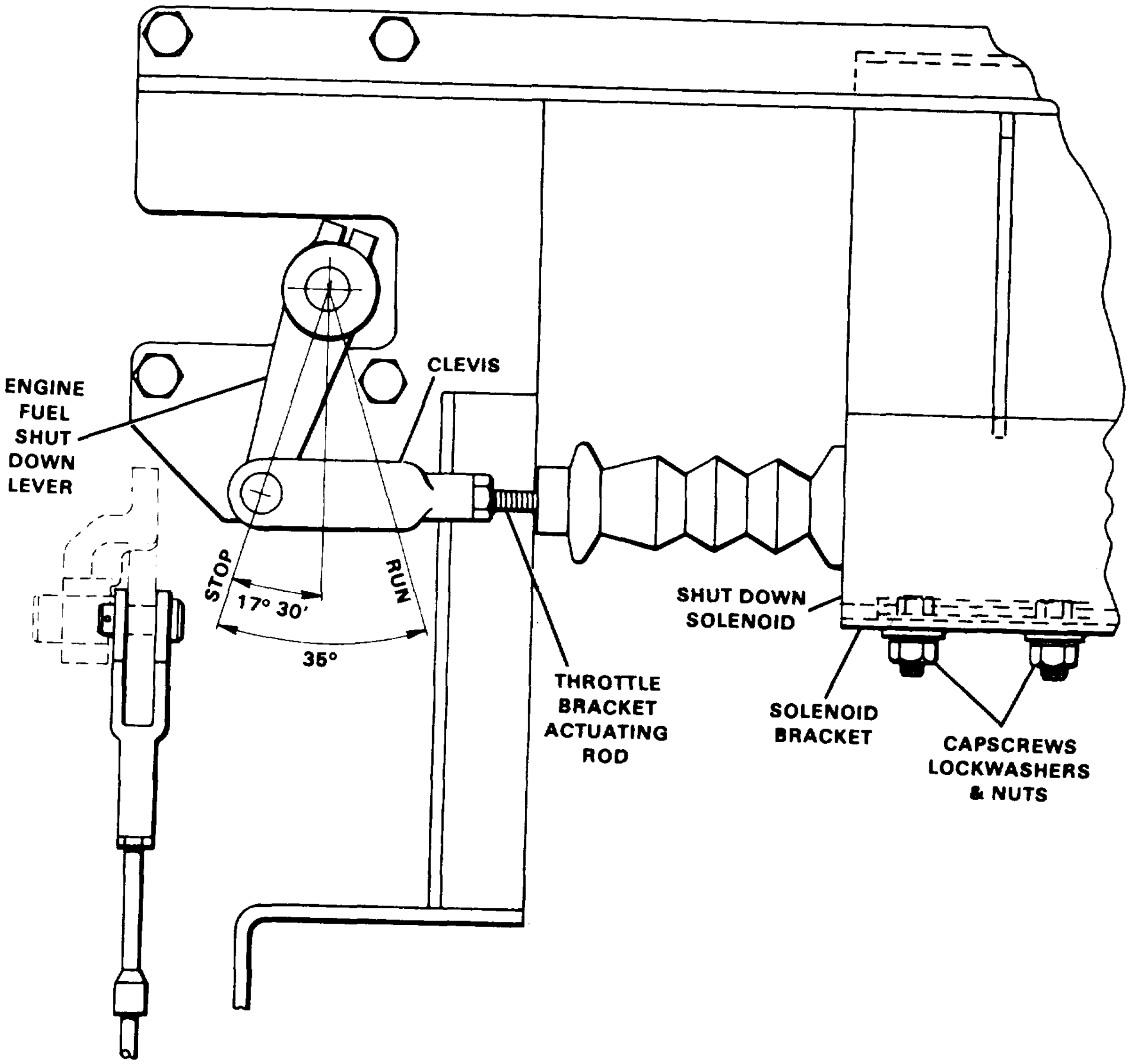


Figure 10D-21. Throttle Shut Down Solenoid

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SUBSECTION 11A

GENERAL INFORMATION

GENERAL

This subsection contains information on principles of operation, serial number information and general procedures that apply to all of the subsections in Section 11 (Disassembly, Cleaning, Inspection, Assembly and Safety).

PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder; then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively as shown in Figure 11A-1. In contrast, a four cycle engine requires four piston strokes to complete an operating cycle; thus, during one half of its operation, the four cycle engine functions merely as an air pump.

A blower is provided to force air into the cylinders for expelling the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports as shown in Figure 11A-1 (scavenging).

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

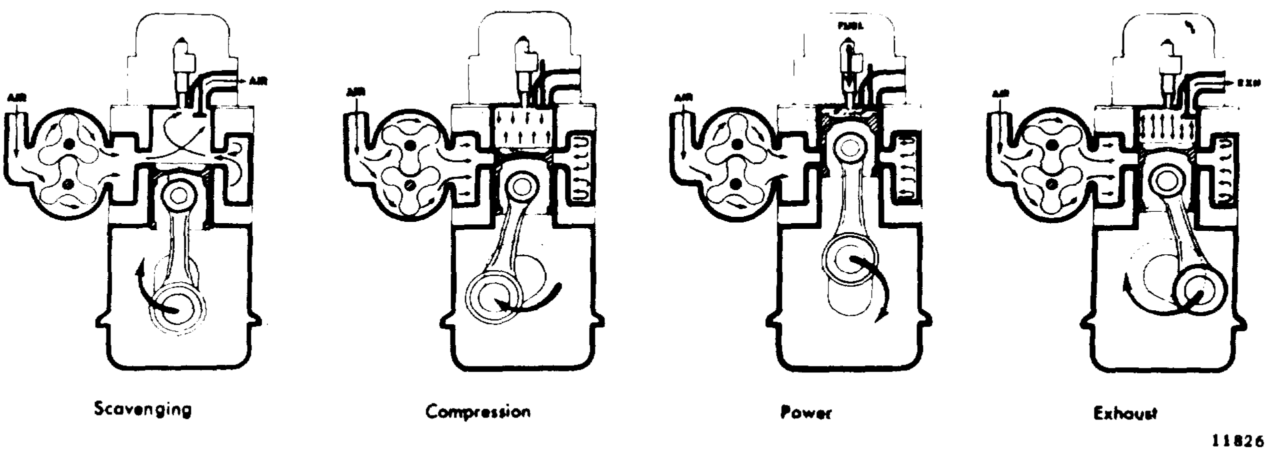

Figure 11A-1. The Two Stroke Cycle

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression as shown in Figure 11A-1 (compression).

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector as shown in Figure 11A-1 on page 11A-1 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The compression continues until the fuel injected has been burned.

The resulting pressure forces the piston downward on its power stroke.. The exhaust valves are again opened when the piston is about half way down, allowing the burned gases to escape into the exhaust manifold as shown in Figure 11A-1 on page 11A-1 (exhaust). Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or in other words, in two strokes; hence, it is a “two stroke cycle”.

GENERAL DESCRIPTION

The two cycle diesel engine covered in this section is a 4 cylinder model having the major working parts such as injectors, pistons, connecting rods, cylinder liners and other parts that are interchangeable. The blower, water pump, governor and fuel pump form a group of standard accessories.

Each engine is equipped with an oil cooler, lubricating oil filter fuel oil strainer, fuel oil filter, air cleaner, governor, heat exchanger and water pump and fan, and starting motor.

Full pressure lubrication is supplied to all main, connecting rod camshaft bearings, and to other moving parts within the engine. a gear type pump draws oil from the oil pan through an intake screen, through the oil filter and then to the oil cooler. From the oil cooler, the oil enters a longitudinal oil gallery in the cylinder block when the supply divides; a portion entering the by-pass filter, if used, and then draining back into the oil pan, part going to the cam and balance shaft end bearings and cylinder head, with the remainder going to the main bearings and connecting rod bearings via the drilled crankshaft.

Coolant is circulated through the engine by a centrifugal type water pump. Heat is removed from the coolant which circulates in a closed system, by the radiator. Control of the engine temperature is accomplished by a thermostat which regulates the flow of the coolant within the cooling system.

Fuel is drawn from the supply tank through the fuel strainer by a gear type fuel pump. It is then forced through a filter and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifold and connecting lines. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and also carries off any air in the fuel system.

Air for scavenging and combustion is supplied by a blower which pumps air into the engine cylinders via the air box and cylinder liner ports. All air entering the blower first passes through an air cleaner.

Engine starting is provided by an electrical starting system. The electric starting motor is energized by a storage battery. A battery charging alternator, with a suitable voltage regulator, serves to keep the battery charged.

Engine speed is regulated by a mechanical engine governor.

ENGINE MODEL AND SERIAL NUMBER

On all engines, the engine serial number and the engine model number are stamped on the cylinder block (see Figure 11A-2 on page 11A-3). The engine serial number and model number are also stamped on the option plate attached to the valve rocker cover.

GENERAL SPECIFICATIONS

Type	2 Cycle
Number of Cylinder	4
Bore (inches)	4.25
Bore (mm)	108
Stroke (inches)	5
Stroke (mm)	127
Compression Ratio (Nominal)	17 to 1
Total Displacement - cubic inches	284
Total Displacement - litres	4.66
Firino Order - R.H. Rotation	1-3-4-2
Number of Main Bearings	5

The engine serial number is prefixed by numerals indicating the number of cylinders and the letter "A" which designates a Series 71 engine.

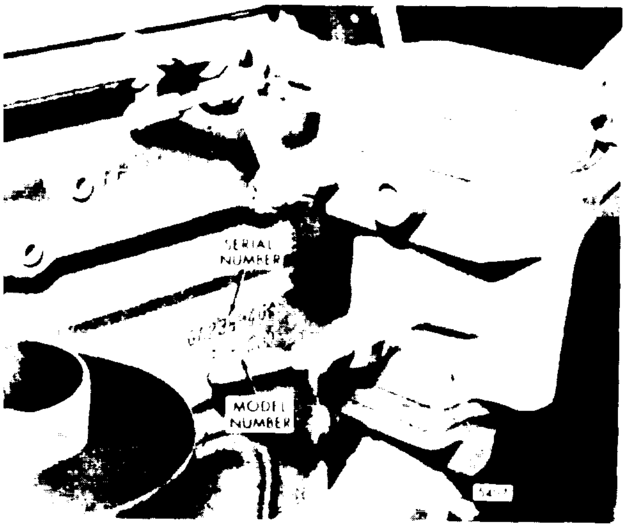

Figure 11A-2. Engine Model and Serial Number

OPTION PLATE

An option plate, attached to the valve rocker cover, carries the engine serial number and model number and, in addition, lists any optional equipment used on the engine (see Figure 11 A-3).

On-highway vehicle engines also carry an exhaust emission certification label next to the option plate. It is separate from the option plate and is mounted permanently in the option plate retainer. The label includes information relating to an engine family for the maximum fuel injector size and maximum speed. Due to Federal regulations, the exhaust emission plate should not be removed from the rocker cover. Refer to Subsection 11I

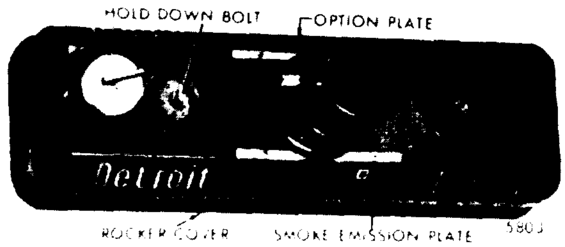

Figure 11A-3. Option Plate

for further information regarding emission regulations.

With any order for parts, the engine model number and serial number must be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

All groups of parts used on a unit are standard for the engine model unless otherwise listed on the option plate.

GENERAL PROCEDURES

General

In many cases, a serviceman is justified in replacing parts with new material rather than attempting repair. However, there are times where a slight amount of reworking or reconditioning may save considerable added expense. Crankshafts, cylinder liners and other parts are in this category. For example, if a cylinder liner is only slightly worn and within usable limits, a honing operation to remove the glaze may make it suitable for reuse, thereby saving the expense of a new part. Exchange assemblies such as injectors, fuel pumps, water pumps and blowers are also desireable service items.

Various factors such as the type of operation of the engine, hours in service and next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble free operation.

For convenience and logical order in disassembly and assembly, the various subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various subsection of this section.

Disassembly

Before any major disassembly, the engine must be drained of lubricating oil, water and fuel. Lubricating oil should also be drained from the torque converter.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the machine, should be mounted on an engine overhaul stand; then the various subassemblies should be removed from the engine. When only a few items need replacement, it is not always necessary to mount the engine on an overhaul stand.

Parts removed from an individual engine should be kept together so they will be available for inspection and assembly. Those items have machined faces, which might be easily damaged by steel or concrete should be stored on suitable wooden racks or blocks, or a parts dolly.

Cleaning

GENERAL. Before removing any of the subassemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is outlined under Clean Cylinder Block (subsection 11B); any special cleaning procedures will be mentioned in text wherever required.

STEAM CLEANING. A steam cleaner is a necessary item in a large shop and is most useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its subassemblies.

SOLVENT TANK CLEANING. A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 180-200°F (82-90°C).

Fill the tank with a commercial heavy duty solvent which is heated to the above temperatures . Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all of the grease and dirt.

RINSING BATH. Provide another tank of similar size containing hot water for rinsing the parts.

DRYING. Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete the drying of the parts without the use of compressed air.

RUST PREVENTIVE. If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed before installing the parts in an engine.

Inspection

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgment must be exercised by the inspector .

The guiding factors in determining the usability of worn parts, which are otherwise in good condition, is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated.

Many service replacement parts are available in various undersize and/or oversize as well as standard sizes. Also, service kits for reconditioning certain parts and service sets which include all of the parts necessary to complete a particular job are available.

A complete discussion of the proper methods of precision measuring and inspection are outside the scope 'of this manual. However, every shop should be equipped with standard gauges, such as dial bore gauges, dial indicators, and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping and other defects.

Assembly

Following cleaning and inspection, the engine should be assembled using new parts as determined by the inspection.

Use of proper equipment and tools makes the job progress faster and produces better results. Likewise, a suitable working space with proper lighting must be provided. The time and money invested in providing the proper tools, equipment and space will be repaid many times.

Keep the working space, the equipment, tools and engine assemblies and parts clean at all times. The area where assembly operations take place should, if possible, be located away from the disassembly and cleaning operation. Also, any machining operations should be removed as far as possible from the assembly area.

Particular attention should be paid to storing of parts and subassemblies, after removal and cleaning and prior to assembly, in such a place or manner as to keep them clean. If there is any doubt as to the cleanliness of such parts, they should be recleaned.

When assembling an engine or any part thereof, refer to the table of torque specifications at the end of each subsection for proper bolt, nut and stud torques.

To ensure a clean engine at time of rebuild, it is important that any plug, fitting or fastener (including studs) that intersect with a through hole and comes in contact with oil, fuel or coolant must have a sealer applied to the threads.

A number of universal sealers are commercially available. It is recommended that Loctite J 26558-92 pipe sealer with teflon, or equivalent, be used.

NOTE

Certain plugs, fittings and fasteners already have a sealer applied to the threads. This pre-coating will not be affected when the pipe sealer with teflon is also applied. The sealer information given must not be confused with International Compound No. 2, which is a lubricant applied before tightening certain bolts. Use International Compound No. 2 only where specifically stated in the manual.

Work Safely

A serviceman can be severely injured if caught in the pulleys, belts or fan of an engine that is accidentally started. To avoid such a misfortune, take these precautions before starting to work on an engine:

Disconnect the battery from the starting system by removing one or both of the battery cables. With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start.

Make sure the mechanism provided at the governor for stopping the engine is in the stop position. This will mean the governor is in the no fuel position. The possibility of the en ine firing by accidentally turning the an is minimized.

Some Safety Precautions To Observe When Working On The Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard hat, etc. to provide adequate protection.

2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

3. Always use caution when using power tools.

4. When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the section. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury.

5. Avoid the use of carbon tetrachlbride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichorethylene. However, while less toxic than other chorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield, and apron.

Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

6. Use caution when welding on or near the fuel tank. Possible explosion could result if heat build-up inside the tank is sufficient.

7. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions in the operator manual on the use of the starting aid.

8. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing.

OPERATING SPECIFICATIONS

	1800 RPM	2100 RPM	2300 RPM
LUBRICATION SYSTEM			
Lubricating oil pressure (psi)			
Normal..................................	43-65	45-65	45-65
Min. for safe operation..	28	30	30
Lubricating oil temperature[1] (degrees F)			
Normal..................................	200-235	200-235	200-235
AIR SYSTEM			
Air box pressure (inches mercury)-min. at full load			
At zero exhaust pressure..	21.0	30.0	37.0
At max. full load exhaust pressure (clean ports).	19.5	27.7	34.7
Air inlet restriction (inches water)-max			
Full load speed			
Dirty air cleaner (dry).	14.5	20.0	20.0
Clean air cleaner (dry).	8.7	12.0	12.0
No load speed			
Dirty air cleaner (dry).	8.7	12.0	12.0
Clean air cleaner (dry).			7.2
Crankcase pressure (inches mercury)-max.. .	5.2	0.9	1.2
Exhaust back pressure (inches mercury)-max			
Full load	2.0	3.0	3.0
FUEL SYSTEM			
Fuel pressure at inlet manifold (psi)-normal..	50-70	50-70	50-70
Fuel spill (gpm) -min. at no load (0.080” orifice)	0.9	0.9	0.9
Pump suction at 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 sea level)			
Average - new engine at 600 RPM..	475		
Minimum at 600 RPM..	425		

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1 The lubricating oil temperature range is based on the temperature in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil galley, it will be approximately 10° lower than the oil pan temperature.

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SUBSECTION 11B

ENGINE (LESS MAJOR ASSEMBLIES)

GENERAL

This subsection contains repair information on the block items such as cylinder blocks, cylinder head, valves crankshaft, flywheel, pistons rods, rings, camshaft, etc..

CYLINDER BLOCK

Description

The cylinder block (Figure 11B-1 and Figure 11B-2 on page 11B-2) serves as the main structural part of engine. Transverse members, cast integrally, 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 (see Figure 11B-2 on page 11B-2). Coolant from the pump enters at the bottom through holes which register with corresponding openings in the cylinder head.

An air box (Figure 11B-2 on page 11B-2) surrounding the water jackets conduct the air from the blower to the air inlet ports in the cylinder liners. Air box openings (Figure 11B-3 on page 11B-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 camshaft and balance shaft bores are located on opposite sides near the top of the block.

The upper halves of the main bearing support 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.

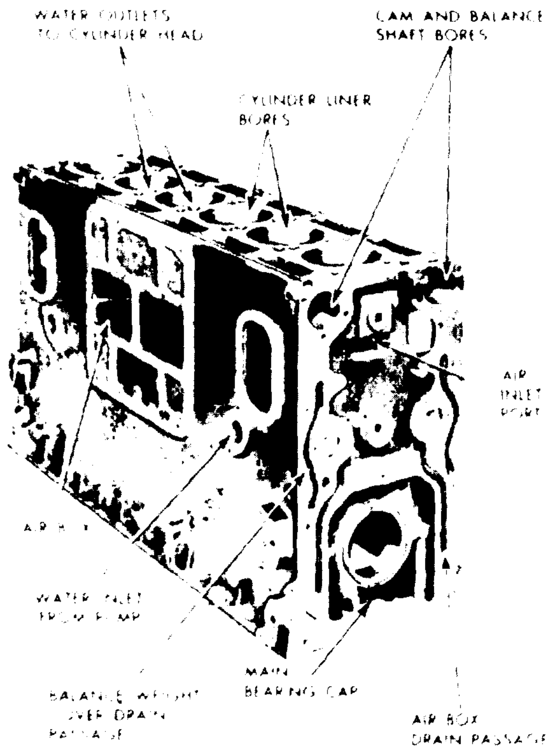


Figure 11B-1. Cylinder Block

The perimeter of the top surface of the cylinder block is grooved, outside of the cam pockets, to accommodate a

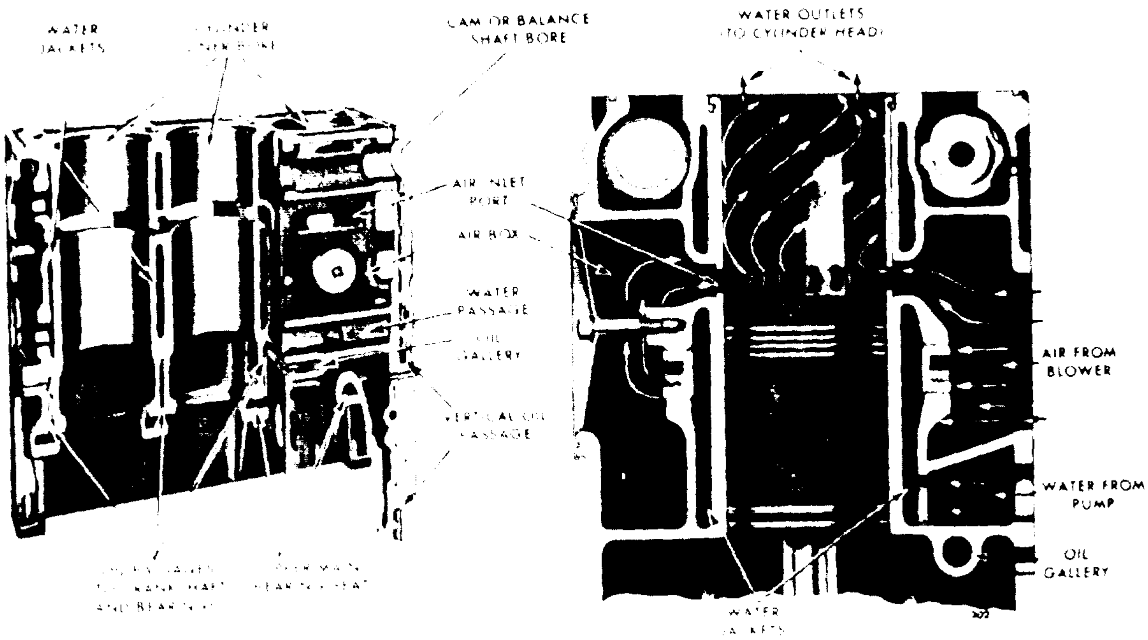


Figure 11B-2. Cutaway of Cylinder Block Showing Air and Water Passages

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 (see Figure 11B-4 on page 11B-3).

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 gasket 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 main bearing caps and bolts, dowels and the necessary plugs.

Since the cylinder block is the main structural part of the engine, the various subassemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand (Figure 11B-5 on page 11B-3), 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.

Remove and Disassemble Engine

Before mounting an engine on an overhaul stand, it must be removed from its base and disconnected from the torque converter.

1. Remove the air cleaner and mounting bracket.

2. Remove the turbocharger.

3. Disconnect the exhaust piping and remove the exhaust manifold.

4. Disconnect the throttle controls.

5. Disconnect and remove the starting motor, battery charging alternator and other electrical equipment.

6. Remove the radiator and fan guard and other related cooling system parts.

7. Remove the air box covers.

8. Disconnect any other lubricating oil lines, fuel lines or electrical connections.

9. Remove the engine mounting bolts.

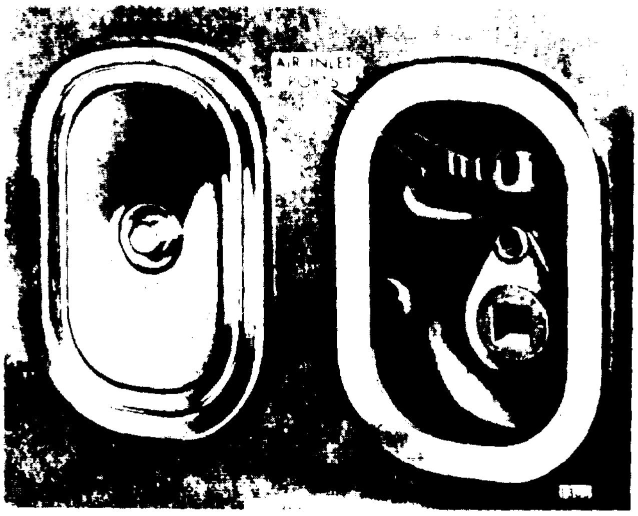


Figure 11B-3. Air Box Covers and Air Inlet Ports

10. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base (see Figure 11B-6 on page 11B-4). To prevent bending of the engine lifter brackets the lifting device should be adjusted so the lifting hooks are vertical. To ensure proper weight distribution, all engine lifter brackets should be used to lift the engine.

CAUTION

Do not lift an engine by the webs in the air inlet openings of the cylinder block.

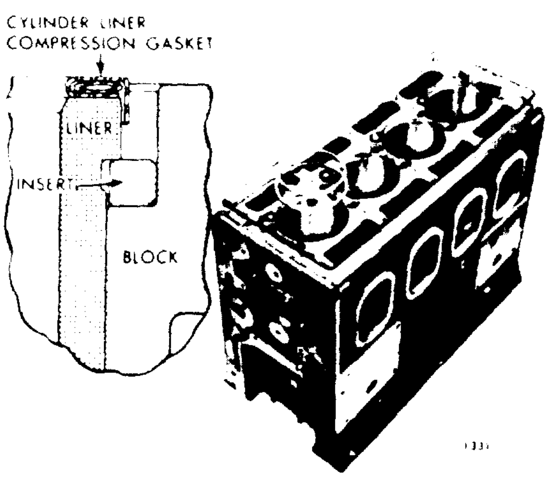


Figure 11B-4. Sealing Arrangement of Cylinder Block

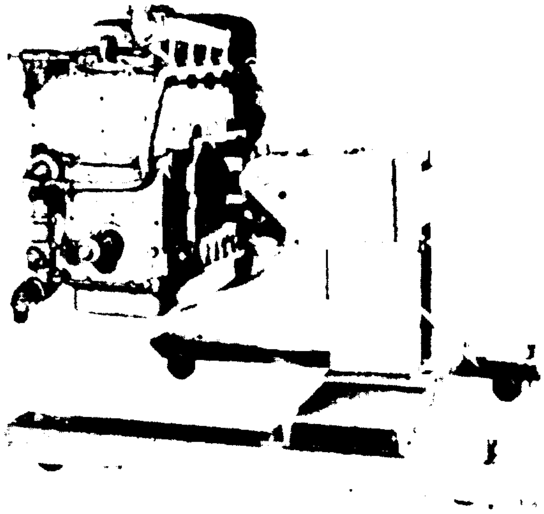


Figure 11B-5. Engine Mounted on Overhaul Stand

11. 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 two opening.

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 (see Figure 11B-5). Long spacers and bolts are used with the four 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.

12. Loosen the locknuts on the two holding lugs on the adaptor plate and lower the engine while guiding the lugs into the air box openings.

13. Turn the holding lug crosswise in the air box openings and tighten the locknuts, drawing the engine tight against the adaptor plate.

14. To be sure the engine does not shift on or break away from the overhaul stand, insert 7/16"-14x2" 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.

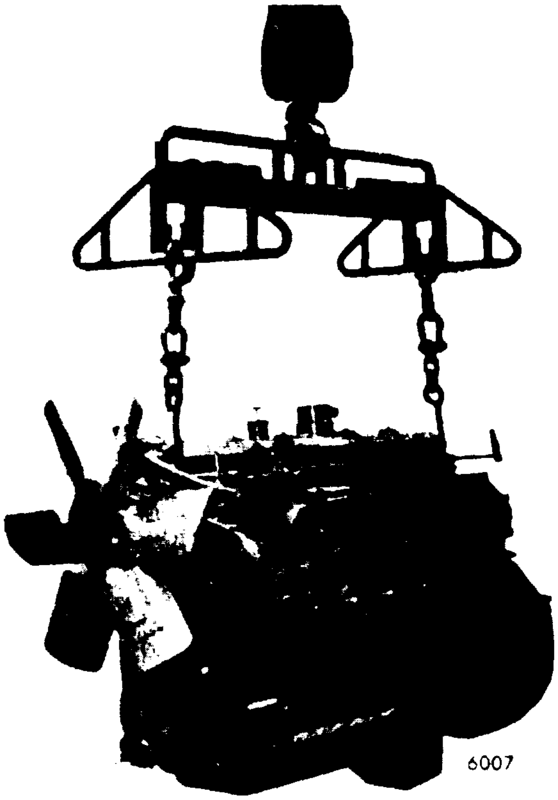


Figure 11B-6. Lifting Engine with Spreader and Sling

15. With the engine mounted on the overhaul stand, remove all of the remaining subassemblies and parts from the cylinder block.

The procedure for removing each subassembly from the cylinder block, together with disassembly, inspection, repair and reassembly of each, will be found in the various subsections of this section.

After stripping, the cylinder block must be thoroughly cleaned and inspected.

Clean Cylinder Block

Scrape all gasket material from the cylinder block. Then remove all oil gallery plugs and core plugs (except cap 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 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 (see Figure 11B-7).

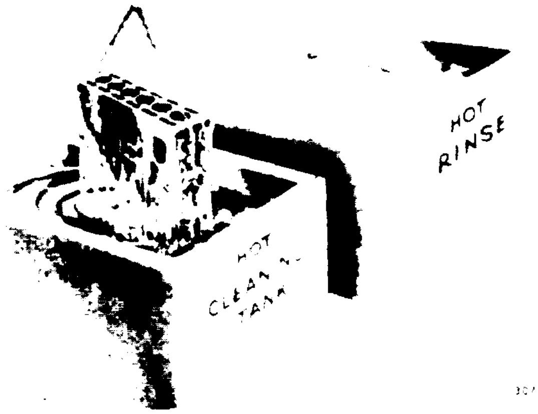


Figure 11B-7. Cleaning Cylinder block

2. Wash the block in a 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.

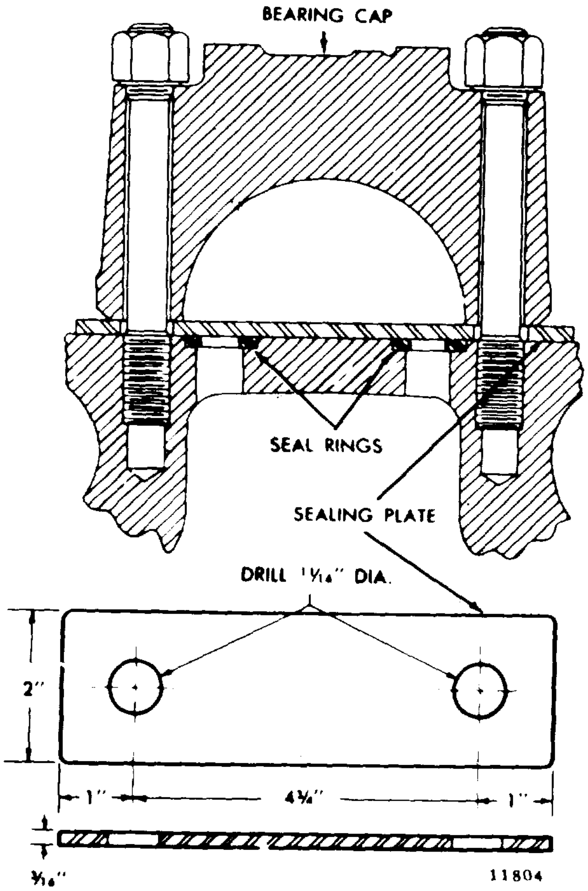


Figure 11B-8. Sealing Plate Detail for Pressure Test

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.

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.

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 (Figure 11B-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 (see Figure 11B-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:

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 (82-93°C).

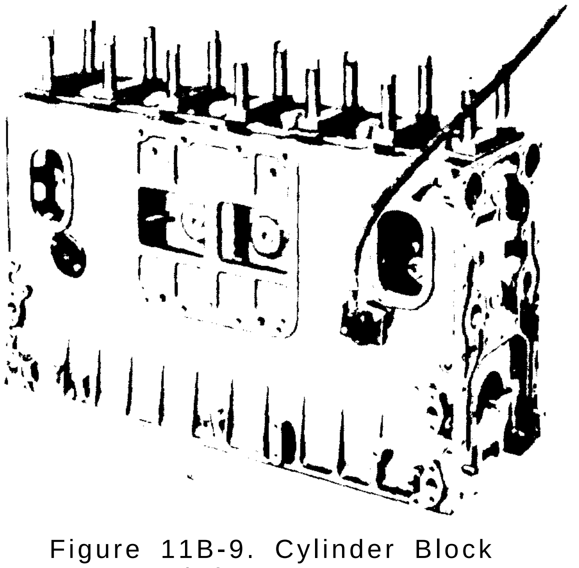


Figure 11B-9. Cylinder Block Prepared for Pressure Test

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.

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 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.

CAUTION

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 replace by a new block.

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

Before attempting to check the block bore, hone them throughout their entire length until about 70% of the area above the ports has been "cleaned up".

1. Hone the block bores as follows:

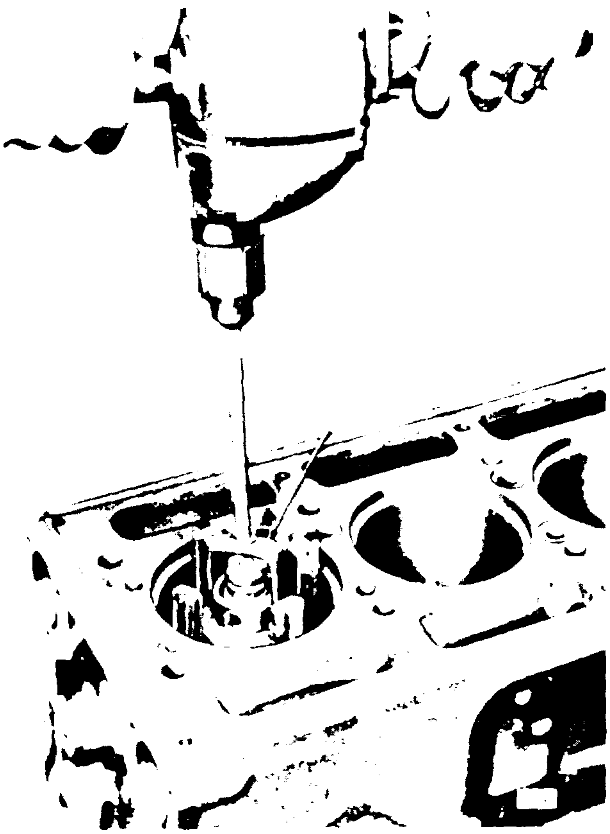


Figure 11B-10. Honing Bore of Cylinder block

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 on 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.

B. Insert the hone in the bore (Figure 11B-10 on page 11B-6) and adjust the stones snugly to the narrowest 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. Concentrate on the high spots in the first cut. As these are removed, the drag on the hone will become lighter and smoother. 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 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 (Figure 11B-11). A slight increase in block bore size is normal with long periods of engine operation.

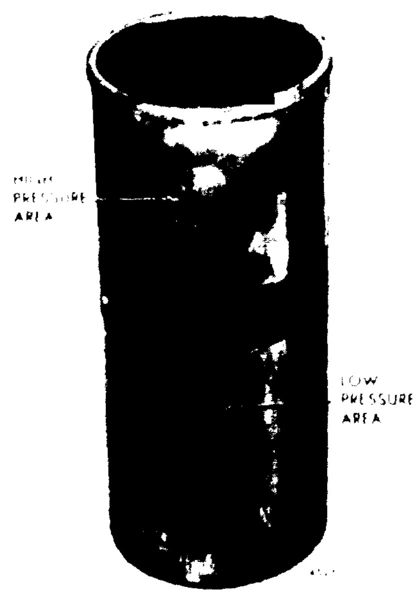


Figure 11B-11. High Pressure Areas on Cylinder Liners

A. Visually check the contact area as revealed by the honed surface. The must not be any low spots which are large than a half dollar.

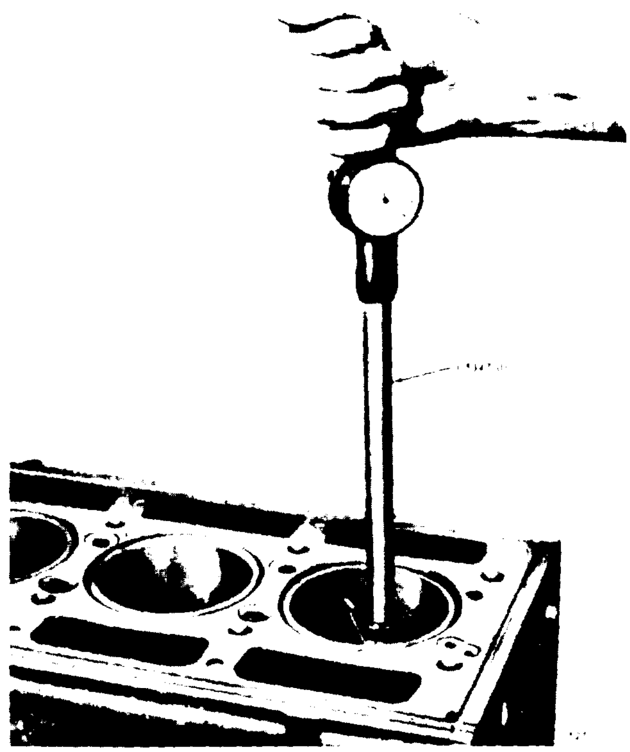


Figure 11B-12. Checking Bore of Cylinder Block

B. Measure the entire bore of each cylinder with bore gauge J 5347-01 (Figure 11B-12) which has a dial indicator calibrated in 0.0001" increments. The standard block bore is 4.6260" to 4.16275". Place the bore guage 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, E and F in the bore on axes 45° apart (Figure 11B-1. Read the measurements from the zero mark on the gauge. The reading may be recorded on a form similar to the one illustrated in Figure 11B-14.

3. The liner-to-block clearance with new parts is zero to 0.0015". With used parts, the maximum clearance is 0.0025". After measuring the block bores, measure the outside diameter of the cylinder liners. Then determine the block-to-liner clearance and whether it will be necessary to bore the block for oversize cylinder liners.

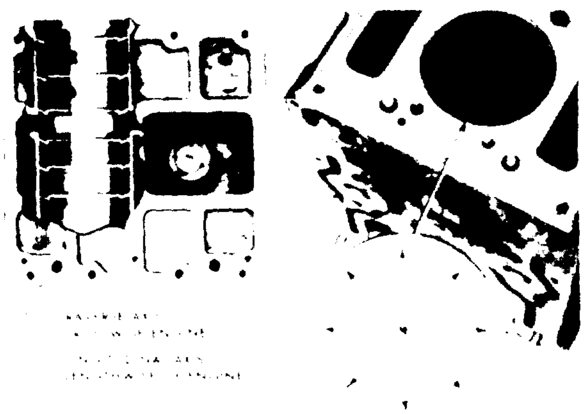


Figure 11B-13. Cylinder Bore Measurement Diagram

NOTE

Dial bore gauge setting master tool J 23059-01 may be used in place of the master ring gauge.

	Trans.	45°	Long.	45°
	1	2	3	4
A				
B				
C				
Port Belt				
D				
E				
F				

Figure 11B-14. Block Bore Measurement Form

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 0.002". If the average block bore is over 4.6285", the block should be bored oversize (refer to Table 11B-1 on page 11B-9).

B. A typical commercially available portable boring bar is illustrated in Figure 11B-15 on page 11B-9. Instructions on the correct use of the boring bar are provided by the manufacturer.

C. After boring the block for an oversize cylinder liner, check the bore finish to be sure it is smooth (120 RMS). Heat transfer from the cylinder liner to the block will be adversely affected if the block bore is not 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 insert must be installed whenever an oversize liner is used.

5. Check the top of the block for flatness with an accurate straight edge and a feeler gauge (see Figure 11B-16 on page 11B-9).

A. The top surface of the block must not vary more than 0.003" transversely and not over 0.007" longitudinally. It will be difficult to prevent water, oil and compression leaks if the top surface of the block exceeds these tolerances.

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 11B-1. Cylinder Bore Clearances

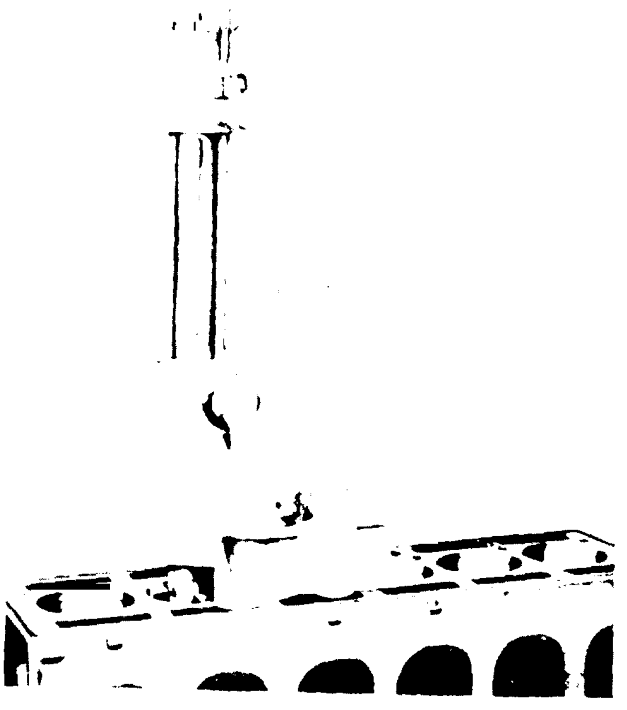


Figure 118-15. Boring Cylinder Block with Portable Boring Bar

Figure 11B-16. Checking Top Face of Cylinder Block

6. If it is necessary to machine the top surface of the block to correct for the above conditions, do not remove-more than 0.008" 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" (see Figure 11B-17 on page 11B-10).

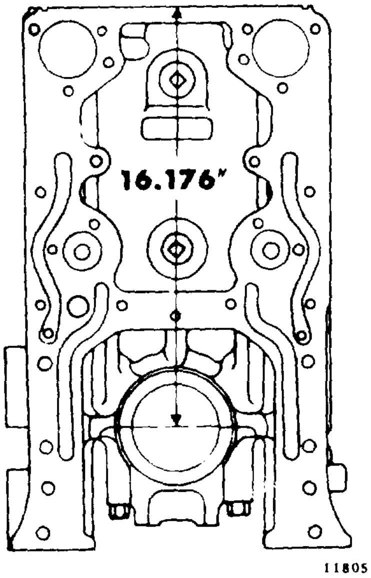


Figure 11B-17. Centerline of Crankshaft to Top of Block

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 0.092"-0.107" deep. The large water hole counterbores (between the cylinders) must be 0.109"-0.120" deep and the combination water and oil hole counterbores and small water holes must be 0.087"-0.098" 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 of the cylinder liners since 0.004" and 0.008" undersize thickness inserts are available for adjusting the liner position.

6. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth (Figure 11B-18). The depth must be 0.4770" to 0.4795" and must not vary more than 0.0015" throughout the entire circumference. The counterbore surfaces must be smooth and square with the cylinder bore within 0.001" total indicator reading. There must not be over 0.001" difference between any two adjacent cylinder counterbores when measured along the cylinder longitudinal centerline of the cylinder block.

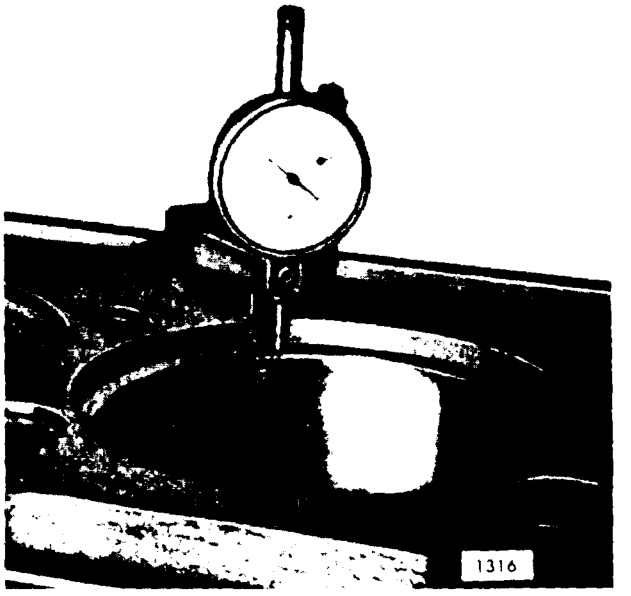


Figure 11B-18. Checking Cylinder Liner Counterbore with J 22273

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 lb-ft (224-238 Nm) torque or stud nuts to 140-155 lb-ft (190-211 Nm) 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 replace 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 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. 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 "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 renumbered.

6. 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.

NOTE

Use the unfinished bearing caps for the front and immediate bearing positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the rear bearing position.

C. 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 tightened. If a main bearing bore is more than 0.001" out of alignment, the block must be line-bored or scrapped. Misalignment may be caused by a broken crankshaft, damage. 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. Install the bearing caps in their original positions and tighten the bolts to 165-175 lb-ft (224-238 Nm) torque. Line bore the block, but do not remove more then 0.001" stock. After boring, all bores must be within the specified limits of 3.812" to 3.813".

8. Refer to the Cylinder Block Plugging Charts at the end of this subsection 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 0.625" from the face of the block.

The dowels used to retain the crank shaft thrust washers on the rear main bearing cap must extend 0.110" to 0.120" 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 (0.1910") or No. 12 (0.1890") drill. After pressing the pins into the bearing cap, remove all burrs from the base of the dowel pins to ensure proper sealing of the thrust washers.

10. Replace main bearing cap studs, if used, which are damaged or broken. Install new studs to a height of 4"±1/32" above the upper bearing seat at a torque of 35-75 lb-ft or 47-102 Nm.

11. Replace damaged or broken cylinder head studs. Install and drive a new stud to a height of 4-3/8"±1/32" at a minimum torque of 75 lb-ft or 102 Nm.

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 maybe 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 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 0.004". Clean up damaged threads in tapped holes with a tap or install helical thread 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.

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 (Figure 11B-19) and the position of the No. 1 bearing on the oil pan mounting flange of the block.

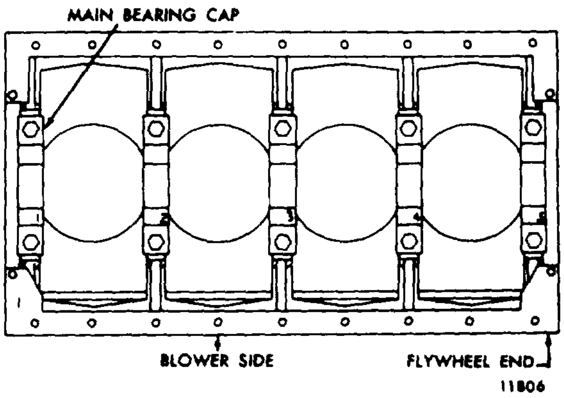


Figure 11B-19. Cylinder Block Markings

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 subassemblies are outlined in the following subsections of this section.

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 Subsection 11H, Engine Tune-Up.

CYLINDER BLOCK END PLATES

Description

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,

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 as outlined under "Clean Cylinder Block" on page 11B-4.

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 plate are too deep to be cleaned up, replace the end plates.

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

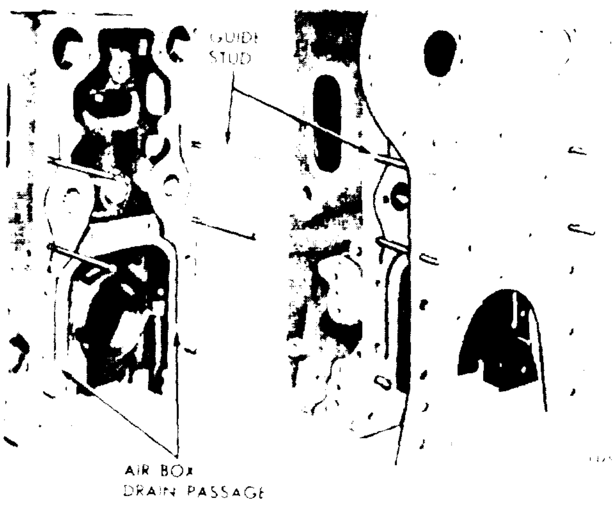


Figure 11B-20. Installing Front End Plate

2. Use guide studs J 1927-01 as shown in Figure 11B-20 to set the front end plate next to the cylinder block and install the bolts and lockwashers. 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 Figure 11B-21.

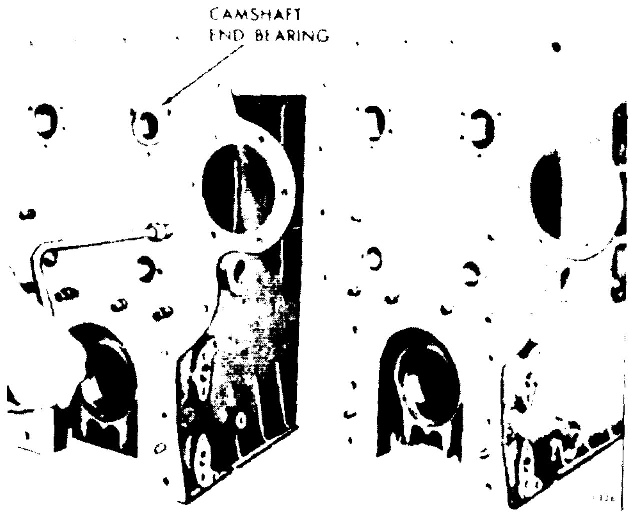


Figure 11B-21. Installing Rear End

4. With the bearing in place, tighten the 3/8"-16 end plate retaining bolts to 30-35 lb-ft (41-47 Nm) torque. Tighten the 1/2"-13 bolts to 71-75 lb-ft (96-102 Nm) torque. 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.

AIR BOX DRAINS

Description

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 cored passages located at the front and rear of the cylinder block with drain outlets in the side of the block.

This engine is equipped with a drain tank (see Figure 11B-22) to collect and retain the sediment from the air box.

Air box drains must be kept open at all times, otherwise water and oil that may accumulate will be drawn into the cylinders.

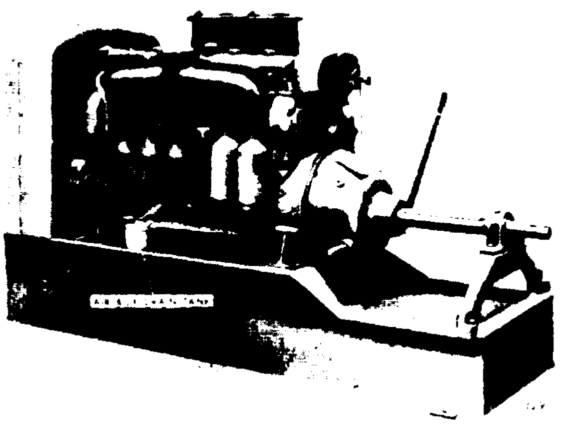


Figure 11B-22. Air Box Drain Tank Installation

CYLINDER HEAD

Description

The cylinder head (Figure 11B-23 on page 11B-15) is a one piece casting securely held to the top of the cylinder block by special bolts.

The exhaust valve, fuel injectors and the valve and injector operating mechanism are 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 (Figure 11B-25 on page 11B-16) 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 neoprene seal. The sealed upper end and flared lower end of the injector tube prevents 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 insured by the use of water nozzles (Figure 11B-26 on page 11B-16) 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 manifold 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 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 in the 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 (see Figure 11B-27 on page 11B-17). The 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.

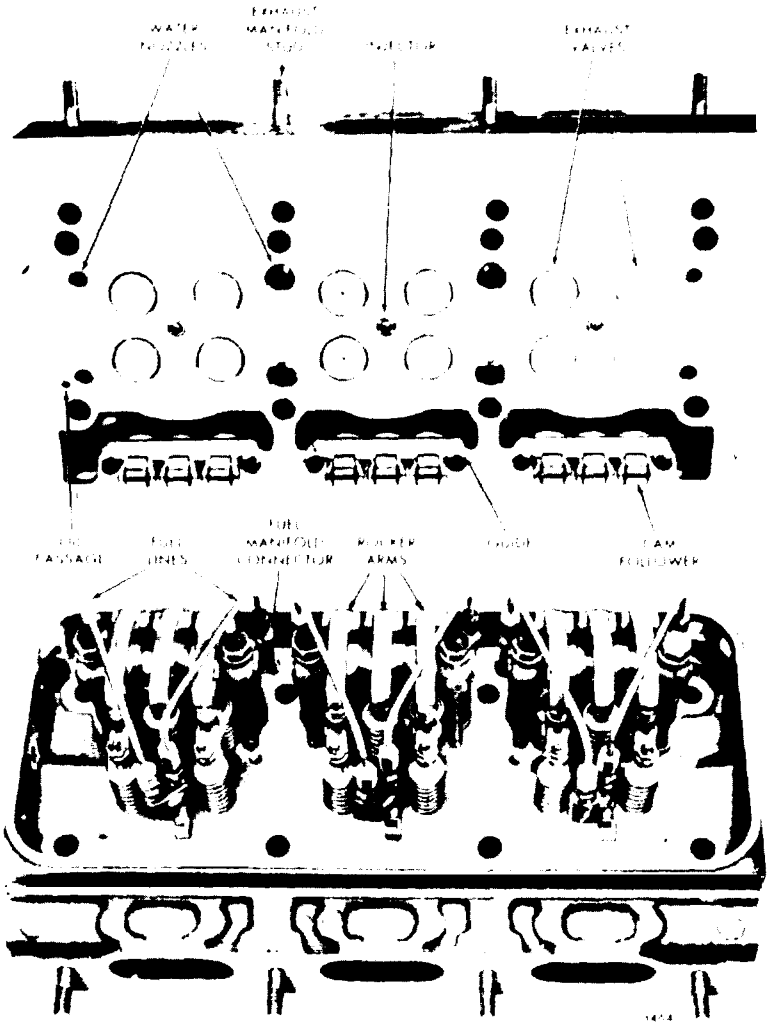


Figure 11B-23. Cylinder Head Assembly

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 coolant does not cover the fire deck surface. When necessary, add coolant 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 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.

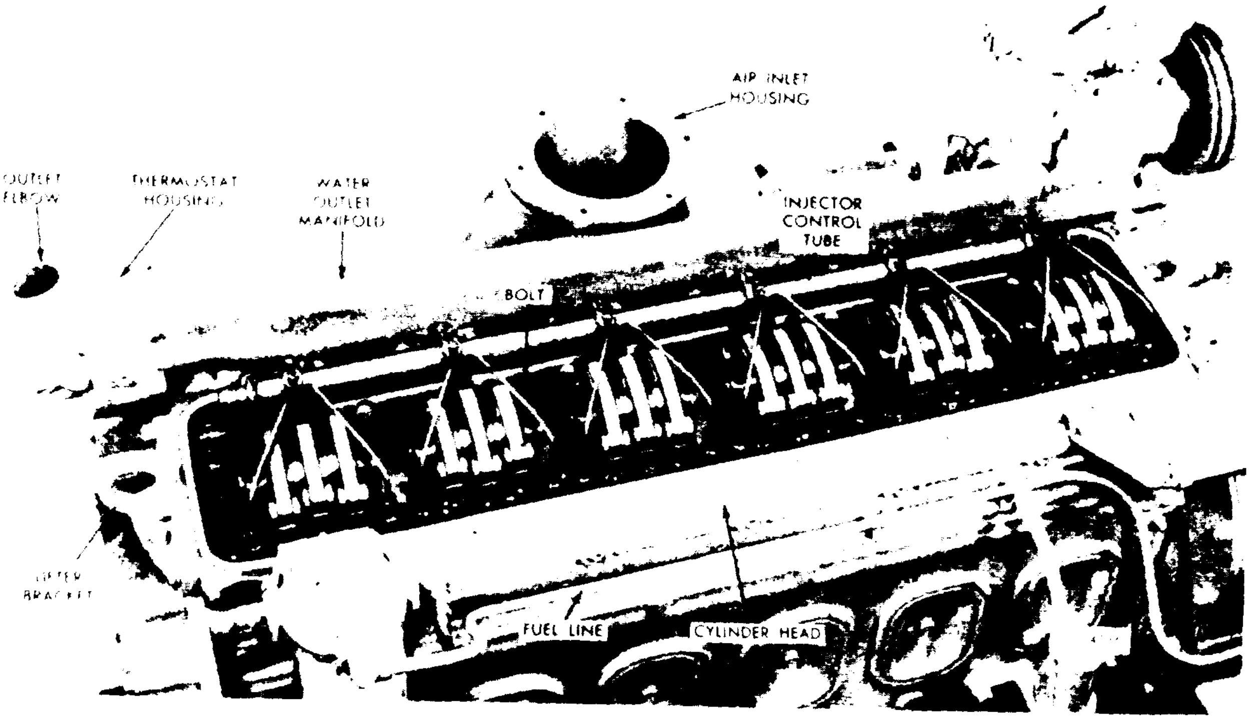


Figure 11B-24. Mounting of Cylinder Head

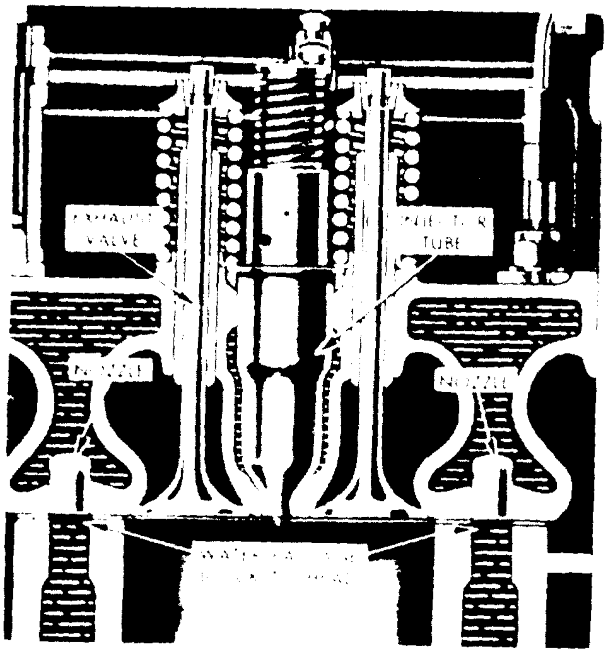


figure 11B-25. Exhaust Valve and Injector Coolant Passages

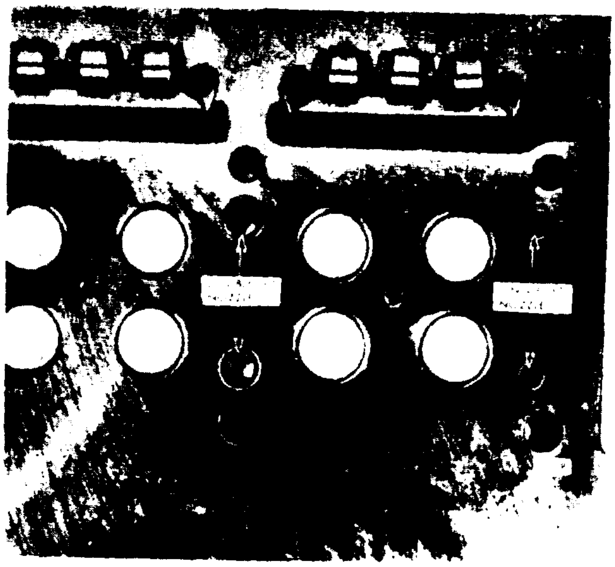


Figure 11B-26. Water Nozzles in Cylinder Head

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.

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.

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.

Refer to Figure 11B-24 on page 11B-16 and remove the cylinder head as follows:

1. Drain the cooling system.

2. Disconnect the exhaust piping at the exhaust manifold. Remove the connections from the exhaust manifold to the turbocharger. Remove the turbocharger, if necessary.

3. Remove the air cleaner and the air inlet housing.

4. Remove the exhaust manifold.

5. Disconnect the fuel lines at the cylinder head and remove the fuel filter.

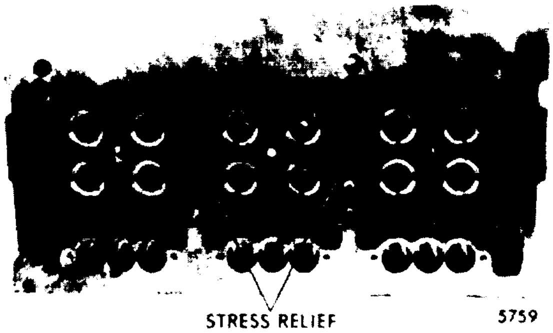


Figure 11B-27. Four Valve Cylinder Head

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.

10. Remove the injector control tube and brackets as an assembly (see Figure 11B-28 on page 11B-18.

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 (see Subsection 11C).

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 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 re-

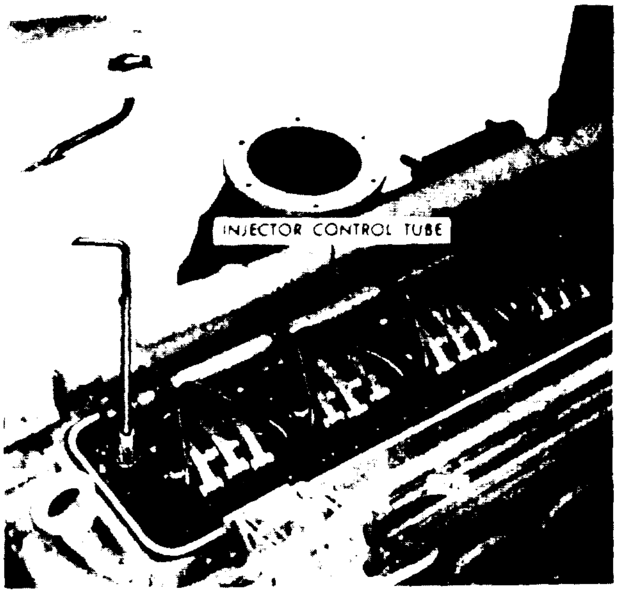


Figure 11B-28. Removing or Installing Injector Control Tube

moved may reveal the causes of any cylinder head problems.

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" thick wood blocks.

15. Place the cylinder head on its side and remove the engine lift brackets and gaskets. Then attach the cylinder head holding plates J 3087-01 to raise the head above the work bench (see Figure 11B-29).

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.

Disassemble Cylinder Head

If complete disassembly of the cylinder is necessary refer to the information later

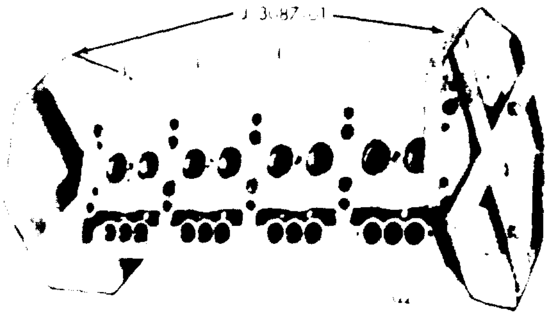


Figure 11B-29. Cylinder Head Holding Plates-J 3087-01

in this subsection for removal of the exhaust valve and injector operating mechanism.

Clean Cylinder Head

After the cylinder head has been disassembled and all of the plugs (except cup plugs) have 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.

Clean all of the cylinder head components with fuel oil and dry them with compressed air.

Inspect Cylinder Head

1. Before a cylinder can be reused, it must be inspected for cracks. Five prescribed 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.

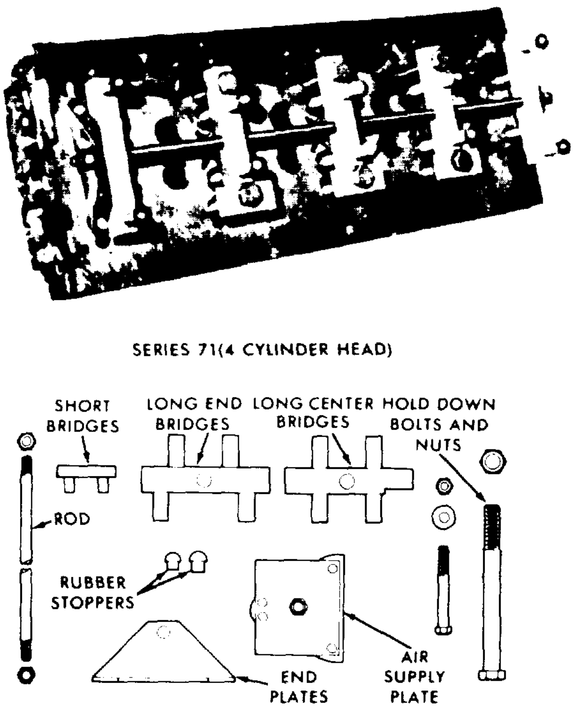


Figure 11B-30. Cylinder Head Prepared for Pressure Test

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 Meth-
Light". be disclosed under the Black

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 “Spotcheck” or Dye Check. Allow one to thirty minutes to dry. Remove the excess surface penetrant with clean cloths premoisened 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. Specific details should be obtained from the supplier of the equipment or material.

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 (see Figure 11B-30):

1) Install the rubber stoppers on the bridge.

a) Large stoppers are installed on the long center bridge feet opposite the notch and on the lon end bridge feet closest together.

b. Small stoppers are installed opposite the large stoppers on center bridge and end bridge feet and on all short bridges.

2) Install the necessary parts, loosely, on the cylinder head.

3) Tighten the hold down bolts until the stoppers start to distort. A 5 lb-ft (7 Nm) torque is usually sufficient.

NOTE

Do not overtighten the hold down bolts. The rubber stoppers could distort enough to seal both the inner and outer diameter of the water nozzle. If the outer diameter is sealed, a leak from the outer diameter would not be detected.

6. Install the air supply plate.

NOTE

Do not hook onto the pressure checking tool, or any part of it, to move the cylinder from one location to another. If this is done it could result in permanent damage to the tool.

C. Install scrap or dummy injectors to ensure proper seating of the injector tubes. Dummy injectors may be made from oil injector nuts and bodies; the injector spray tips are not necessary. Tighten the injector clamp to 20-25 lb-ft (27-34 Nm) torque.

D. Apply 40 psi (276 kPa) air pressure to the water jacket. Then immerse the cylinder head in a tank of water, previously heated to 180-2OO°F (82-93°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.

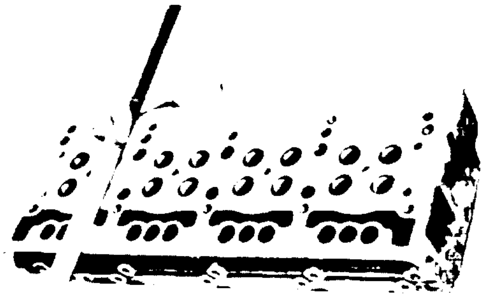
E. Relieve the air pressure and remove the cylinder head from the water tank. Then remove the plates, gaskets and injectors and dry the head with compressed air.

2. Check the bottom (fire deck) of the cylinder head for flatness:

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 Figure 11B-31. The maximum allowable transverse warpage is 0.004"; longitudinal warpage is 0.008".

B. Use the measurement obtained and the limits given in step A as a guide to determine the advisability of reinstalling 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 metal from the fire deck of any cylinder head below the minimum distance of 3.356" (see Figure 11B-32 on page 11B-21).



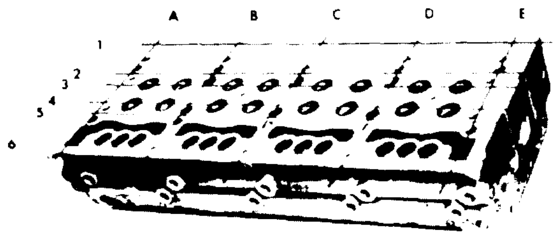


Figure 11B-31. Checking Bottom Face of Cylinder Head

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 on the engine.

3. Install new injector tubes if the old tubes leaked or the cylinder head was refaced.

4. Inspect the exhaust valve seat inserts and valve guides.

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 gauge and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record and compare the readings of the follower and bores to determine the cam follower-to-bore clearances. The clearances must not exceed 0.006” with used parts. If the bores are excessively scored or worn, replace the cylinder head.

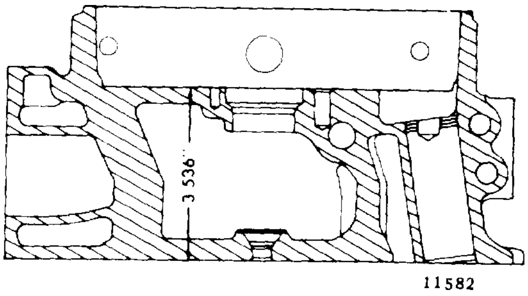


Figure 11B-32. Minimum Distance Between Top and Bottom of Cylinder Head

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. Break the edges of the holes slightly.

C. For the positioning of the nozzles, refer to Figure 11B-33. Press the nozzles flush to 0.0312" 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 lb-ft (14-34 Nm) torque (water manifold cover studs) or to 25-40 lb-ft (34-54 Nm) 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. Make sure the sleeves are flush or recessed below the fire deck of the cylinder head. Replace damaged sleeves. The sleeves, which act. as a hollow dowel and the cylinder head, help to guide the head in place without disturbing the seals and gaskets.

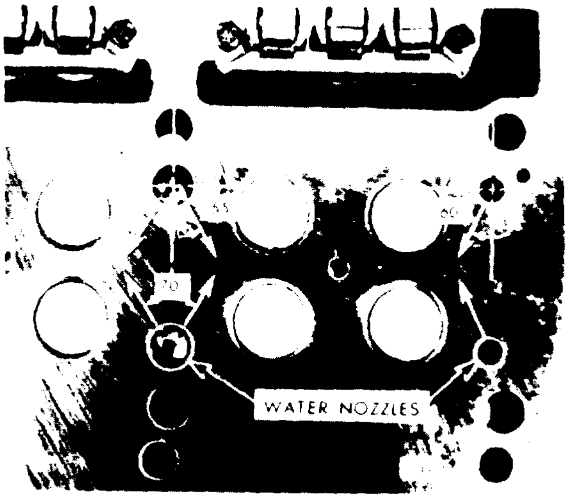


Figure 11B-33. Correct Installation of Water Nozzles

9. Inspect all other components removed from the cylinder head.

If a service replace cylinder head is to be installed, it must be thoroughly cleaned of all rust preventative compound, particularly inside the integral fuel manifolds, before installing the plugs. A simple method of removing the rust preventative compound is to immerse the head in a mineral spirits based solvent 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.

Assemble Cylinder Head

After cleaning and inspection, assemble the cylinder head as follows:

1. Coat the threads of the plugs with Loctite Pipe Sealant with Teflon, then install the necessary plugs and tighten them to the specified torque. Drive headless plugs flush to 0.0625" 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 0.0625", and a 0.2187" diameter rod placed in the vertical oil feed hole must pass the inner face of the plug. Refer to the Cylinder Head Plugging Charts shown as foldouts at the end of this section.

2. After the following parts are cleaned, 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.

B. Cam followers, guides, push rods, springs, retainers, rocker arms, shafts, brackets and other related parts.

C. Place new washers on the fuel connectors. Then install the connectors and tighten them to 40-45 lb-ft (54-61 Nm) torque.

D. The fuel injectors, fuel pipes, injector control tube assembly and water manifold can be installed at this time or after the cylinder head is installed on the engine.

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.

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.

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 rotated 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 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.

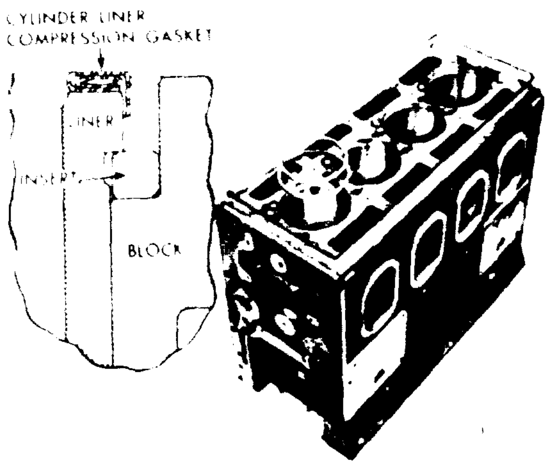


Figure 11B-34. Cylinder Head Seals and Gaskets

Install Cylinder Head

1. Refer to Figure 11B-34 and install the water and oil seal rings and compression gaskets as follows:

NOTE

Never install used compression gaskets or seals.

A. Place a new compression gasket on top of each cylinder liner. A new cylinder liner compression gasket with improved sealing capabilities is now being used (see Figure 11B-35). The compression gasket is also color coded black, orange or white. The service gasket kits will only include a single color (black or orange). Only one color compression gaskets (seal) can be used under a single cylinder head to provide proper clamping.

NOTE

The new cylinder liner compression gasket is not interchangeable on an engine under the same cylinder head with the former compression gasket. Mixing of the former gasket with the new gasket could result in uneven loading.

B. 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) Attach a mask or template to the cylinder block fire deck to minimize overspray.

2) Using a high tack, spray tube 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.

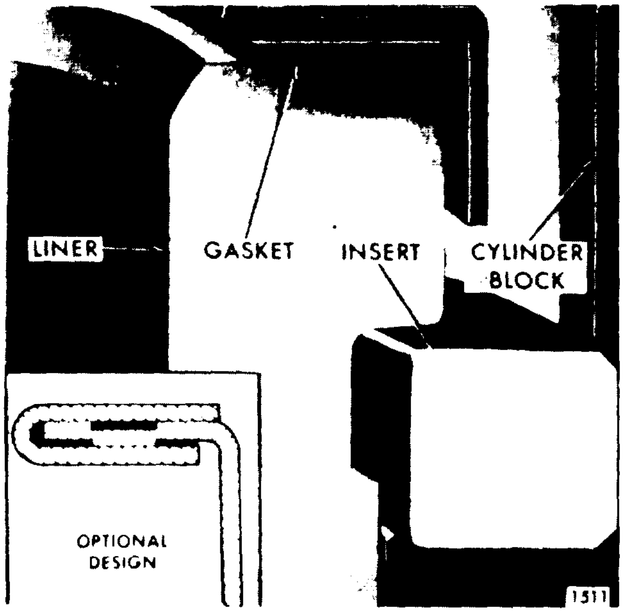


Figure 11B-35. Compression Gasket Mounting in Cylinder Block

3) Allow the adhesive to dry to a high tack consistency (stickness) before installing the seal. This permits the evaporation of the liquid propellant used with the adhesive. Do not apply adhesive directly to the seal. The adhesive will coat the inner diameter of the seal and the spray propellant may cause the seal to swell temporarily.

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 or stretched when installed. Installing the seal strip in the groove with the colored strip 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.

2. To install the cylinder head on the engine without disturbing the gasket and seals, install guide studs J 9665 in two corner bolt holes in the cylinder block.

NOTE

The 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 vent holes of the cylinder head, or 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 a very important check. Gasket 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. Either one or 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.

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 chain hoist and install the remaining bolts, running all bolts down snug tight with a speed wrench (15-20 lb-ft or 20-27 Nm torque). However, before tightening the lifter 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 bosses on the cylinder block.

8. Tighten the bolts (or nuts) to 175-185 lb-ft (238-251 Nm) torque in 50 lb-ft (68 Nm) increments with a torque wrench, in the sequence shown in Figure 11B-36 on page 11B-25. Repeat the tightening sequence at least once, because the first bolts tightened in the sequence tend to lose significant clamp load during tightening 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.

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 lb-ft (75-81 Nm) torque (see Figure 11B-37 on page 11B-25).

10. Affix a new gasket to the front lifter bracket (or vent casting) 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.

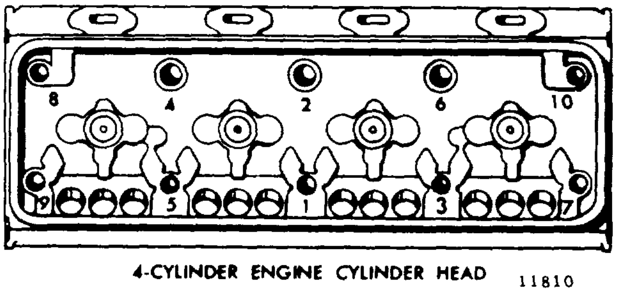


Figure 11B-36. Cylinder Head Bolt Tightening Sequence

11. If the fuel injectors were not previously installed, install them at this time.

12. Adjust the exhaust valve bridges as outlined later in this subsection.

13. Tighten the rocker arm bracket bolts to the specified torque.

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 lb-ft (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 damaged to the engine bearings.

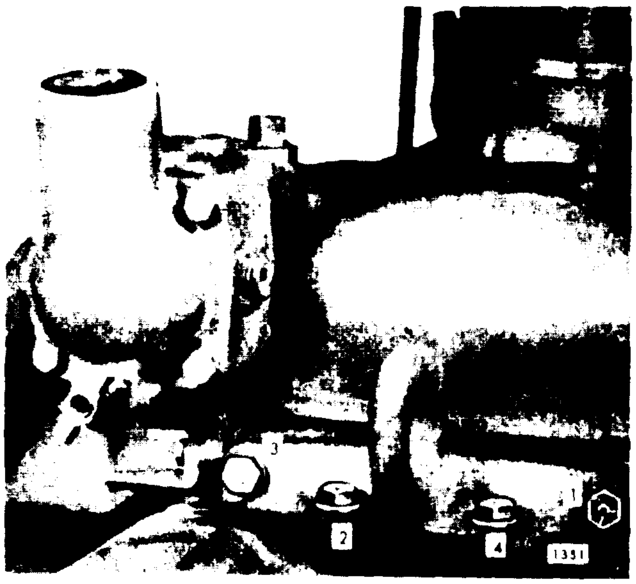


Figure 11B-37. Lifter Bracket Bolt Tightening Sequence

15. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight. When positioning 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 lb-ft (14-16 Nm 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 temperature gauge thermocouple in the adaptor at the rear of the water manifold.

22. Install the thermostat and secure the thermostat housing to the water manifold with four bolts and lockwashers.

23. Position the seal and clamp between the water manifold and the thermostat housing on a heat exchanger unit and tighten the seal clamp. Slide the hose into position on the radiator and secure it with two clamps.

24. Install any other equipment or parts that were previously removed.

25. Refer to Subsection 11H and fill the cooling system and lubrication system.

26. Before starting the engine, perform an engine tune-up as outlined in Subsection 11H.

VALVE AND INJECTOR OPERATING MECHANISM

Description

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 rock 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 follower 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.

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 (see Figure 11B-38).

Overflow oil from the rocker arms lubricates the exhaust valves, valve bridges

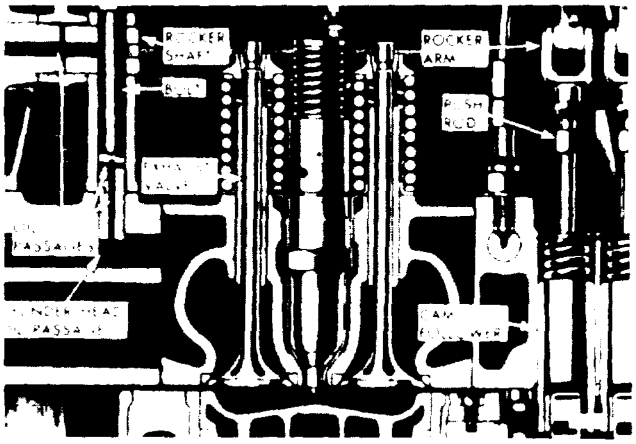


Figure 11B-38. Lubrication of Valve Operating Mechanism

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.

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.

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.

CAUTION

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 lock nuts at the upper ends of the push rods, next to the clevies, and unscrew the rocker arms from the push rods.

NOTE

If the rocker arms and shafts from two or more cylinder are to be removed, tag them so they may be reinstalled in their original positions.

Inspection

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 0.004" is allowable with used parts. 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). If worn, the surface may be refaced up to a maximum of 0.010". 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.

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 followers 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 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 the groove in the cylinder head (see Figure 11B-39 on page 11B-28).

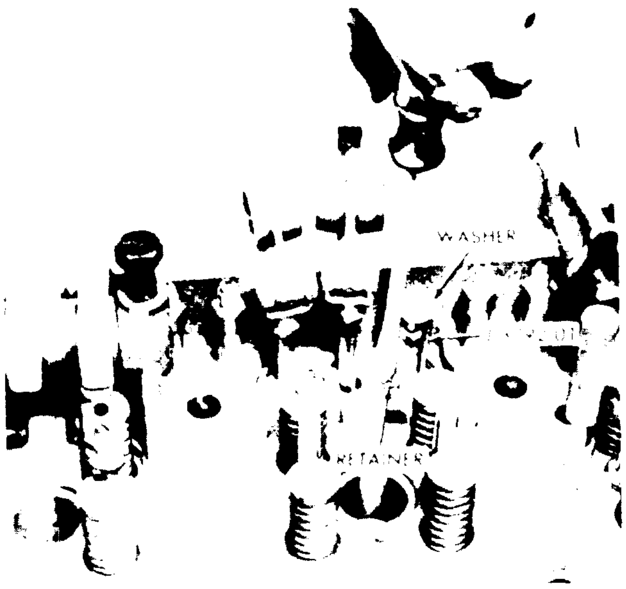


Figure 11B-39. Removing Push Rod from Upper Side of Cylinder Head

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.

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 locations.

1. Rest the cylinder head on its side (Figure 11B-40) and remove the cam follower guide.

2. Remove the cam follower out of the cylinder head.

3. Remove the fuel pipes from the injectors and the fuel connectors.

NOTE

> Immediately after removing the fuel pipes, cover the injector 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.

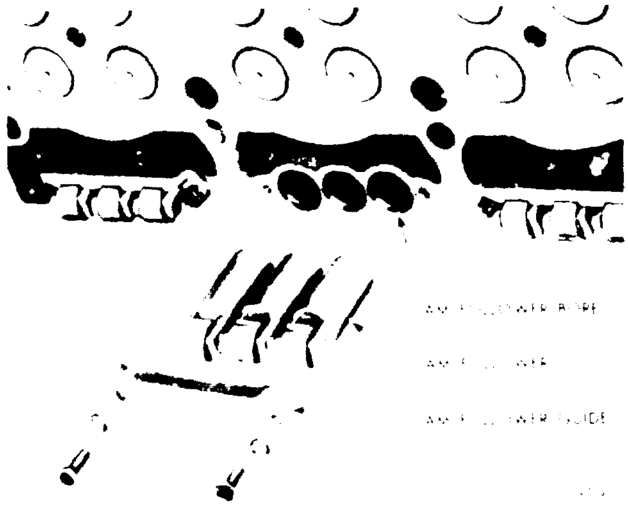


Figure 11B-40. Cam Followers and Guides

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.

Inspection

Proper inspection and service of the cam follower is 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.

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 roller must turn freely on their pins. Measure

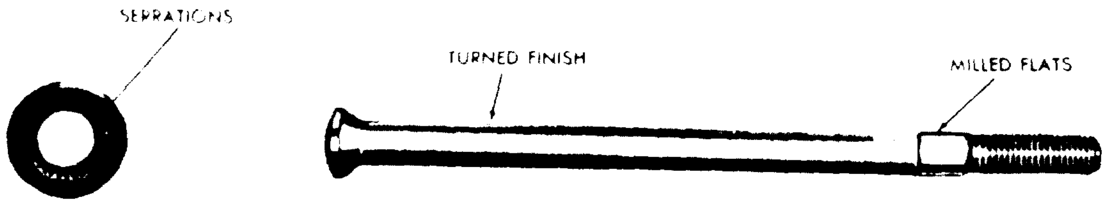


Figure 11B-42. Push Rod and Lower Spring Seat

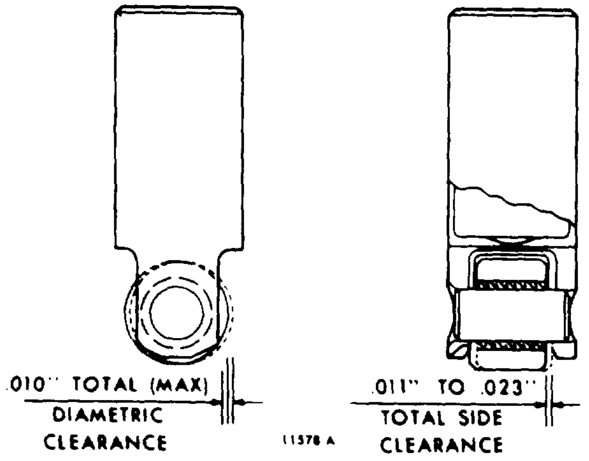


Figure 11B-41. Cam Roller Clearance

the total diametric clearance and side clearance. Install a new roller and pin if the clearances exceed those specified in Figure 11B-41 on page 11B-29. 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 reading. Measure the diameter of the cam follower with a micrometer. Record the readings and compare the readings of the followers and bores to determine the cam follower-to bore clearances.

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 (see Figure 11B-42).

Examine the cam follower springs for wear or damage and check the spring load. Replace a spring when a load of less then 172 lbs (765 N) will compress it to a length of 2.125". Use spring tester J 22738-02 to check the spring load (see Figure 11B-43).

Replace Cam Roller and Pin

To replace a cam roller and pin, proceed as follows:

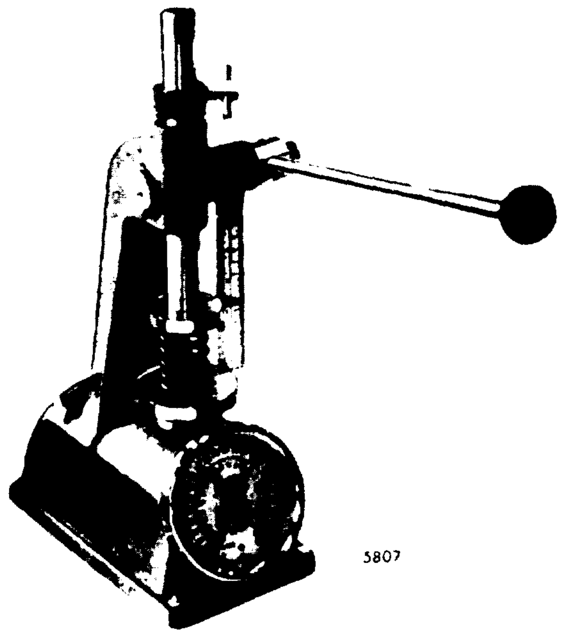


Figure 11B-43. Testing Cam Follower Spring

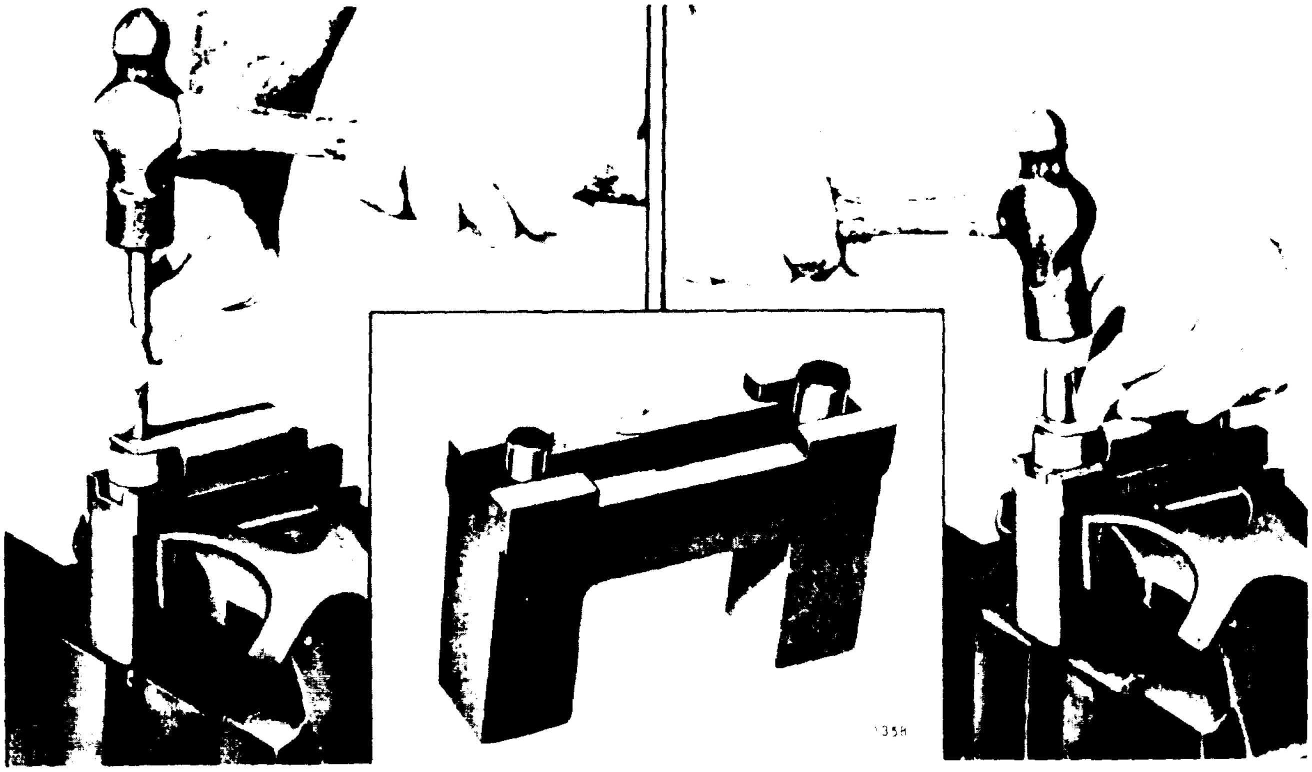


Figure 11B-44. Removing or Installing Cam Follower Roller

NOTE

Do not attempt to bore out the legs of a standard cam follower for an oversize pin.

1. Clamp fixture J 5640-01 securely in a vise as shown in Figure 11B-44. 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 (see Figure 11B-41 on page 11B-29). The clearance must be 0.011” to 0.023”.

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 then 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 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

Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent the cam followers from touching the bottom of the pail. and avoid the possibility of contamination.

Install used cam followers and push rods in their original locations. Refer to Figure 11B-45 and proceed as follows:

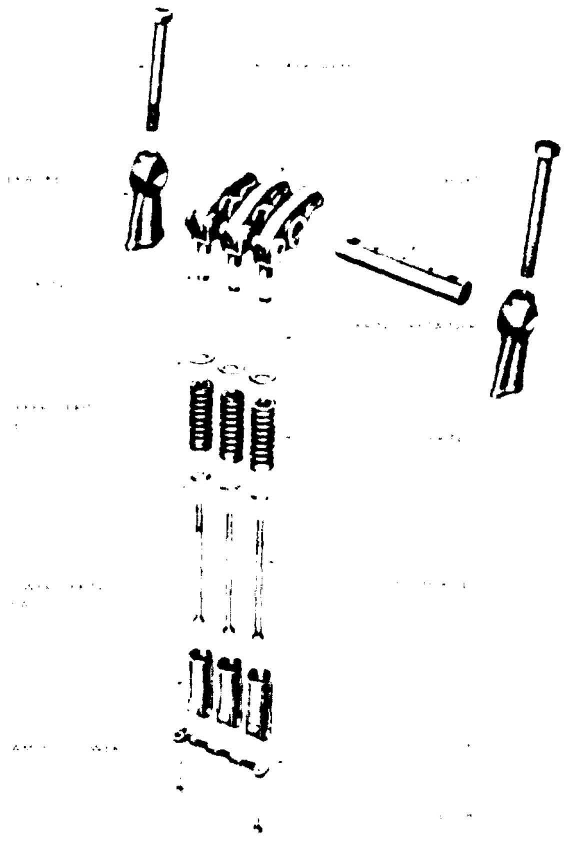


Figure 11B45. Valve Operating Mechanism

CYLINDER HEAD ON ENGINE. Use the following procedure if the cylinder head has not been removed from the cylinder block

1. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust (Figure 11B-46), slide the cam follower in position in the cylinder head.

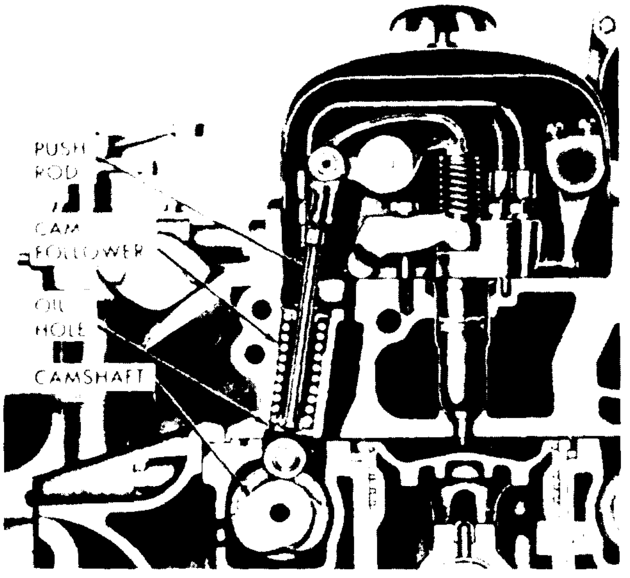


Figure 11B-46. Installation of Cam Followers

2. Assemble the serrated lower spring seat (Figure 11B-42 on page 11B-29), 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. If the cylinder head has been removed from the engine, proceed as follows (see Figure 11B-45):

1. Assemble the serrated lower spring seat (Figure 11B-42 on page 11B-29), 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 oil directed away from the exhaust valves (Figure 11B-46), 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. Tighten the guide bolts to 12-15 lb-ft (16-20 Nm) torque. Check to be sure there is at least 0.005" clearance between the cam follower legs and the cam follower guide (see Figure 11B-47) If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (see Figure 11B-48). Then retighten the bolts to the specified torque.

NOTE

It is important to use the correct bolts as prescribed in the parts manual. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation.

Install Rocker Arms and Shaft

Note that the injector rock 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 rock arms are 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.

2. If removed, install the cylinder head on the engine.

3. Lubricate the valve bridge guide with sulphurized oil (E.P. type) and position the valve bridges in place on the guides. Refer to Exhaust Valve Bridge Adjustment, and adjust the valve bridges.

4. If removed, install the fuel injectors.

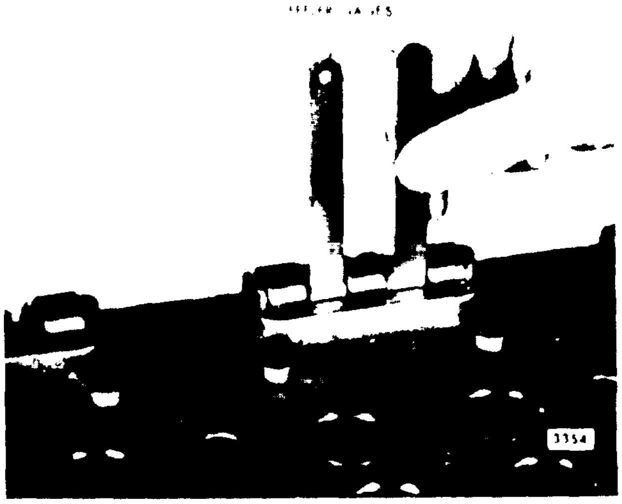


Figure 11B-47. Checking Cam Follower to Guide Clearance

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. Tight the bolts to the specified torque.

7. Align the fuel pipes and connect them to the injectors and fuel connectors. Tighten the fuel pipe nuts to 12-15 lb-ft (16-20 Nm) torque using socket J 8932-01.

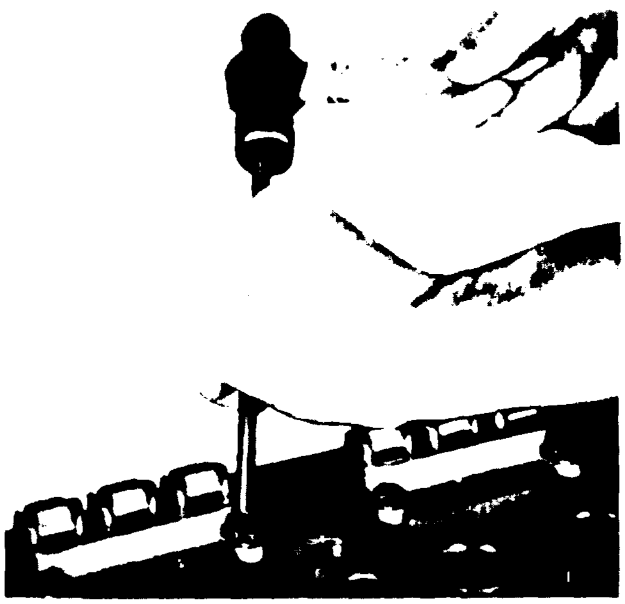


Figure 11B-48. Adjusting Cam follower Guide

NOTE

> Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end 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.

10. If necessary, perform an engine tune up.

EXHAUST VALVES

Description

Four exhaust valves are provide for each cylinder (see Figure 11B-49). 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.

Exhaust valve seat inserts (Figure 11B-50 on page 11B-341, pressed into the cylinder head permit accurate seating of the exhaust valve 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 lubricate 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.

Figure 11B-49. Location of Exhaust Valves

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 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 (71-85°C). 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 valve and valve seats and loss of compression will result.

Lubricating oil and oil filter 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 accurate adjusted and checked periodically. Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion.

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.

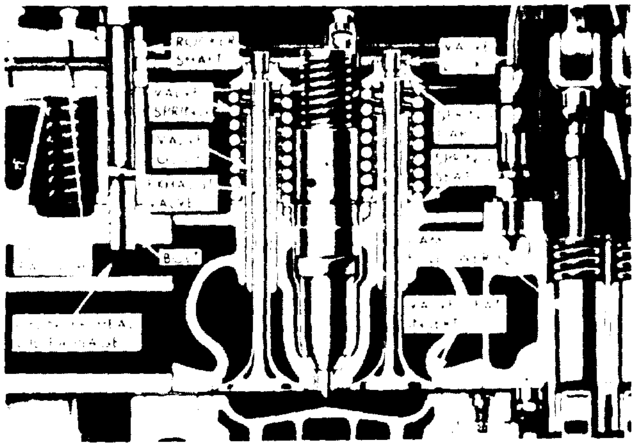


Figure 11B-50. Assembly of Exhaust Valves and Guides

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 7455-1 into one of the rocker arm bracket bolt holes in the cylinder head (see Figure 11B-51 on page 11B-35). 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.

Remove Exhaust Valves and Valve Springs (Cylinder Head Removed)

With the cylinder head removed from the engine, remove the exhaust valve and springs as follows:

1. Support the cylinder 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.

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 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.

7. Thread the valve spring compressor adaptor J 7455-1 into one of the rocker arm bracket bolt holes in the cylinder head (see Figure 11B-51). 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.

9. Turn the cylinder head over, using care to keep the valves from falling out of the head. If the valves are to be reused, number each valve to facilitate reinstallation in the same location. Then withdraw the valves from the cylinder head.

10. Remove the cam followers and push rod assemblies as outlined under Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).

Inspection

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 (see Figure 11B-52 on page 11B-36). The exhaust valve spring has

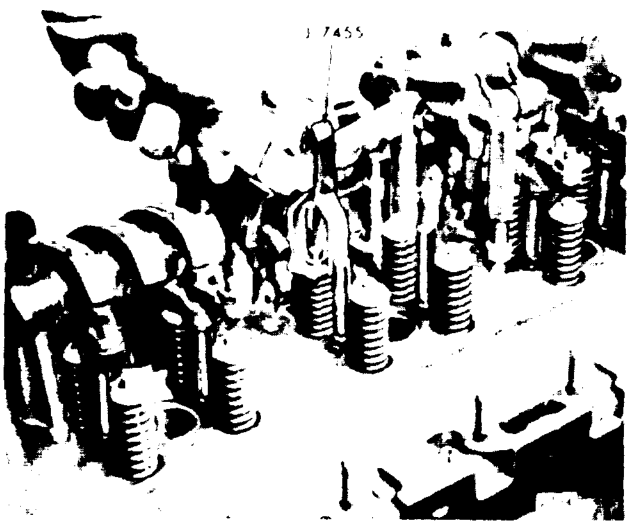


Figure 11B-51. Removing Exhaust Valve Spring

an outside diameter of approximately 0.953". Replace this 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 or galling. Replace excessively worn parts.

Carbon on the face of a valve could indicate blow-by due to a fault 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 (see Figure 11B-53 on page 11B-36). 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 ob-

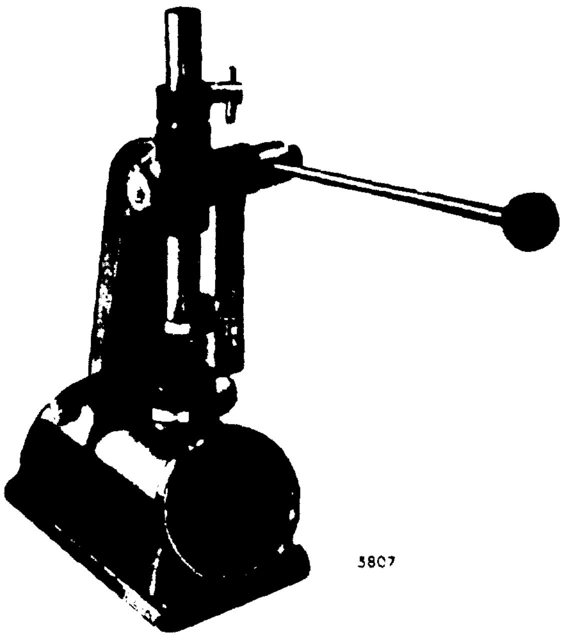


Figure 11B-52. Testing Exhaust Valve Spring

tain the valve-to-guide clearance. If the clearance exceeds 0.005", replace the valve guides.

Replace Exhaust Valve Guide

Remove an exhaust valve guide as follows:

1. Support the cylinder, bottom side up, on 3" thick wood blocks.

2. Drive the valve guide out of the cylinder head with valve guide remover J 6569 shown in Figure 11B-54 on page 11B-37.

Place the cylinder head right side up on the bed of an arbor press and install the valve guide as follows (see Figure 11B-55 on page 11B-37):

1. Insert the internally threaded end of the valve guide in valve guide installation tool J 21520. Be sure to use the correct tool to avoid damage to the valve guide, and to locate the valve guide to the proper dimension.

2. Position the valve guide squarely in the bore in the cylinder head and press the installing tool gently to start the guide in place (see Figure 11B-56 on page 11B-37). Then press the guide in until the tool contacts the cylinder head.

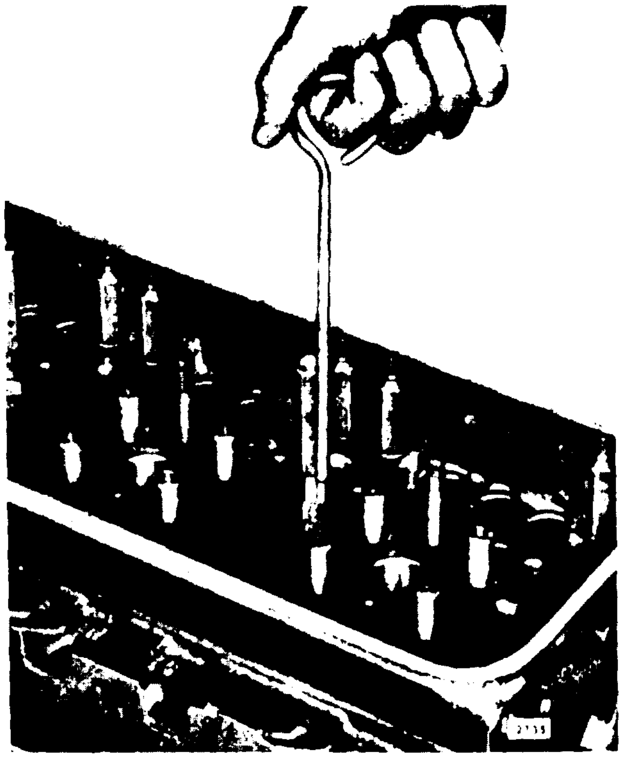


Figure 11B-53. Cleaning Valve Guide

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.

Remove Exhaust Valve Bridge Guide

Remove the press-fit valve bridge guide with tool J 7091-01 as follows (see Figure 11B-57 on page 11B-37):

1. 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.

2. Place spacer J 7091-3 over the guide. Then slide 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.

3. Place spacer J 7091-4 over the guide remover. Thread the nut on the guide

Figure 11B-54. Removing Exhaust Valve Guide

remover and turn it clockwise to withdraw the guide from the cylinder head.

To remove a broken valve bridge drill a hole approximately 1/2" deep in the end of the guide with a No. 3 (0.2130") 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 (see Figure 11B-58 on page 11B-38).

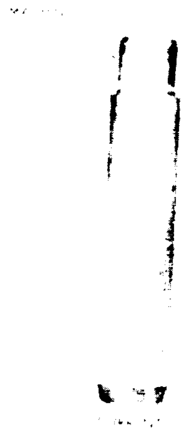


Figure 11B-55. Valve Guide

Install Exhaust Valve Bridge Guide

Install the press-fit bridge guide as follows:

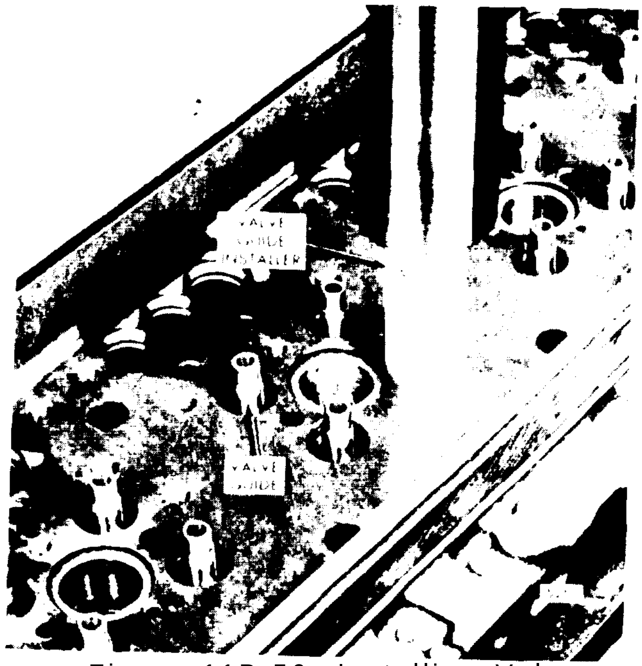


Figure 11B-56. Installing Valve Guide

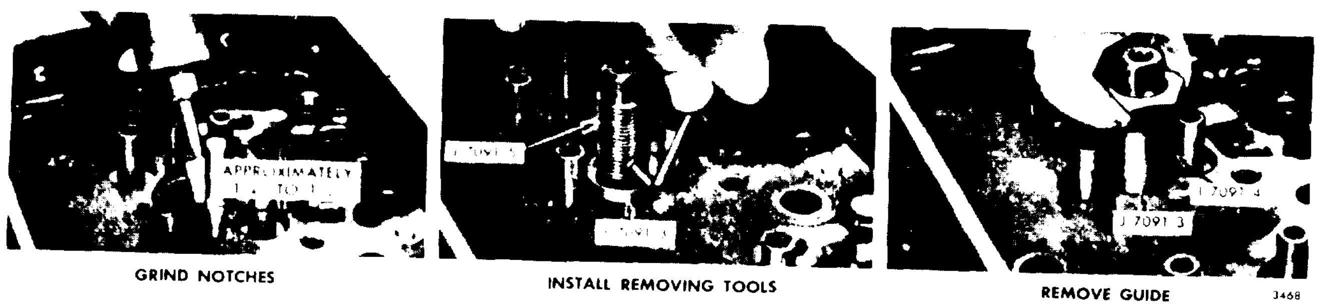


Figure 11B-57. Removing Press-Fit Exhaust Valve Bridge Guide

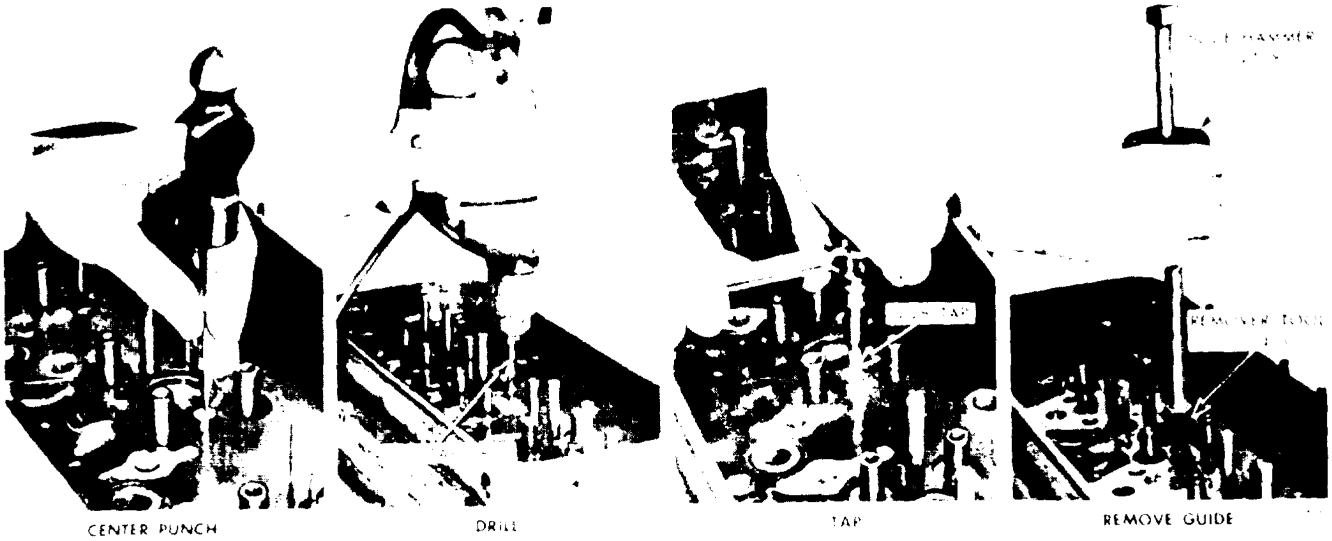


Figure 11B-58. Removing Broken Exhaust Valve Bridge

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").

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 0.002".

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°.

Remove Exhaust Valve Seat Insert

The valve seat inserts are pressed into the cylinder 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 Figure 11B-59 on page 11B-39.

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.

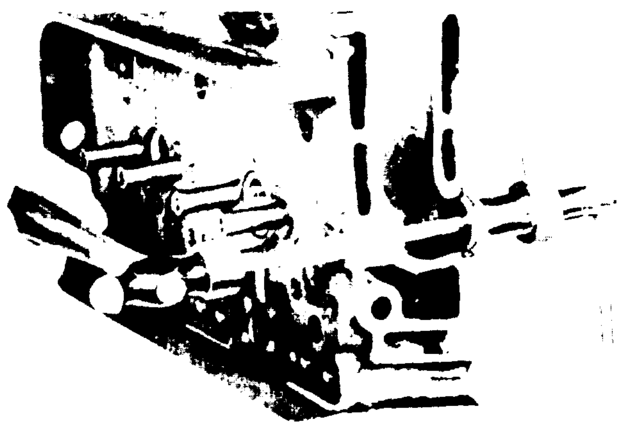


Figure 11B-59. Removing Valve Seat Insert

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.

Install Exhaust Valve Seat Insert

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 counter bores have a diameter of 1.260" to 1.261" and a depth of 0.338" to 0.352". The counterbores must be concentric with the valve guides within 0.003” total indicator reading. Valve seat inserts which are 0.010" oversize on the outside diameter are available, if required.

3. Immerse the cylinder head for at least thirty minutes in water heated to 180-200°F (82-93°C).

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 6568 as shown in Figure 11B-60 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.

Recondition Exhaust Valve and Valve Seat

An exhaust valve which is to be reused may be refaced, if necessary (see Figure 11B-62 on page 11B-40). To provide sufficient valve strength and spring tension, the edge of the valve at

Figure 11B-60. Installing Valve Seat

the valve head must not be less the 0.031" in thickness and must still be within the specifications shown in Figure 11B-61 after refacing.

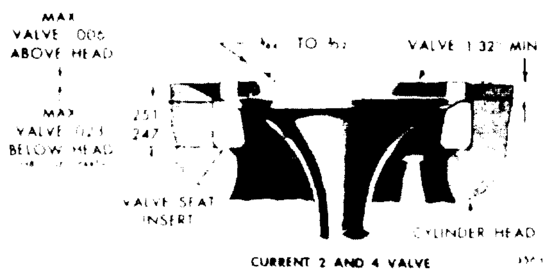


Figure 11B-61. Relationship of New Valve, Insert and Cylinder Head

NOTE

The seating area of the exhaust valve is aluminized, which gives the valve seat a dull finish. Do not remove the aluminum coating on a new valve. However, a used valve may be refaced if necessary.

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 30° and for the valve seat insert it is 31°.

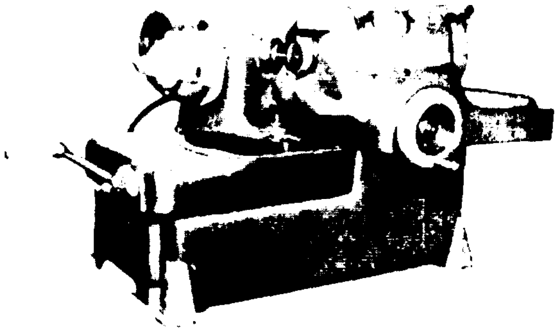


Figure 11B-62. Refacing Exhaust Valve

When a new valve insert is installed or an old insert is reconditioned, the work must done with a grinding wheel (see Figure 11B-63 on page 11B-40).

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 0.001" at a time.

Eccentric valve seat grinder set J 7040, which includes the grinder, dress stand and pilot, and dial gauge, 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, consists of the following:

1. Pilot, tool J 7659-1
2. Grinding wheel (15°), tool J 6390-2
3. Grinding wheel (31°), tool J 6390-3
4. Grinding wheel (60°), 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 Figure 11B-61 on page 11B-39. The 31° face of the insert may be adjusted relative to the center of the valve face with the 15° and 60° grinding wheels.

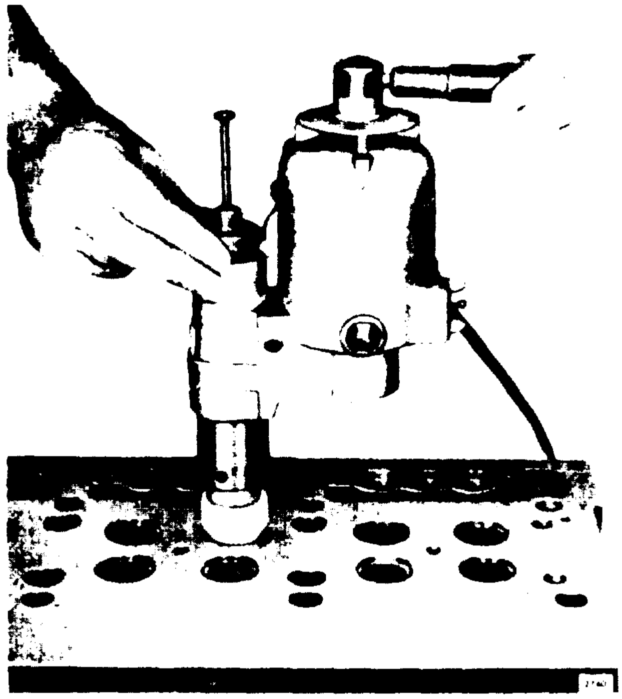


Figure 11B-63. Reconditioning Valve Seat Insert

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 Figure 11B-61 on page 11B-39. Grinding will reduce the thickness of the valve seat insert and cause the valve to receded into the cylinder head. If, after several grinding operations, the valve recedes beyond the specified limits, replace the valve seat insert.

When occasion requires, the grinding wheel may be dressed to maintain the desire seat angle with the dressing tool provided with the grinder set (see Figure 11B-64 on page 11B-41).

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 Figure 11B-65 on page 11B-41 and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. If the runout exceeds 0.002", check for a bent valve guide before regrinding the insert.

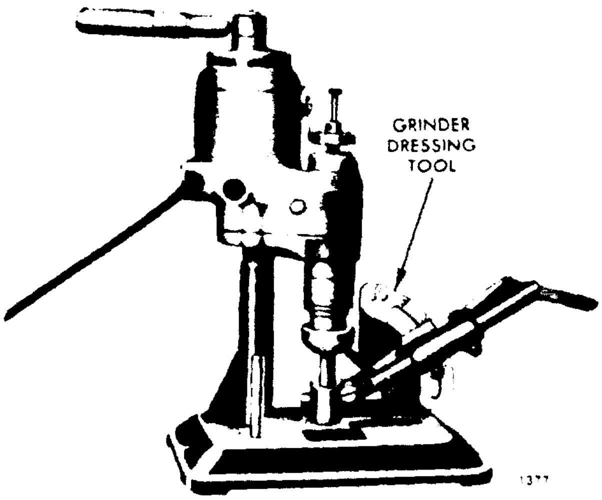


Figure 11B-64. Grinding Wheel Dressing Tool

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:

A. Apply a light coat of Prussian blue, or a similar paste, to the valve insert.

B. 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 cylinder of the valve face.

NOTE

The use of valve lapping compound is not recommended.

After the valve seat inserts have been ground and checked, clean the cylinder head before installing the valves.

Install Exhaust Valves and Springs

Install the exhaust valve as follows:

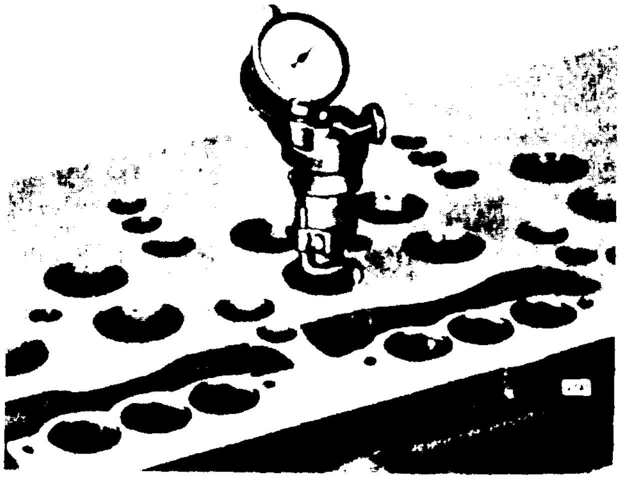


Figure 11B-65. Determining Concentricity of Valve Seat Insert

1. Clean the valve guides.

2. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valve all the way into the guides.

CAUTION

If reconditioned valves are used install them in the same relative location from which they were removed.

3. Hold the valve 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 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 (see Figure 11B-51 on page 11B-35).

7. Apply pressure to the free end of the tool to compress the valve sprin 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 springs too far may result in damage to the 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 valves (see Figure 11B-61 on page 11B-39). Support the cylinder head at each end with wood blocks and remove the masking tape so that the exhaust valve 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 reduces the chances of failure.

10. With exhaust valves installed in the cylinder head, us spring checking gauge J 25076-01 and note the gauge reading the moment the exhaust valve starts to open (see Figure 11B-66). The minimum allowable pressure required to start to open the exhaust valve must not be less then 20 pounds (89 N).

11. Install the injectors, rocker arms, shafts, brackets and any other parts previously removed from the cylinder head.

12. Install the cylinder. Refer to Pre-Installation Inspection and Install Cylinder Head. Adjust the exhaust valve bridges as outlined below.

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.

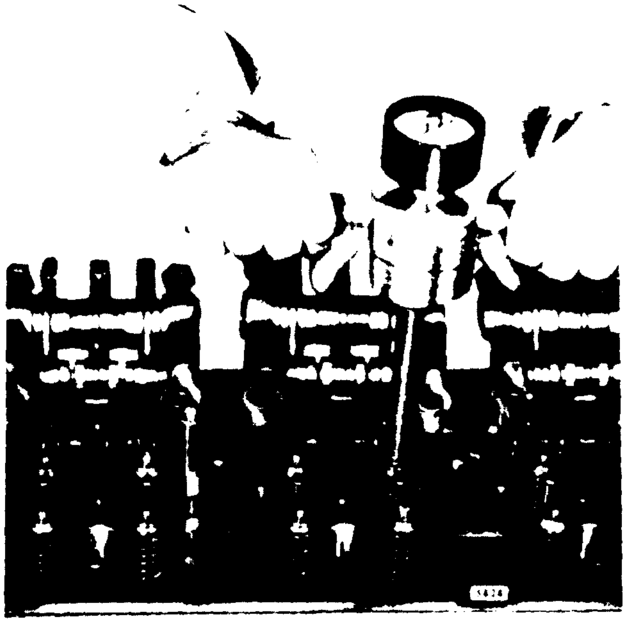


Figure 11B-66. Checking Pressure Required to Open Exhaust Valve

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 1/4 turn clockwise and tighten the lock nut finger tight (see Figure 11B-67 on page 11B-43.

4. Remove the valve bridge and place it in a vise. Use a screwdriver to hold the adjustment screw from turning and tighten the lock nut to 20-25 lb-ft (27-34 Nm) 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 0.0015” feeler gauge (J 23185) under each end of the valve bridge or use a narrow strip cut from 0.0015” feeler stock to fit in the bridge locating groove over the inner exhaust valve. While pressing down on the pallet surface

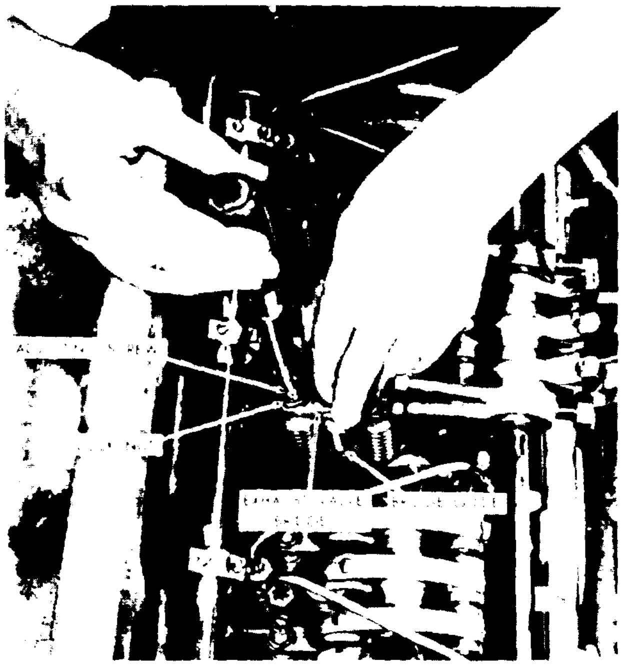


Figure 11B-67. Valve Bridge Adjustment

of the valve bridge, both feeler gauges must be tight. If both of the feeler gauges are not tight, readjust the adjusting screw.

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 over 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 at the end of this subsection.

Figure 11B-68. Lifter Bracket Bolt Tightening Sequence

After the cylinder head is installed and the valve bridges adjusted, proceed as follows:

1. Install the fuel pipes.

2. Fill the cooling system.

3. Adjust the exhaust valve clearance and time the injectors. See Subsection 11H.

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 Subsection 11H.

ENGINE LIFTER BRACKETS

Description

The engine lifter brackets not only provide a means of lifting the engine assembly, the cylinder head or the flywheel housing, but also serve as a vent for the crankcase vapors.

Lifter brackets require no servicing other than removal during other service operations.

Install Engine Lifter Brackets

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.

NOTE

> The lifter brackets must not be permanently attached until all of the cylinder head stud nuts or retaining bolts have been tighten 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 (Figure 11B-68) for each of these steps to draw the mating parts together evenly, thus providing a good seal. Tighten the bolts to 55-60 lb-ft (75-81 Nm) torque.

5. Install the rear lifter bracket to the cylinder head and flywheel housing in a similar manner.

VALVE ROCKER COVER

Description

The valve rocker cover assembly (Figure 11B-69 on page 11B-45) 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 cover.

The rocker cover 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. 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 lb-ft (20-27 Nm) torque.

CAUTION

> The shorter rocker cover bolt, which threads into the throttle delay bracket, can crack the bracket if overtightened. Also, the rocker cover bolt is especially designed for this purpose and must not be replaced with an ordinary bolts.

The valve rocker cover assembly includes: a breather assembly and an oil filler.

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 reinstalling the cover.

Before the cover is installed on a cylinder head, it is important that the silicone gasket be properly installed in its groove in the rocker cover.

1. Clean and blow out the groove in the rocker cover with compressed air. Oil in the groove or on the silicone gasket will make it difficult to install.

2. Press the stem side of the new Y shaped gasket down into the groove at the four corners of the cover first. Then press the remainder of the gasket into place in the groove (see Figure 11B-69 on page 11B-45). Be sure the stem of the entire gasket bottoms in the groove.

NOTE

> When the gasket is completely installed in the groove it should not fall out.

3. Before installing the rocker cover, lubricate the cylinder head rail and the flat surface of the gasket with a thin film of engine oil. This will keep the gasket from sticking to the cylinder head rail.

CRANKSHAFT

Description

The crankshaft 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 rod and main bearings is provided by drilled passages within the crankshaft and cylinder block.

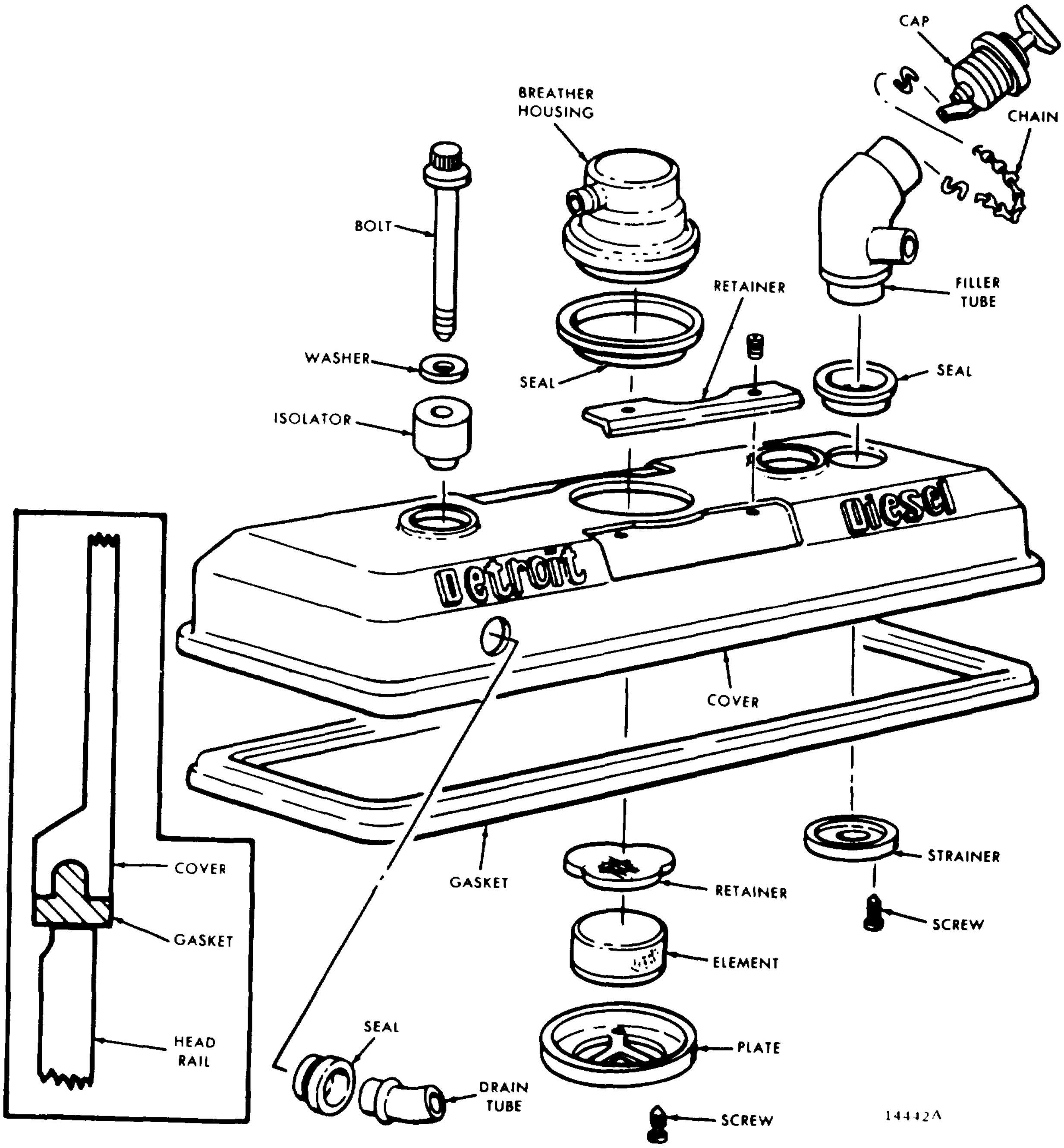


Figure 11B-69. Valve Rocker Cover Assembly

CAUTION

Extreme caution should be used when removing a flywheel by either leaving one or two bolts in the flywheel, or installing two suitable guide pins to support the flywheel until a lifting tool or some other suitable safe lifting device is attached to the flywheel.

Each main bearing journal is 3-1/2" in diameter and each connecting rod journal is 2-3/4" in diameter.

Remove Crankshaft

When removal of the crankshaft becomes necessary, first remove the torque converter, 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 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 overhaul stand.

6. Mount the engine on an overhual stand and fasten it securely to the mounting plate (see Figure 11B-5 on page 11B-3).

WARNING

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.

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.

21. Refer to this subsection for removal of the crankshaft timing gear and Subsection 11E for the procedure covering removal of the oil pump drive gear.

Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

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 (see Figure 11B-70 on page 11B-47). Ridges exceeding 0.0002" 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 0.0005", 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 wrapping 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 0.001", the crankshaft may have to be reground.

Carefully inspect the rear 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.

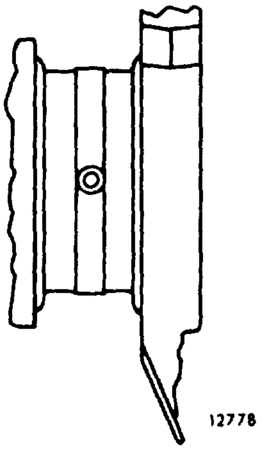


Figure 11B-70. Ridging of Crankshaft

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 this subsection.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise 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.

Check the crankshaft dowel extension. Dowels extend 1/2" from the crankshaft. Check to make sure the dowels DO NOT extend more than 1/2", otherwise interference with the torque converter flywheel will result.

Inspect the crankshaft for cracks as outlined under Inspection for Cracks.

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 0.003" total indicator reading. When the run out on the adjacent journals is in the same direction, the difference must not exceed 0.003" total indicator reading. If the runout limit is greater than 0.002" at the No. 2 and 4 journal, or 0.004" at the No. 3 journal, the crankshaft must be replaced.

Measure all of the main and connecting rod bearing journals (see Figure 11B-73 on page 11B-49). 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 0.0044", the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest 0.0002". Also, if the journal taper of a used crankshaft exceeds 0.0015" or the out-of-round is greater than 0.001", the crankshaft must be reground.

Also measure the crankshaft thrust surfaces (see Figure 11B-75 on page 11B-50).

Inspection for Cracks

Carefully check the crankshaft for crack which start at an oil hole and follow the journal surface at an angle of 45° 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.

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”.

FLOURESCENT PENETRANT METHOD. This is a method which may be used on both non-magnetic and magnetic materials. A highly fluorescent liquid penetrant is applied to the part. Then the excess penetrant is removed from 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 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 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 break 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 (see Figure 11B-71).

Bending fatigue failures result from bending of the crankshaft which take 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

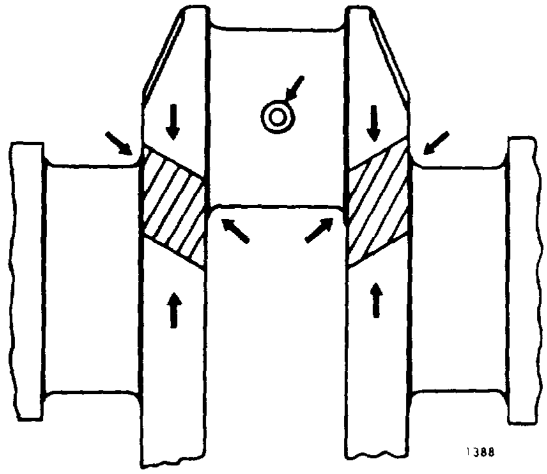


Figure 11B-71. Critical Crankshaft Loading Zones

tight may impose a bending load upon the crankshaft.

Failure 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 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 Figure 11B-71.

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, damage or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are 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 crankshaft 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 Figure 11B-72. Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, 0.002", 0.010", 0.020" and 0.030" undersize bearings are available.

NOTE

The 0.002" undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

If the crankshaft is to be reground, proceed as follows:

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Figure 11B-73 and determine the size to which the journals are to be reground.

2. If one or more main 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 0.130" to 0.160" radius between the crank cheek and the journal and must not have any sharp grind marks (see Figure 11B-74 on page 11B-50). 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 gauge.

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 8-12 RMS finish. The reground journals will be subject to excessive wear unless polished smooth.

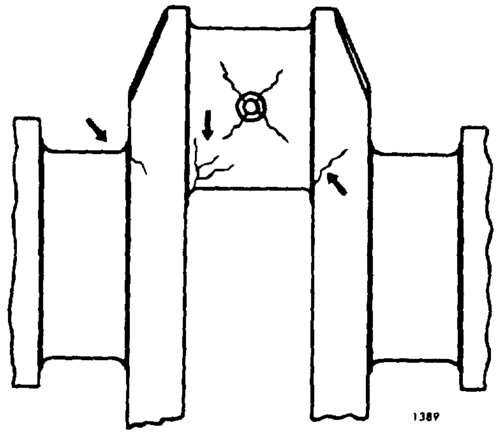
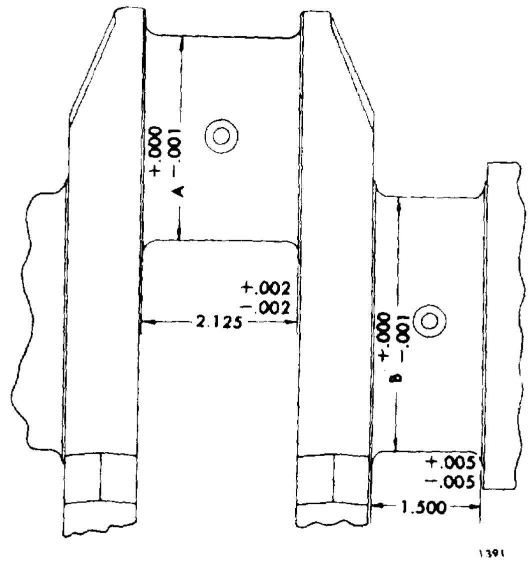


Figure 11B-72. Crankshaft Fatigue Cracks

6. If the thrust surfaces of the crankshaft (Figure 11B-76 on page 11B-50) are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a 0.130" to 0.160"



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"

Figure 118-73. Dimension of Crankshaft Journals

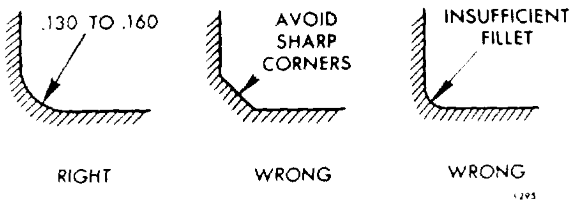


Figure 11B-74. Crankshaft Journal Fillets

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 has originated due to the grinding operation.

9. Demagnetize the crankshaft.

10. Remove the plugs and clean the crankshaft and oil passage thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventative, blow out the oil passages with compressed air and install the plugs.

NOTE

A new or remanufactured crankshaft receives a rolling process in the fillet area for added strength. Oftentimes this leaves a slightly raised area at each end of the fillet (see Figure 11B-75). This is an acceptable shaft and must not be confused with outside reground shafts that are left with a notch rather than a required blend as outlined under "Crankshaft Grinding" on page 11B-49.

Then install the crankshaft as follows:

1. Assemble the crankshaft timing gear and the oil pump drive gear on the crankshaft (refer to Subsection 11E).

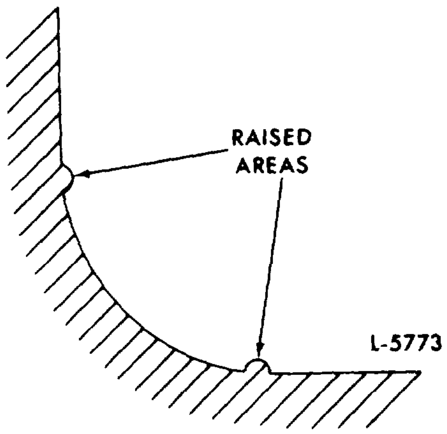
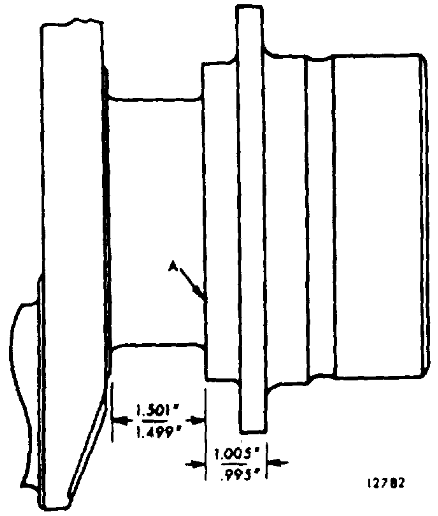


Figure 11B-75. New or Remanufactured Crankshaft

2. Refer to this subsection for main bearing details and install the upper grooved main bearing shell 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)



Nominal Size	Thrust Washer Thickness	
	Min.	Max.
Standard	.1190"	.1220"
.005" Oversize	.1240"	.1270"
.010" Oversize	.1290"	.1320"

Figure 11B-76. Standard Dimensions at Crankshaft Thrust Surfaces bearing shells and new thrust washers must also be installed.

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 this subsection for the correct method of timing 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

If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both of the rear main bearing journal. Refer to Figure 11B-76 on page 11B-50.

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 (Crankshaft in Place)" on page 11B-60.

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.

7. Check the crankshaft end play by moving the crankshaft toward the gauge (Figure 11B-77) with a pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. them 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 0.004" to 0.011" with new parts or a maximum of 0.018" with used parts. Insufficient end play can be to result of a misaligned rear main bear-

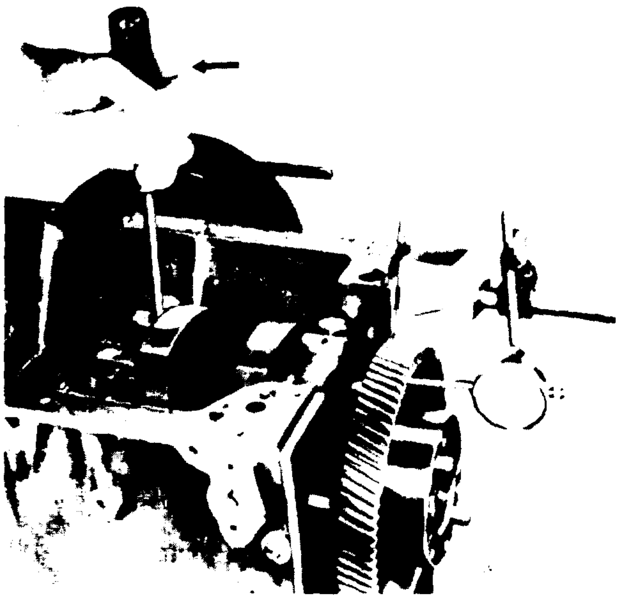


Figure 11B-77. Checking Crankshaft End Play

ing 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.

9. Install the cylinder head.

10. Install the flywheel housing, then install the flywheel.

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.

14. Install the vibration damper assembly.

15. Install the crankshaft cap or pulley.

16. Install the lubricating oil pump assembly.

17. Check the crankshaft for distortion at the rear connecting rod journal counterweights before and after installing the torque converter. An improperly in-

stalled torque converter can distort the crankshaft and cause a crankshaft failure

Check the crankshaft distortion as follows:

A. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the six o'clock position.

B. Center punch a hole in the inside face of each counterweight cheek, one quarter of an inch from the lower end of each counterweight, to support the gauge.

C. Install a gauge (Starret Co. No. 696 dial gauge or equivalent) in the center punch holes in the cheek of each counterweight as shown in Figure 11B-78.

D. Set the dial indicator at zero, then rotate the crankshaft approximately 90° in both directions. Do not allow the gauge to contact the connecting rod caps or bolts. Note and record the dial indicator readings at the 3, 6 and 9 o'clock crankshaft counterweight positions. The maximum allowable variation is 0.0045" total indicator reading.

NOTE

Remove the tool that was used to rotate the crankshaft when taking the dial indicator readings.

E. If the reading on the gauge exceeds 0.0045", check the torque converter for improper installation and realign as necessary.

18. Affix a new gasket to the oil pan flange and install the oil pan.

19. Use a chain hoist and sling attached to the lifting brackets at each end of the engine and remove the engine from the overhaul stand.

20. Install all of the accessories that were removed.

21. After the engine has been completely reassembled refer to Section 11H and refill the crankcase to the proper level on the dip stick.

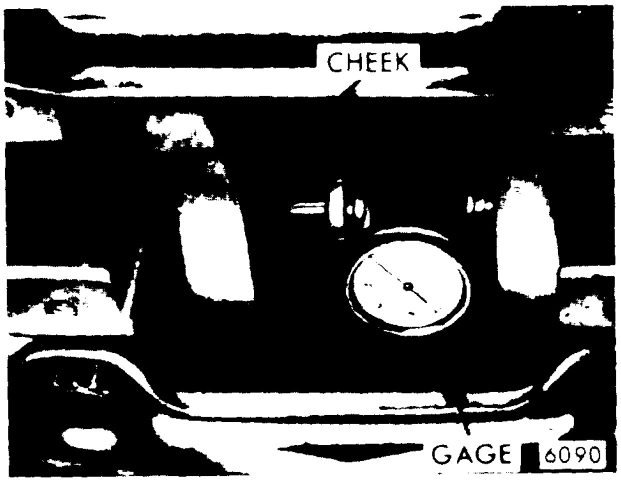


Figure 11B-78. Crankshaft Distortion Gauge Mounted on Crankshaft

22. Close all of the drains and fill the cooling system.

23. 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 at the end of the section.

CRANKSHAFT OIL SEALS

Description

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 vibration damper inner cone on the end of the crankshaft, next to the lubricating oil pump drive gear (see Figure 11B-79 on page 11B-53 and Figure 11B-80 on page 11B-53).

A single lip oil seal is used at the rear end of the engine. The rear oil seal is pressed into the flywheel housing (see Figure 11B-81 on page 11B-53).

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

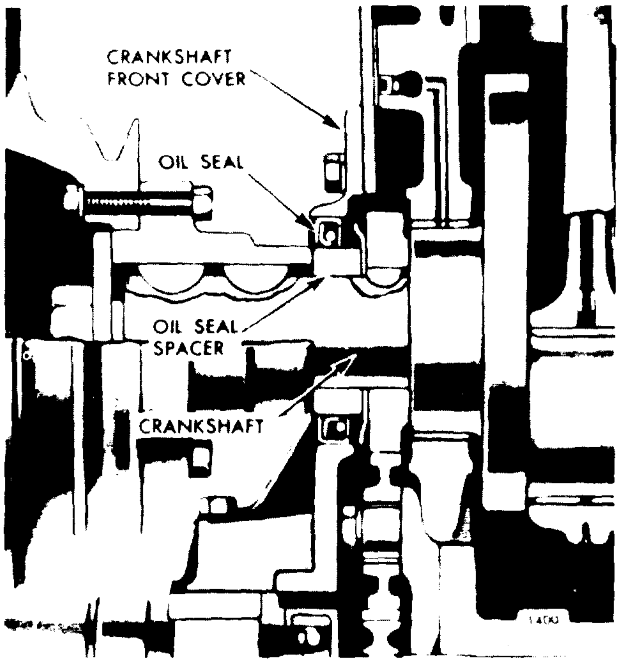


Figure 11B-79. Crankshaft Front Oil Seal

conditions must be checked and corrected.

Remove Crankshaft Oil Seals

Remove the crankshaft front cover and the flywheel housing 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. This may be done by drilling diametrically opposite holes in 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.

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

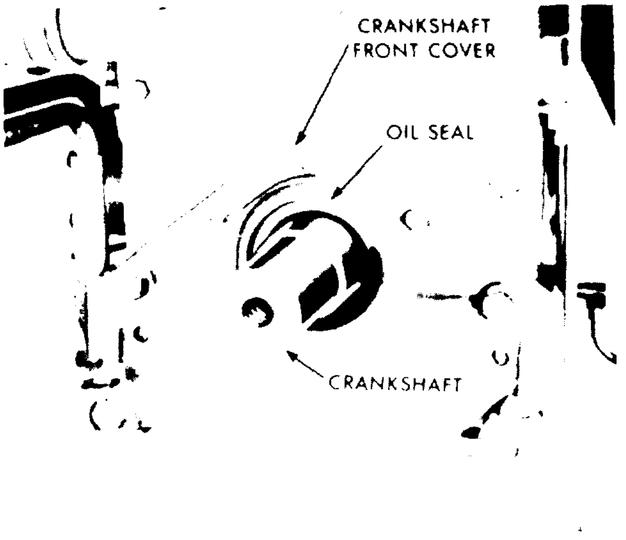


Figure 11B-80. Crankshaft Front Oil Seal Mounting

may be removed from the crankshaft as described earlier.

The maximum runout of the oil seal bore in the flywheel housing is 0.008". 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 later in this subsection. 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

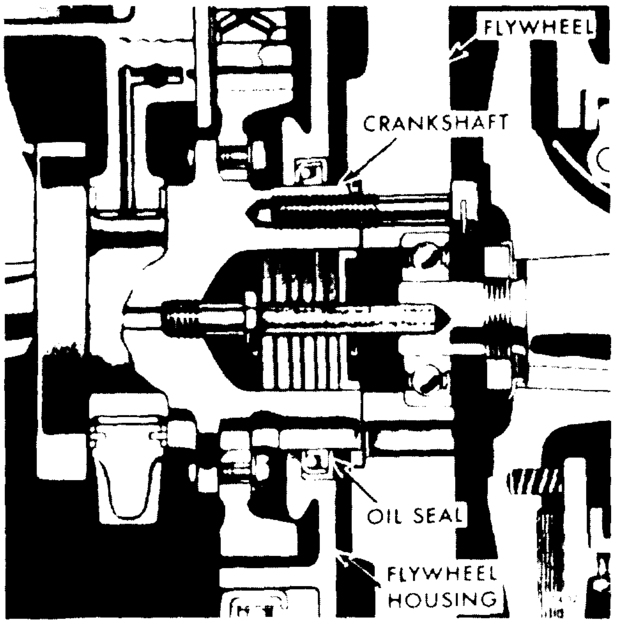


Figure 11B-81. Crankshaft Rear Oil Seal

(Figure 11B-83 on page 11B-55) 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 (Figure 11B-83 on page 11B-55) 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 may 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.

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.

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, a plastic coating which acts as a sealant has been applied to the outer surface of the casting. Do not remove this coating.

The rear oil seal may have either an open or closed back. Both types are serviced.

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.

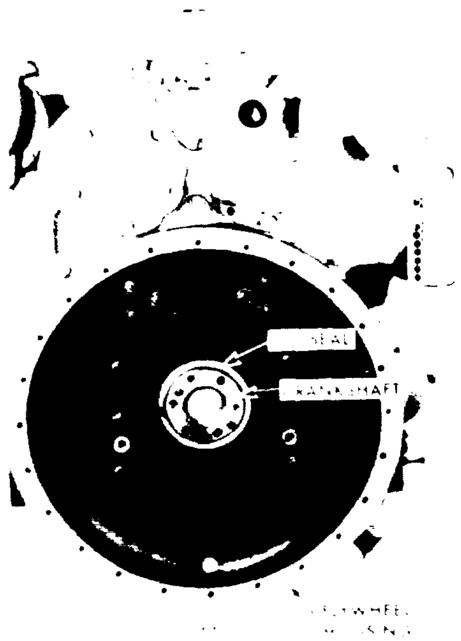


Figure 11B-82. Crankshaft Rear Oil Seal Mounting

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 cover 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.

6. Install the vibration damper inner cover after the front cover and seal assembly is in place.

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.

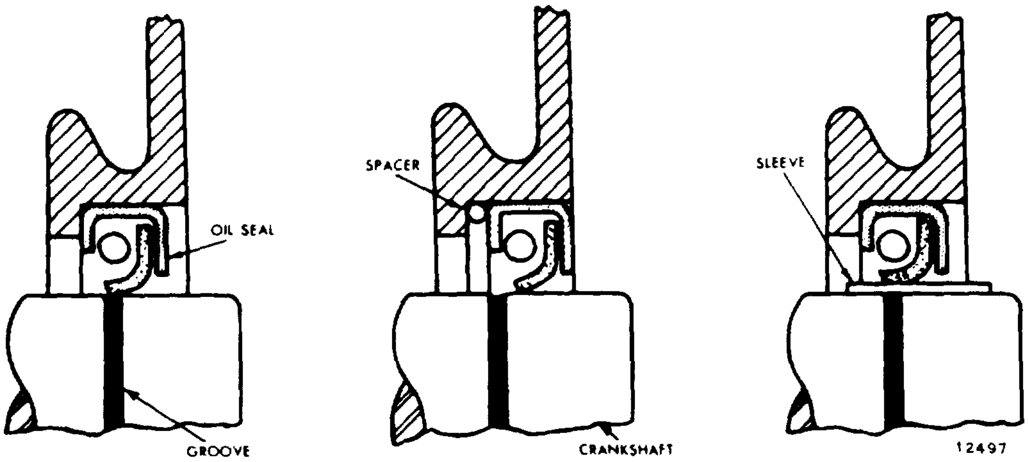


Figure 11B-83. Use of Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft

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 (see Figure 11B-84) 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.

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 J8092 (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.

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.

CRANKSHAFT CAP

A one piece crankshaft cap (Figure 11B-85 on page 11B-56) is installed on the front end of the crankshaft on engines which are not equipped with a crankshaft pulley. The crankshaft cap serves to securely fasten the vibration damper assembly to the crankshaft. The cap is attached to the crankshaft by a special bolt and washer.

Tighten the crankshaft cap retaining bolt as follows:

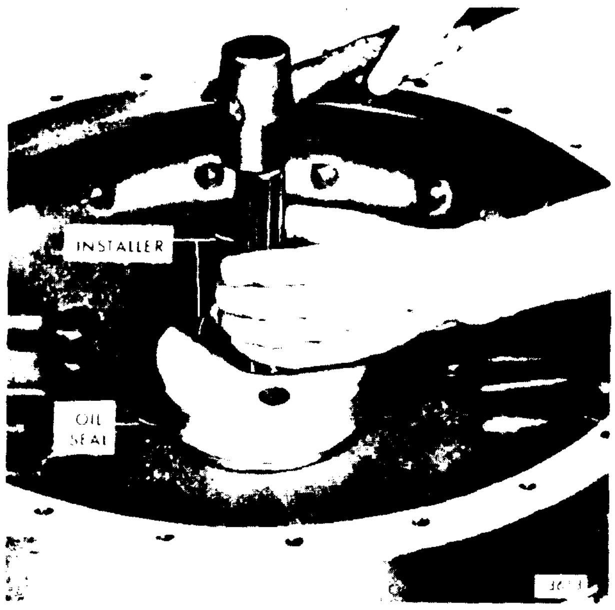


Figure 11B-84. Installing Oil Seal in Flywheel Housing

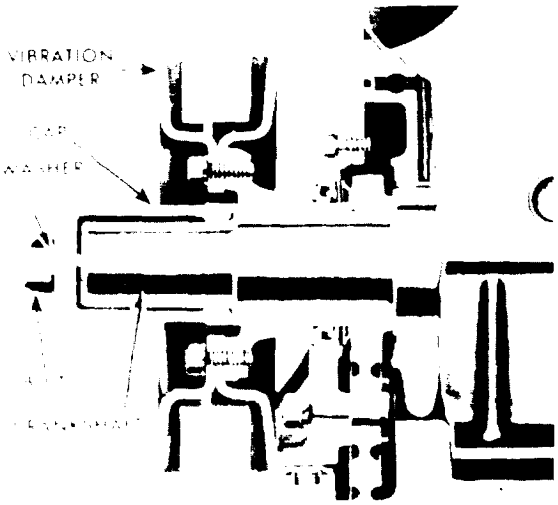


Figure 11B-85. Crankshaft Cap Mounting

1. Tighten the bolt to 180 lb-ft (244 Nm) torque.

2. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.

3. Tighten the bolt to 300 lb-ft (407 Nm) torque and strike again.

4. Tighten the bolt to 290-310 lb-ft (393-421 Nm) torque.

NOTE

Do not strike the bolt after final torque has been applied.

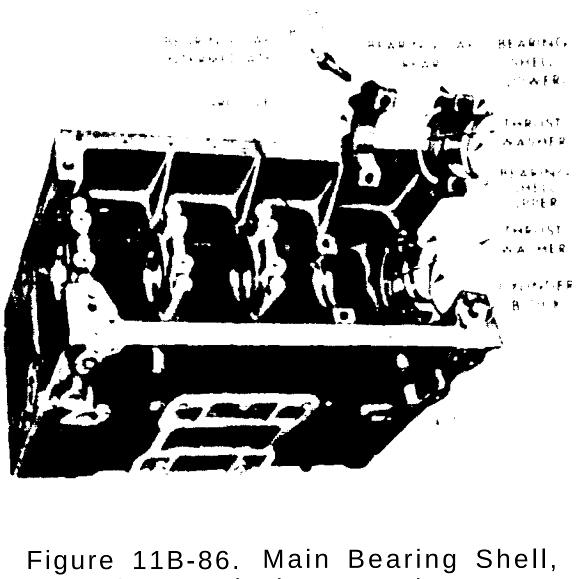


Figure 11B-86. Main Bearing Shell, Caps and Thrust Washers

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 is not securely fastened to the crankshaft.

CRANKSHAFT MAIN BEARINGS

Description

The crankshaft main bearing shells (Figure 11B-86) 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 shell are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

Various types of bearings have been used. Currently multiple layer copper-lead coplated or aluminum triplated bearings are in use. These bearings have an inner surface, call the matrix, of copper-lead or aluminum. A thin deposit of babbitt is then plated onto the matrix. This babbitt 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 babbitt when new and a dull gray after being in service.

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 must not be interchanged.

Thrust washers (Figure 11B-86), on each side of the rear main bearings, 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 shell 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.

Remove Main Bearing Shells (Crankshaft in Place)

The bearing caps are numbered 1, 2, 3, etc., indicate their respective position and when removed, must always be reinstalled in their original position.

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

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.

3. Remove one main bearing cap at a time (Figure 11B-87) and inspect, the bearing shell as outlined under "Inspection". Reinstall each bearing shell and bearing cap before removing another bearing cap:

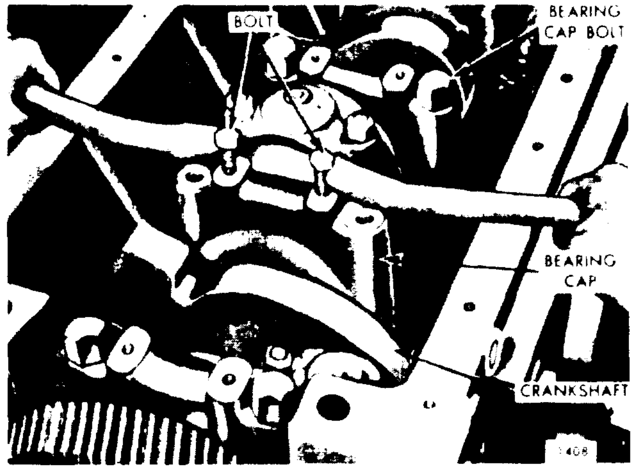


Figure 11B-87. Removing Main Bearing Cap

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 crankshaft journal oil hole. Then revolve the shaft to the right (clockwise) and roll the bearing shell out of position as shown in Figure 11B-88 on page 11B-58. 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 Figure 11B-89 on page 11B-58.

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.

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

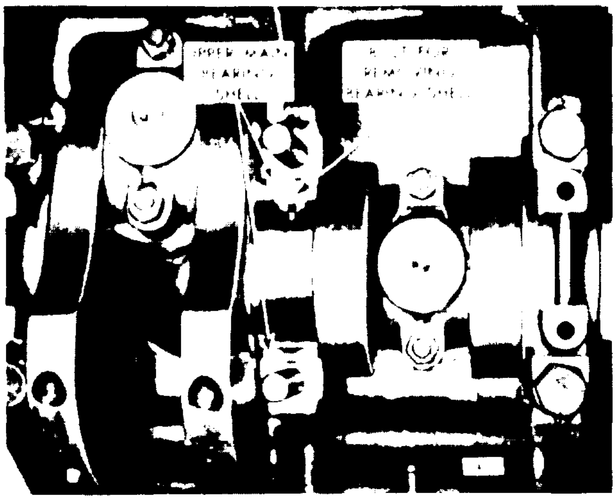


Figure 11B-88. Removing Upper Main Bearing Shell

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 (see Figure 11B-90). The lower bearing shells, which carry the load, will normally show signs of distress 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 bear-

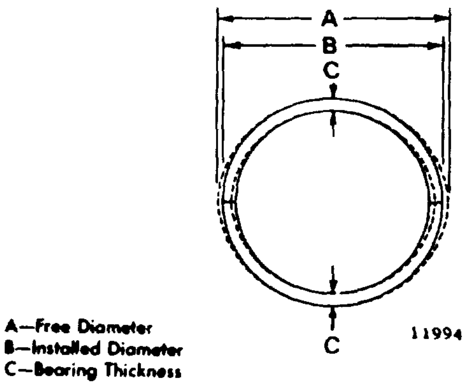
Figure 11B-89. Removing Upper Rear Main Bearing Shell

ings 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

Figure 11B-90. 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"

Figure 11B-91. Main Bearing Measurements

line, as shown in Figure 11B-91 on page 11B-59 and Figure 11B-92 on page 11B-59. Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be 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 standard main bearing shell is 0.1530" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. The thickness of new and undersize bearing shells are given in Figure 11B-91.

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 Note - Troubleshooting" on page 11B-122). 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 0.001" larger in diameter at the parting line than 90° 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 0.0060", all of the bearing shells must be discarded and replaced. This clearance is 0.0014" to 0.0044" 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 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.

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 0.010" 0.020" and 0.030" undersize for service with reground crankshafts. To determine the size bearings required, refer to

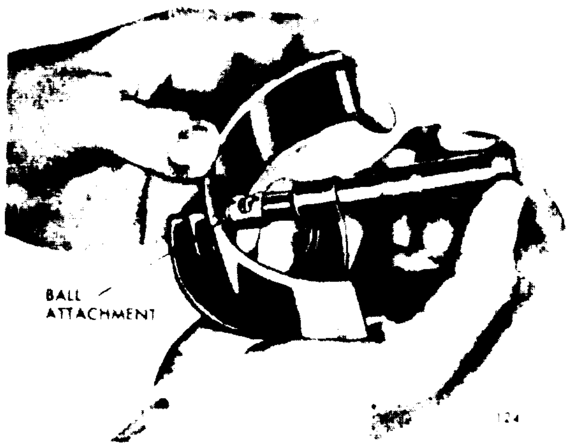


Figure 11B-92. Measuring Thickness of Bearing Shell

"Crankshaft Grinding" on page 11B-49. Bearings which are 0.002" 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 contribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to "Install Crankshaft" on page 11B-50. 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 0.1190" to 0.1220" thick. Thrust washers are available in 0.005" and 0.010" oversize.

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 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.

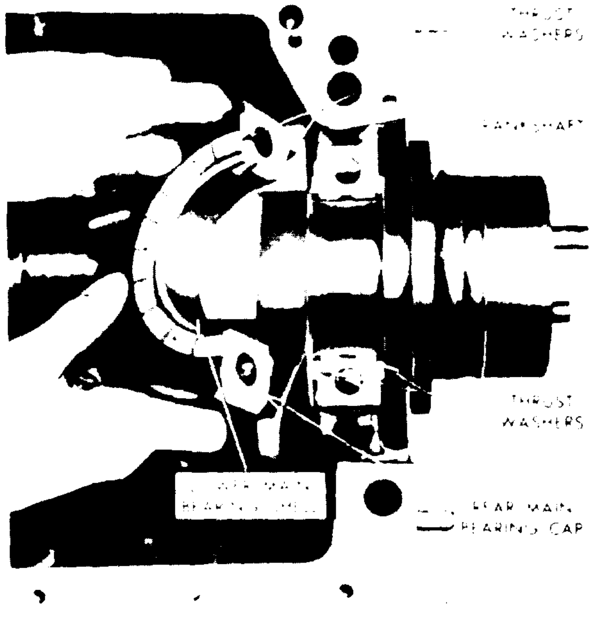


Figure 11B-93. Crankshaft Thrust Washer in Place

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 washer (Figure 11B-93) 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.

NOTE

The main bearing caps are bored in position and stamped 1, 2, 3, etc. (see Figure 11B-94 on page 11B-61). They must be installed in their original positions with the marked side of each cap toward the blower side of the cylinder block.

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 45-55 lb-ft (61-75 Nm)

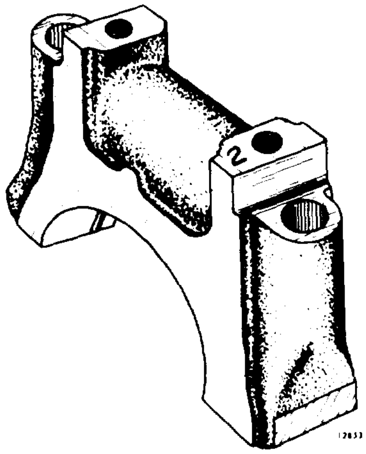


Figure 11B-94. Main Bearing Cap Marking

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

> An accurate way to determine bolt head rotation is to paint or permanently scribe the sockets used with two marks 120° apart (see Figure 11B-95). After torquing bolts to 45-55 lb-ft (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.

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 lb-ft (211-251 Nm) torque, starting with the center bearing cap nuts and working alternately toward both ends of the block. Tighten the rear main bearing nuts to 40-50 lb-ft (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. Re-torque all bearing nuts to 155-185 lb-ft (211-251 Nm).

NOTE

> If 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.

5. Check the crankshaft end play as outlined under "Install Crankshaft" on page 11B-50.

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 clearance.

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 Section 11H).

9. After installing new bearing shells, operate the engine on a run-in schedule as outlined in this section.

CRANKSHAFT FRONT COVER

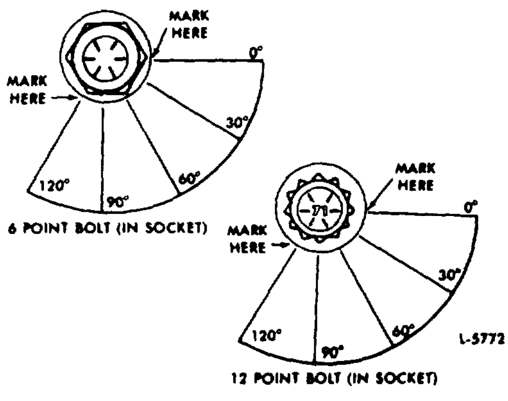


Figure 11B-95. Main Bearing Cap bolt Turn Torque Method

Description

The crankshaft front cover is mounted against the cylinder block end plate at the lower front end of the engine (see Figure 11B-96). 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.

Remove Crankshaft Front Cover

1. Drain the oil and remove the oil pan.

2. Remove the vibration damper 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 (see Figure 11B-97).

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

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 in addition to lockwashers on aluminum covers.

5. Tighten the cover attaching bolts by following the tightening sequence indicated in Figure 11B-98 on page 11B-63. Follow this sequence as the bolts are

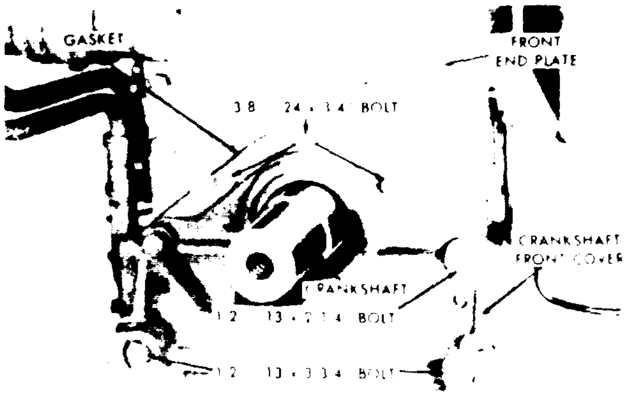


Figure 11B-96. Crankshaft Front Cover Mounting

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 lb-ft (34-41 Nm) and the 1/2”-13 bolts to 80-90 lb-ft (108-122 Nm) torque.

6. Install the oil pan, using a new gasket.

7. Refer to Section 11H and refill the crankcase with oil to the proper level on the dipstick.

CRANKSHAFT VIBRATION DAMPER

Description

This engine uses a vibration damper to reduce the crankshaft stresses to a safe value.

The viscous (fluid) type damper is employed when the equipment the engine

Figure 11B-97. Front Cover Parts

Figure 11B-98. Front Cover Tightening Sequence

powers requires frequent speed and load changes. The viscous damper provides faster response to load and speed changes and high temperatures have a less adverse effect than on the rubber type damper.

The viscous damper assembly consists of a sealed outer shell, and internal flywheel and a quantity of highly viscous fluid (see Figure 11B-99). The small clearance between the flywheel and the outer shell is filled with the fluid which causes the flywheel to be driven upon acceleration and permits it to “freewheel” upon deceleration.

During operation, the outer shell, which is firmly attached to the crankshaft, turns at the same speed as the crankshaft, its motion being transferred to the flywheel through the fluid within the shell. Inasmuch as “fluid-drive” is more or less inefficient with frequent speed changes, considerable slippage of the flywheel will take place as the power impulses are transmitted through the crankshaft. In this type of operation, the slippage is desirable since the acceleration and deceleration of the flywheel in the damper lessens the amplitude of the vibrations, thereby reducing their effects to a point where they are not harmful to the engine.

The vibration damper must be removed whenever the crankshaft, crankshaft front cover or crankshaft front oil seal is removed or replaced.

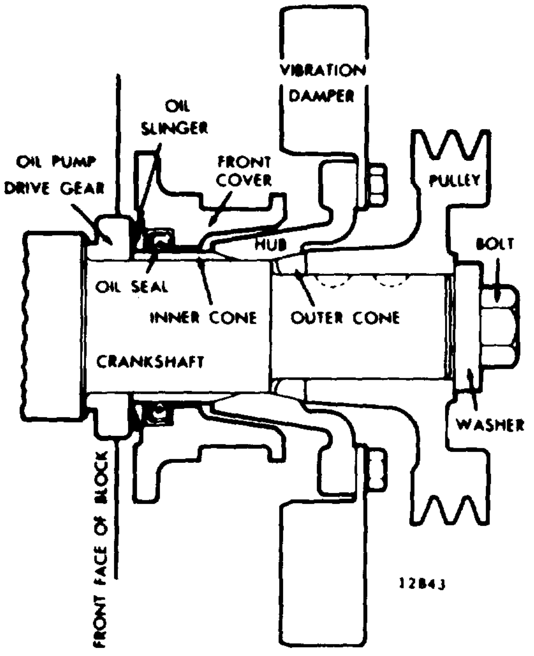


Figure 11B-99. Removing Vibration Damper Assembly

Remove Vibration Damper from Crankshaft

1. Remove the crankshaft pulley bolt.

2. Remove the crankshaft pulley.

3. Reinstall the pulley crankshaft bolt and install a puller as shown in Figure 11B-99 and Figure 11B-100 on page 11B-64 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.

NOTE

Pounding with a hammer or prying with other tools must not be resorted to in removing the viscous type damper from the crankshaft, since the outer shell may be dented and cause the flywheel to turn at the same speed as the outer shell, thus rendering the damper ineffective. The damper cannot be repaired.

4. Slide the vibration damper as an assembly off the end of the crankshaft by hand.

5. Slide the inner cone from the crankshaft.

Inspect Vibration Damper

After Removal, clean the vibration damper in fuel oil and dry it with compressed air.

Examine the viscous type damper for dents, nicks, fluid leakage or bulges in the outer casing of the damper. Any indications of the above are sufficient cause for replacing the damper. Due to the close clearances between the internal flywheel and outer casing, dents may render the damper ineffective. Bulges or splits indicate the fluid has ignited and expansion of the resultant gases has bulged or forced the casing open at its crimped edges.

Since the viscous type damper is a precision built closely fitted and sealed device, it is not possible to repair it.

Regardless of condition, the viscous type damper should be replaced at time of normal periodic major engine overhaul.

If damage to the vibration damper is extensive, inspect the crankshaft. A loose or defective vibration damper, after extended operation, may result in a cracked crankshaft.

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.

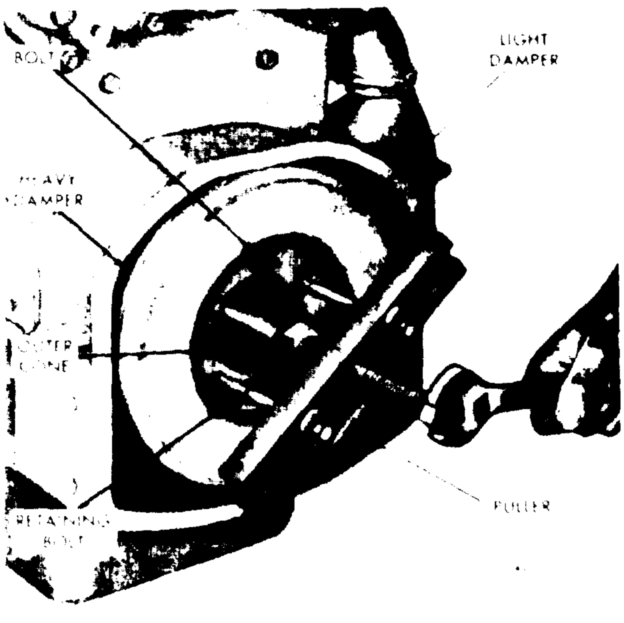


Figure 11B-100. Loosening Vibration Damper Outer Cone

A loose engine mount could damage the vibration damper by allowing the engine to move slightly during operation. Therefore, it is good practice to periodically inspect the engine mounts to be sure they are not loose, cracked or deteriorated.

Install Vibration Damper on Crankshaft

Refer to Figure 11B-99 on page 11B-63 for relative location of the parts and assemble as follows:

1. Coat the lip of the oil seal in the front cover lightly with cup grease or vegetable shortening and lubricate the sleeve and spacer if used, with engine oil.

2. Slide the sleeve, if used, over the large diameter of the crankshaft and against the oil slinger, being sure the slinger is tight against the oil pump drive gear; then slide the spacer against the sleeve.

3. With the Woodruff keys (if used) 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, if used.

NOTE

When the vibration damper and crankshaft pulley are bolted together and mounted on the front end of the crankshaft (see Figure 11B-101 on page 11B-65), extra precaution should be taken to be certain that the inner cone does not prematurely clamp to the crankshaft.

4. Slide the damper and hub as an assembly--long end of the hub facing the crankshaft cover--into position.

NOTE

Do not hit a viscous type damper with a hammer to position it on the crankshaft.

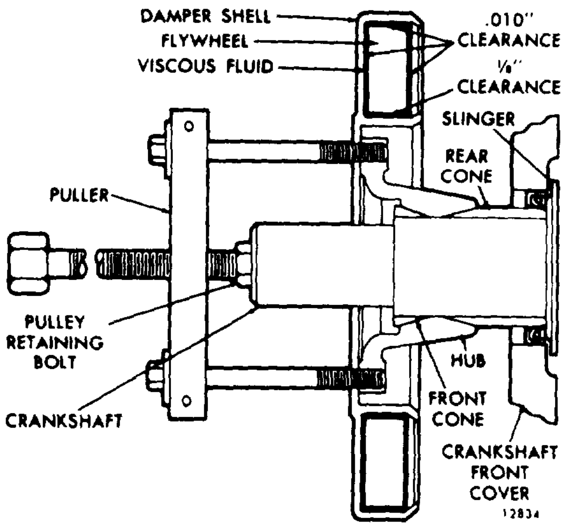


Figure 11B-101. Vibration Damper and Pulley Mounting

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 hub of the vibration damper (or the crankshaft pulley).

7. Install the crankshaft cap (or crankshaft pulley).

8. Thread the crankshaft cap (or pulley) retaining washer, if used, into the crankshaft and tig'hten it as follows:

A. Tighten to 180 lb-ft (244 Nm) torque.

B. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.

C. Tighten to 300 lb-ft (407 Nm) torque and strike the bolt again.

D. Tighten to 290-310 lb-ft (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 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

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.

CRANKSHAFT PULLEY

Description

The crankshaft pulley is keyed to the crankshaft and secured with a special washer and bolt.

The new crankshaft bolts are now 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 new washer (retainer) is now case hardened.

The new bolts and washers can be identified by their black color.

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. Install the pulley bolt in the end of the crankshaft and use puller J 24420.

Install Crankshaft Pulley

Refer to Figure 11B-102 on page 11B-66 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 crankshaft.

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.

4. The engine is equipped with a vibration damper and the pulley must be drawn tight against the outer cone.

5. Tighten the crankshaft pulley retaining bolt as follows:

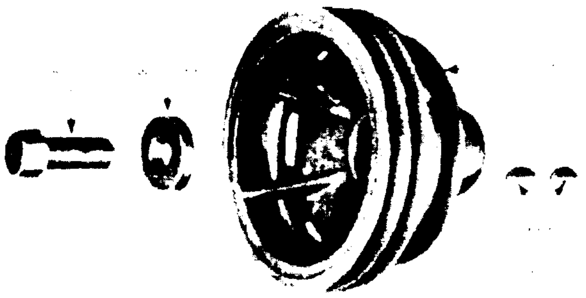


Figure 11B-102. Crankshaft Pulley Details

A. Tighten the bolt to 180 lb-ft (244 Nm) torque.

B. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.

C. Tighten the bolt to 300 lb-ft (407 Nm) torque and strike the bolt again.

D. Tighten the bolt to 290-310 lb-ft (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 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.

FLYWHEEL

Description

The flywheel (Figure 11B-103) 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

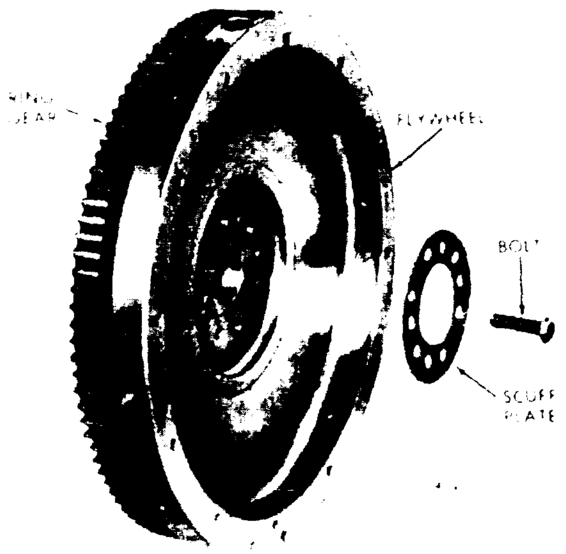


Figure 11B-103. Typical Flywheel Assembly

flywheel bolts are removed. A scuff plate is used between the flywheel 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 flywheel.

A split tube type retainer (Figure 11B-104) 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 a clutch pilot bearing. The clutch driving ring 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.

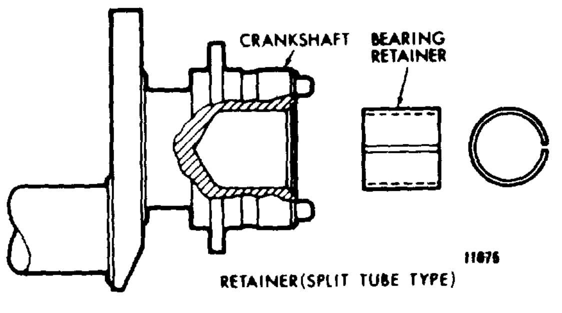


Figure 11B-104. Pilot Bearing Retainer

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing. On torque converter units, the flywheel is part of the torque converter assembly and is covered in Subsection 4C.

FLYWHEEL HOUSING

Description

The flywheel housing (Figure 11B-105) 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 torque converter.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing.

Remove Flywheel Housing

1. Mount the engine on an overhaul stand as outlined earlier (see Figure 11B-5 on page 11B-3).

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 idle 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 (see Figure 11B-105).

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.

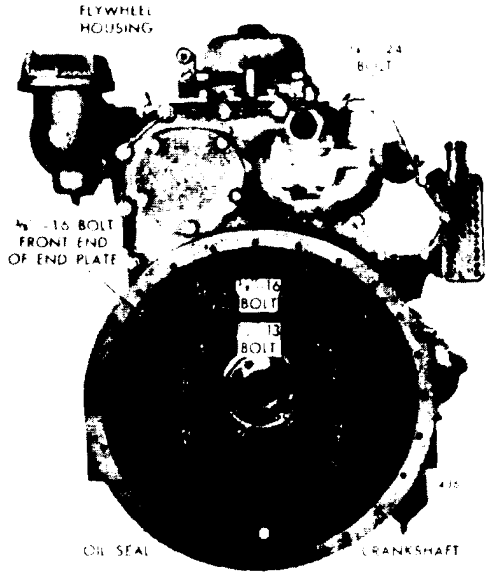


Figure 11B-105. Flywheel Housing Mounting

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 (see Figure 11B-106 on page 11B-68).

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.

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.

Install Flywheel Housing

1. Lubricate the gear train 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. 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 (see Figure 11B-106). Use oil seal expander J 22425 (standard size seal) or expander J 4195-01 and handle J 8092 (oversize seal) 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 Figure 11B-105 on page 11B-67 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.

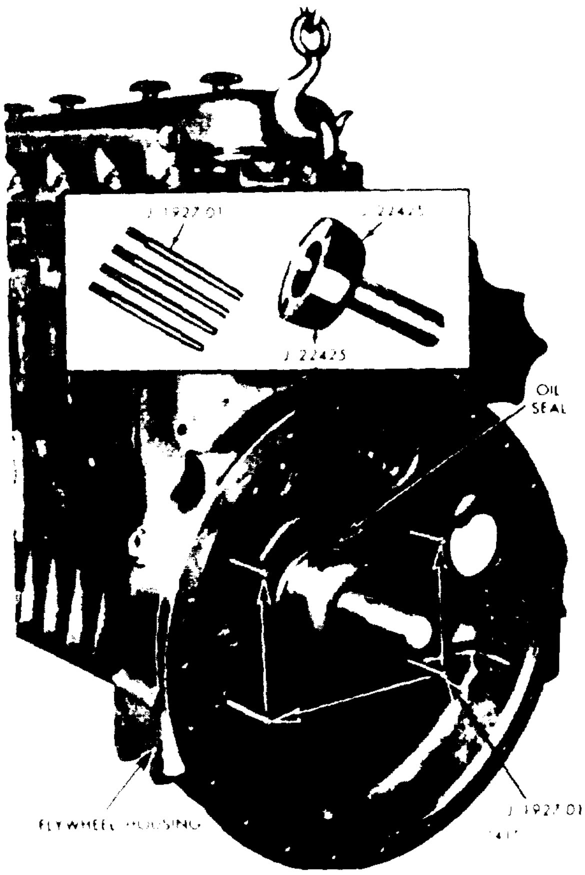


Figure 11B-106. Removing or Installing Flywheel Housing

A self locking type bolt and steel washer are currently being used to attach the flywheel housing to the idler gear hub and hole spacer. With this type of bolt, the additional operation of securing the bolts with lock wire is eliminated, inasmuch as the head of the bolt is designed that it will lock it itself to the attaching member when the specified torque is applied.

NOTE

The self locking bolts must be used in sets of three.

7. Install the six 1/2”-13 housing to block bolts with lock washers, finger tight.

8. Install the remaining flywheel housing attaching bolts and washers, finger tight.

9. Refer to Figure 11B-107 on page 11B-69 for the bolt tightening sequence. Start at number 1 and, using the proper sequence, bring all bolts to within 10-15 lb-ft (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 flywheel housing bell tightening also.

10. Refer to Figure 11B-108 on page 11B-69 for the final bolt tightening sequence and, stating 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 lb-ft 54-61 Nm) torque. Tighten all other 3/8”-16 and 3/8”-24 bolts to 25-30 lb-ft (34-41 Nm) torque, and the 1/2”-13 bolts to 90-100 lb-ft (122-136 Nm) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts and flywheel housing bell.

11. Install the flywheel.

12. Check the flywheel housing concentricity and bolting flange face with tool set J 9737-01 as follows:

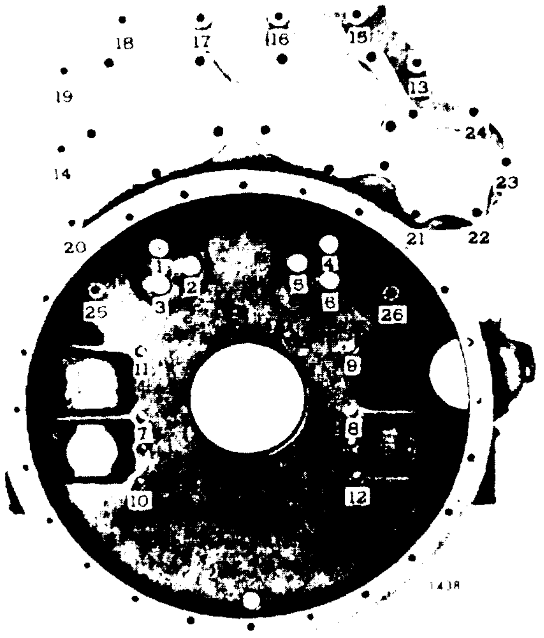


Figure 11B-107. Flywheel Housing Tightening Sequence (Operation 1)

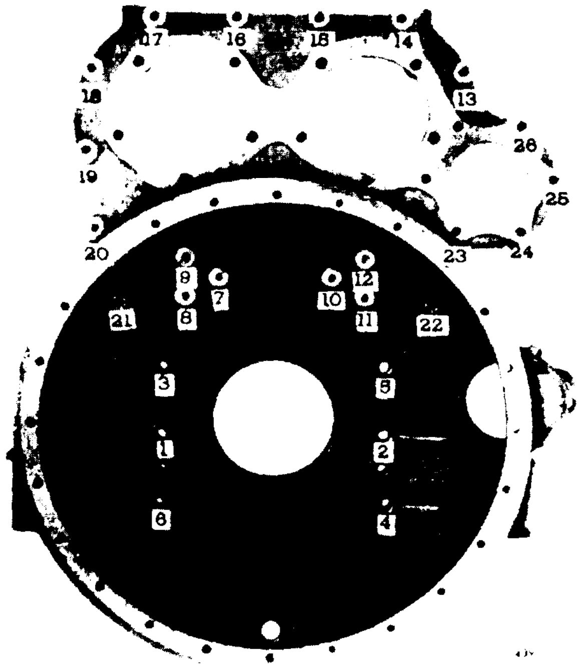


Figure 11B-108. Flywheel Housing Tightening Sequence (Operation 2)

A. Refer to Figure 11B-109 on page 11B-69 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 0.013" 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,

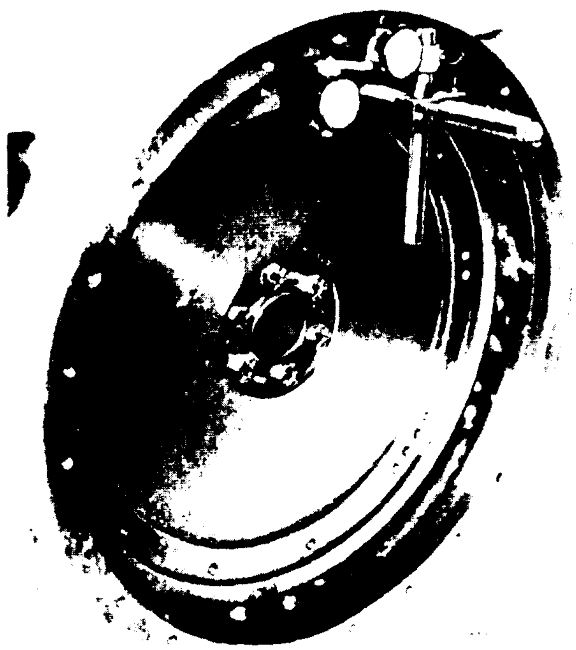


Figure 11B-109. Checking Flywheel Housing Concentricity between the end plate, fly wheel housing and the new gasket and between the end plate and the cylinder block).

F. Re-install 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 the bracket-to-cylinder head bolts, thus drawing the bracket into the corner formed by the cylinder head and housing.

14. Install the oil pan.

15. Remove the engine from the overhaul stand and complete assembly of the engine.

CROSS-HEAD PISTON

Description

The cross-head piston (Figure 11B-110 and Figure 11B-111 on page 11B-71) 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 150° slipper type bushing (bearing). The piston skirt incorporates two oil control ring grooves, piston pin holes and piston pin retainer counterbores. 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. A lubricating oil tube and floating nut are contained inside of the piston pin. Two bolts and spacers are used to attach the connecting rod to the floating nut in the piston pin.

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 in the piston pin,

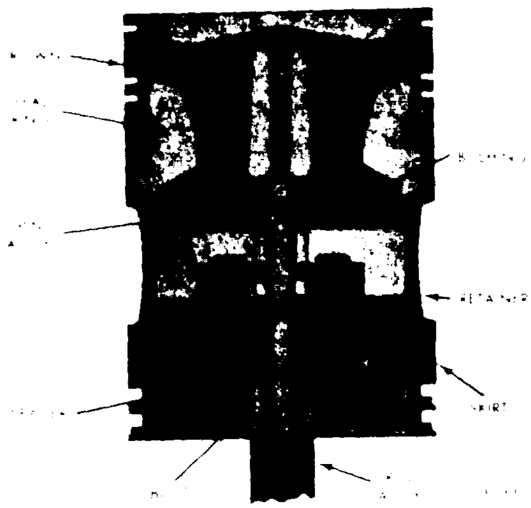


Figure 11B-110. Piston and Connecting Rod Assembly

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 turbocharged engines use a 17 : 1 compression ratio piston. To aid identification of a piston, refer to Figure 11B-112 on page 11B-71. Fit the end of the gauge between the top of the piston crown and the machined step below the third compression ring groove. A “GO” check identifies a piston used in a turbocharged engine. A space of approximately 0.030” (“NO-GO”) identifies a piston used in a naturally aspirated engine.

NOTE

Cross-head pistons and trunk-type pistons must not be used together in an engine. The difference in weight of the pistons will affect engine balance.

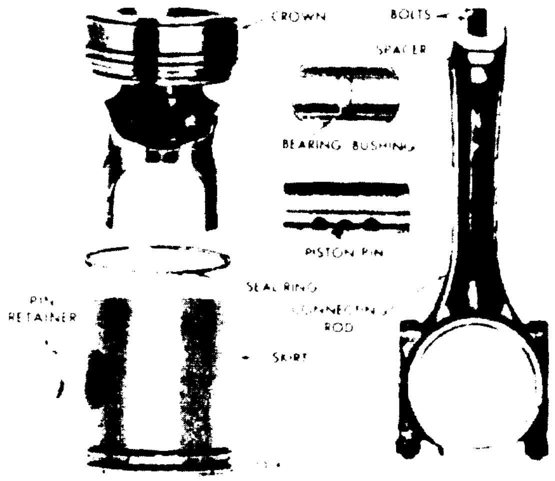


Figure 11B-111. Piston and Connecting Rod Components

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.

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.

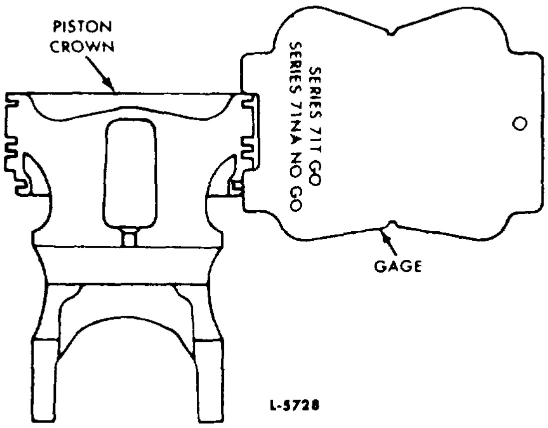


Figure 11B-112. Piston Identification using Gauge J 25397

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.

4. Remove the cylinder head.

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.

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 Figure 11B-113 on page 11B-72.

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 spacer and remove the connecting rod.

4. Withdraw the piston pin.

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.

Figure 11B-113. Removing or Installing Piston Rings

Cleaning

Clean the piston components with fuel oil and dry with compressed air. If fuel oil does not remove the carbon deposits, use a chemical solvent that will not harm the tin-plate 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.

Glass beading can be used to clean a piston crown. Mico Bead Glass Shot MS-M (0.0029"-0.0058") is recommended. Allowable air pressure is 80-100 psi (553-689 kPa). After cleaning, do not leave glass beads in the piston crown.

NOTE

Do not attempt to clean the piston skirt by glass beading, as it will remove the tin-plating.

Inspection

If the tin-plate on the piston skirt and the original grooves in the piston rings are intact (no visible wear step on the lower groove land), 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 type and proper maintenance of the lubricating oil filters and air cleaner 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 Figure 11B-114 on page 11B-73. Slide the "NO-GO" wire (0.106" 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 (0.100" 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.

Figure 11B-114. Checking Fire Ring Groove Using J 24599

Inspection of the connecting rod, piston pin and piston pin bushing are covered in this subsection.

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).

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 0.0005" to 0.0105" clearance between the edge of the bushing and the groove in the piston crown.

NOTE

The bearing must be installed before assembling the piston skirt and crown.

2. Lubricate the metal seal ring (Figure 11B-115) with engine oil and install it with the chamfer or counterbore directed toward the bottom of the piston.

NOTE

The seal rings are made of cast iron and are identified by the tin-plating on the outside diameter, a black oxide finish, or a dull cast iron color. These rings can be mixed in an engine. The former steel rings, identified by a very shiny appearance, must not be used for service.

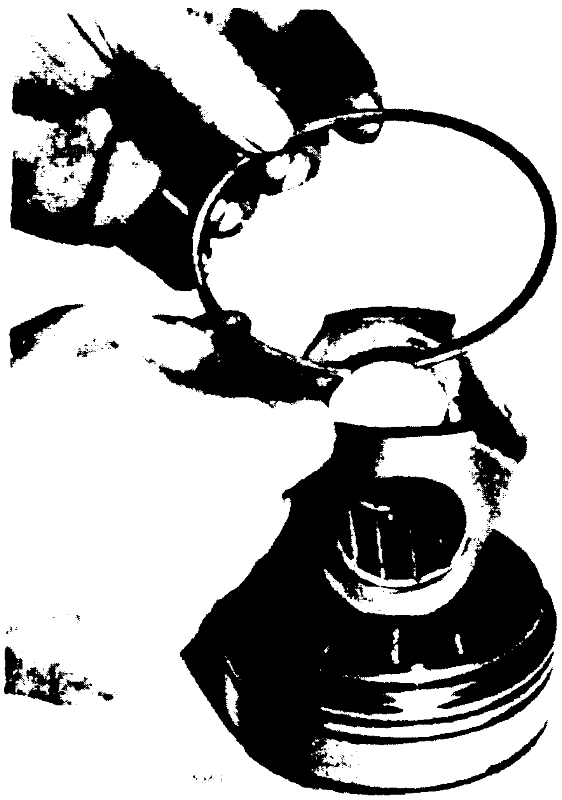


Figure 11B-115. Installing Seal Ring

3. Compress the seal ring with ring compressor J 23453 and push the skirt into position on the piston crown.

NOTE

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 the full 360° circumference of the groove to be sure that 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 in the groove with a flat file. If this does not relieve sticking, replace the piston crown.

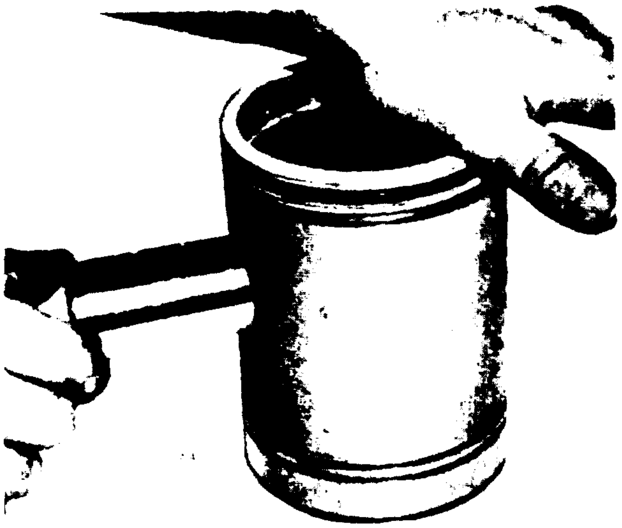


Figure 11B-116. Installing Piston Pin

4. Lubricate the piston pin with clean engine oil and install it as shown Figure 11B-116 on page 11B-74.

NOTE

Line up the piston pin opening in the piston skirt with the bearing (bushing) opening in the piston crown 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.

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 lb-ft (75-81 Nm) torque (see Figure 11B-117). Do not exceed this torque.

8. Place a new piston pin retainer in position. Then 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 (see Figure 11B-118).

9. Install the second piston pin retainer in the same manner.

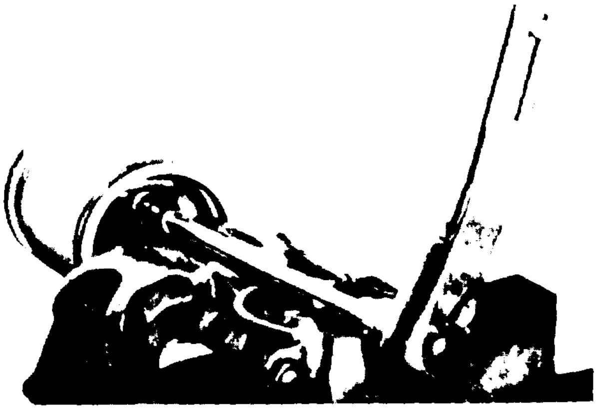


Figure 11B-117. Tightening Connecting Rod to Piston Pin Bolts

NOTE

Due to the size of the counterbore in the piston skirt, be careful with installing the piston pin retainers and inspect them to be sure they are not buckled and that are fully seated in the counterbore. The width of the land should be even around the retainer.

10. On 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 de-

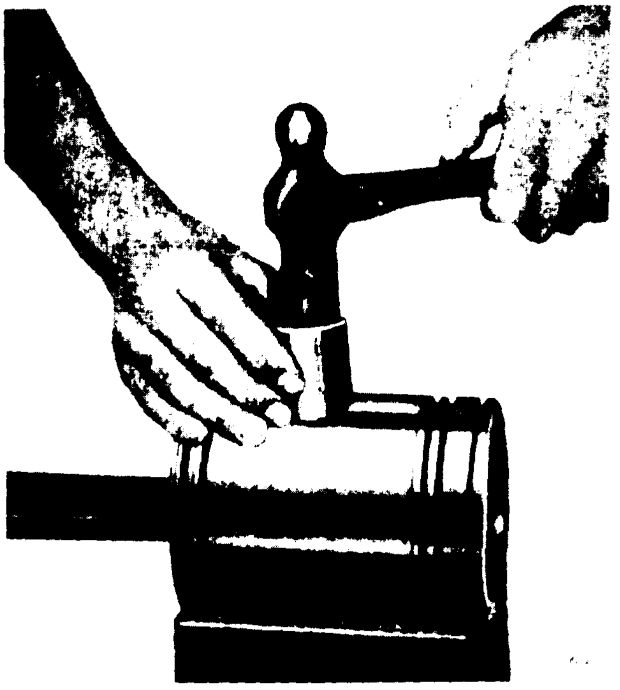


Figure 11B-118. Install Piston Pin Retainer

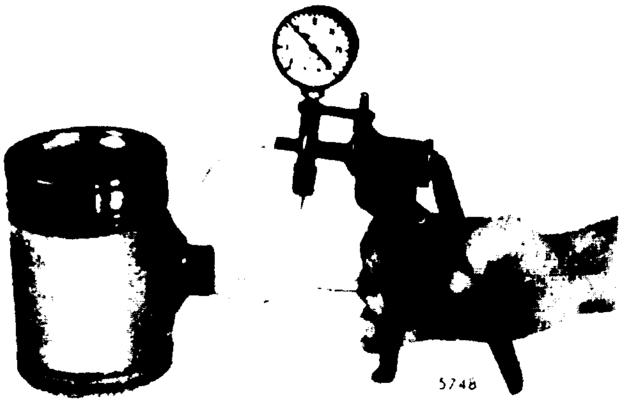


Figure 11B-119. Checking Piston Pin Retainer for Proper Sealing

tector J 23987-01 (Figure 11B-119 on page 11B-75). 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.

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 piston-to-liner clearance, with new parts, will vary with the particular piston and cylinder liner. A maximum clearance of 0.012" 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 90° apart (see Figure 11B-120 on page 11B-76).

Use feeler gauge 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 to remove. The clearance will be 0.001" greater than the thickness of the feeler gauge used, i.e., a 0.004" feeler gauge will indicate a clearance of 0.005" when it is withdrawn with a pull of six pounds. The feeler gauge must be perfectly flat and free of nicks and bends.

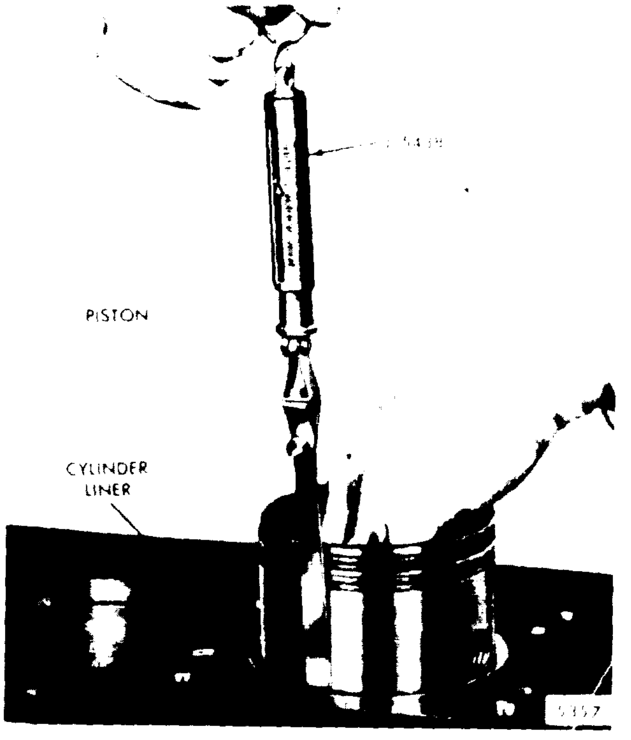


Figure 11B-120. Measuring Piston-to-Liner Clearance

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.

Fitting Piston Rings

Each piston is fitted with a fire ring, two compression rings and two oil control rings (see Figure 11B-121 on page 11B-76).

The top (fire) ring and the upper compression ring (second groove) are pre-stressed. Both are identified by a small indentation mark on the top side. A two-piece oil control ring is used in both oil ring grooves in the pistons.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed. Refer to the parts manual to select the current piston rings.

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

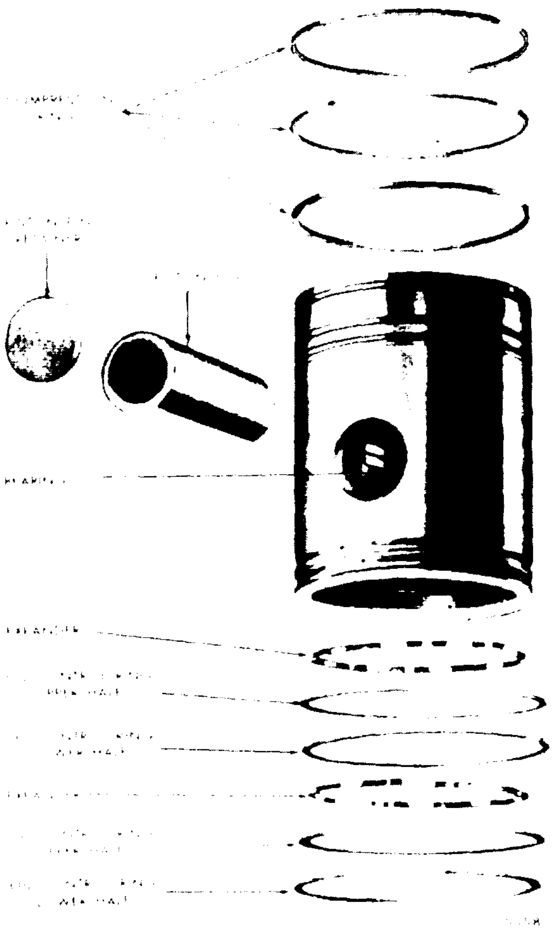


Figure 11B-121. Piston Ring Location

with a feeler guage as shown in Figure 11B-122 on page 11B-76.

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 prevent any chipping or peeling of the chrome plate

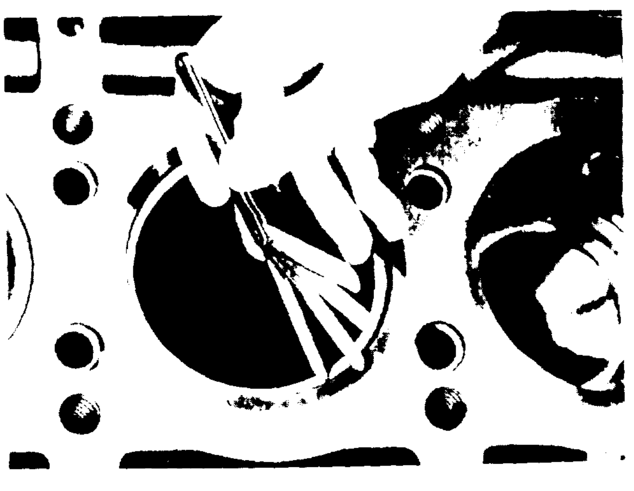


Figure 11B-122. Measuring Piston Ring Gap

on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately 0.015".

Check the ring side clearance as shown in Figure 11B-123 on page 11B-77.

Install Piston Rings

NOTE

Lubricate the piston rings and piston with engine oil before installing the rings.

Starting with the bottom ring, install the compression rings with tool J 8128 as shown in Figure 11B-113 on page 11B-72. To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. Refer to Figure 11B-124 on page 11B-77 for ring identification.

1. Stagger the ring gaps around the piston.

2. Refer to Figure 11B-124 on page 11B-77 for the type and location and install the oil control rings as follows:

A. Install the ring expanders in the oil control ring grooves in the piston skirt. When installing the oil control rings, use care to prevent overlapping the ends of ring expanders. An overlapped expander will cause the oil

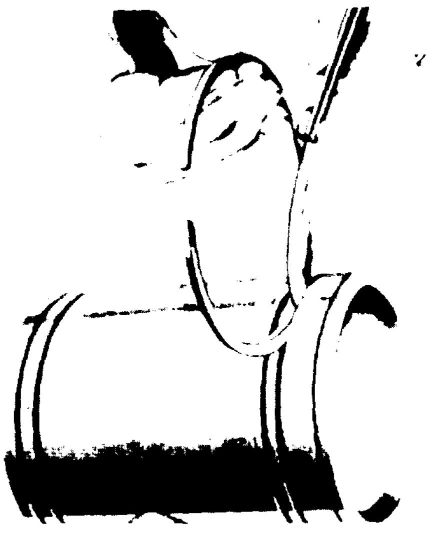


Figure 11B-123. Measuring Piston Ring Side Clearance

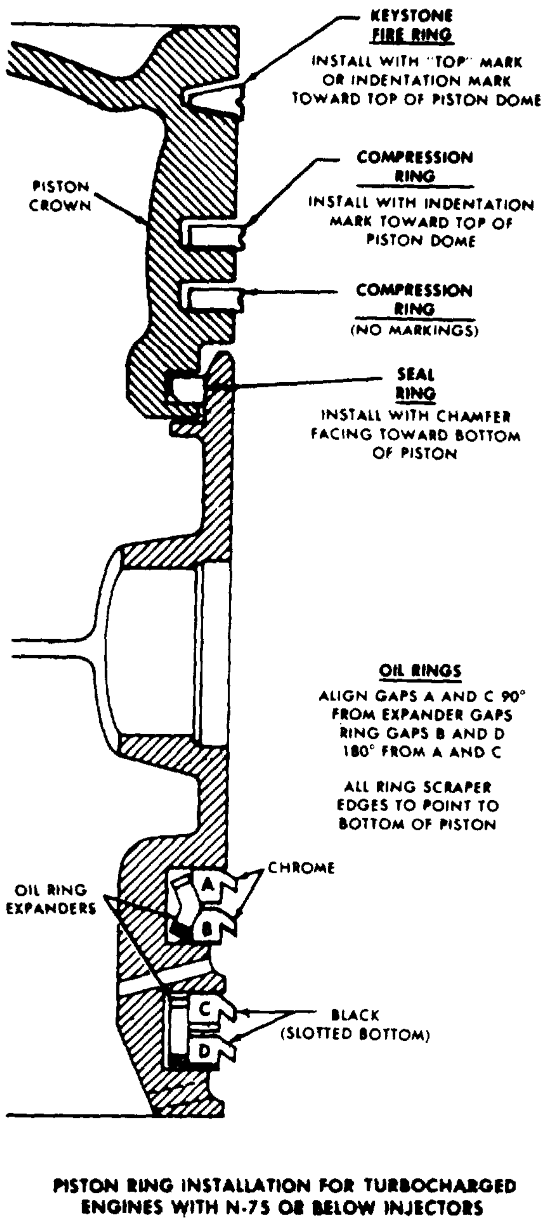


Figure 11B-124. Piston Ring Installation Instructions

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.

B. Install the oil control rings by hand. Start with the upper half of the top oil ring and align the gaps as indicated in Figure 11B-124.

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 in the engine.

CONNECTING ROD

Description

The connecting rod (Figure 11B-125 on page 11B-78) 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 bearing cap is secured to the connecting rod by two specially machined bolts and nuts.

Lubricating oil is forced through a 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.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined under “Disassemble Piston and Connecting Rod” on page 11B-71.

Inspection

Clean the connecting rod and piston pin with a suitable solvent 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 cor-

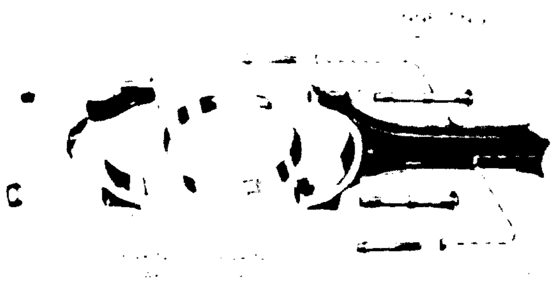


Figure 11B-125. Connecting Rod Details

rosion on the connecting rod saddle and piston pin contact surface with the rod before reassembly.

NOTE

Never use crocus cloth on the bearing side of the pin.

Connecting rods being removed from an original build engine can be reused as is, after considering the following:

1. Check for visual damage (bent).

2. A previous bearing(s) or related failure.

3. Is the connecting rod blue at the top or bottom?

4. Fretting at split line between the connecting rod and cap.

5. Excessive pound-in of the bolt head or nut.

If the connecting rod has been subjected to any of the above, it should be scrapped.

In qualifying a used connecting rod from a source other than an original engine, the following checks should be made in addition to the above.

1. Check for cracks (Figure 11B-126 on page 11B-79) by the magnetic particle method as outlined in "Inspection for Cracks" on page 11B-47.

2. Determine bore diameter of the rod, using a dial bore gauge and master ring as follows (see Figure 11B-127 on page 11B-80).

A. Install the connecting rod cap on the connecting rod and tighten the bolt nuts to 60-70 lb-ft (81-95 Nm) torque.

NOTE

Do not over torque the connecting rod bolt nuts. Over torque may permanently distort the connecting rod cap.

B. Measure diameter A and B as shown in Figure 11B-127 on page 11B-80.

C. Obtain average of A and B to obtain size at split line.

$$\frac{A + B}{2} = X \quad \text{Average of A + B}$$

D. Measure C. The difference in the results of the measurement X and C gives bore out-of round and can be 0.005" maximum.

E. Add C with X and average to obtain average bore size.

$$\frac{C + X}{2} = \text{Average diameter of bore}$$

Specifications : 3.2495" to 3.2515".

NOTE

If the cross-head connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.

3. Determine taper as follows (see Figure 11B-127 on page 11B-80):

A. Subtract D1 from D2 to find the difference.

B. The difference can be 0.0005" maximum.

4. Determine length by finding the distance between E1 and E2 (see Figure 11B-127 on page 11B-80).

Specifications: 10.121" to 10.126".

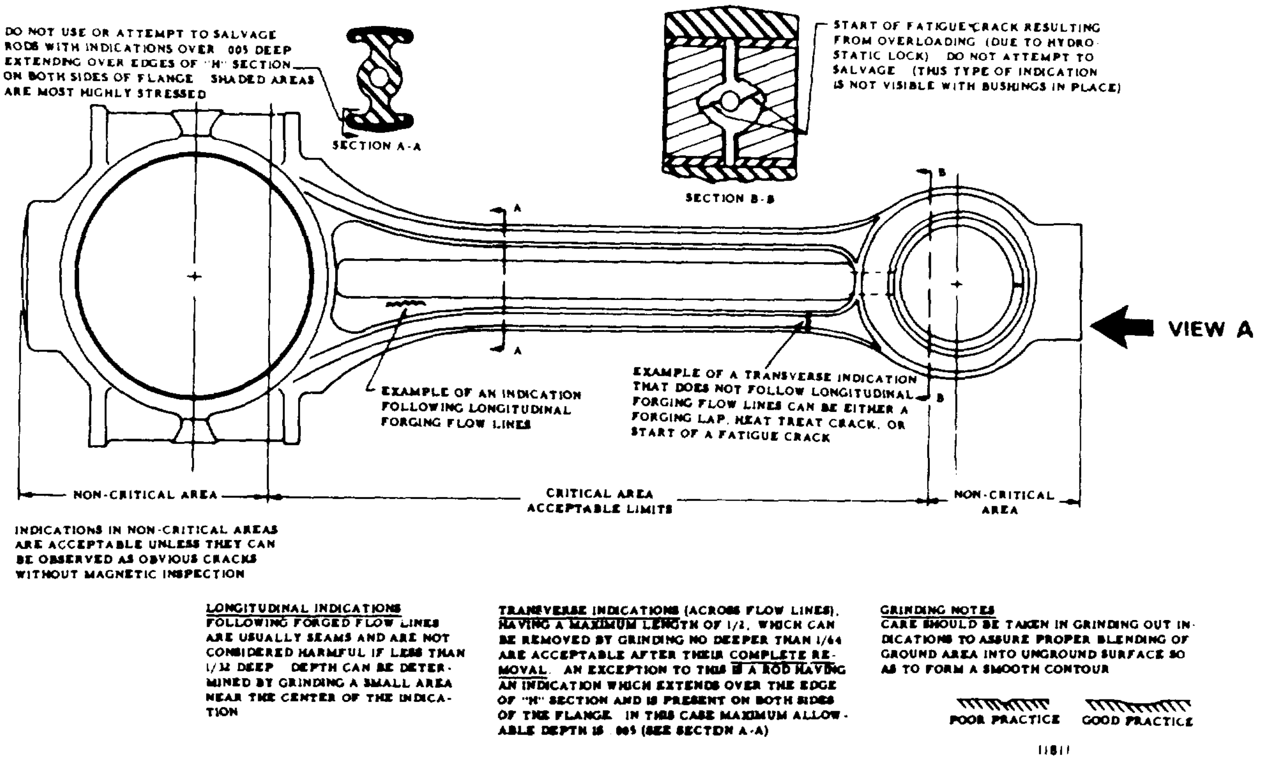


Figure 11B-126. Magnetic Particle Inspection Limits for Connecting Rod

NOTE

The length of the rod can be measured on connecting rod measurement fixtures marketed by B.K. Sweeney, Tobin Arp or equivalent.

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.

CAUTION

Clean the rust preventative 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".

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 0.086" or less. A new bushing is 0.087" to 0.088" thick.

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

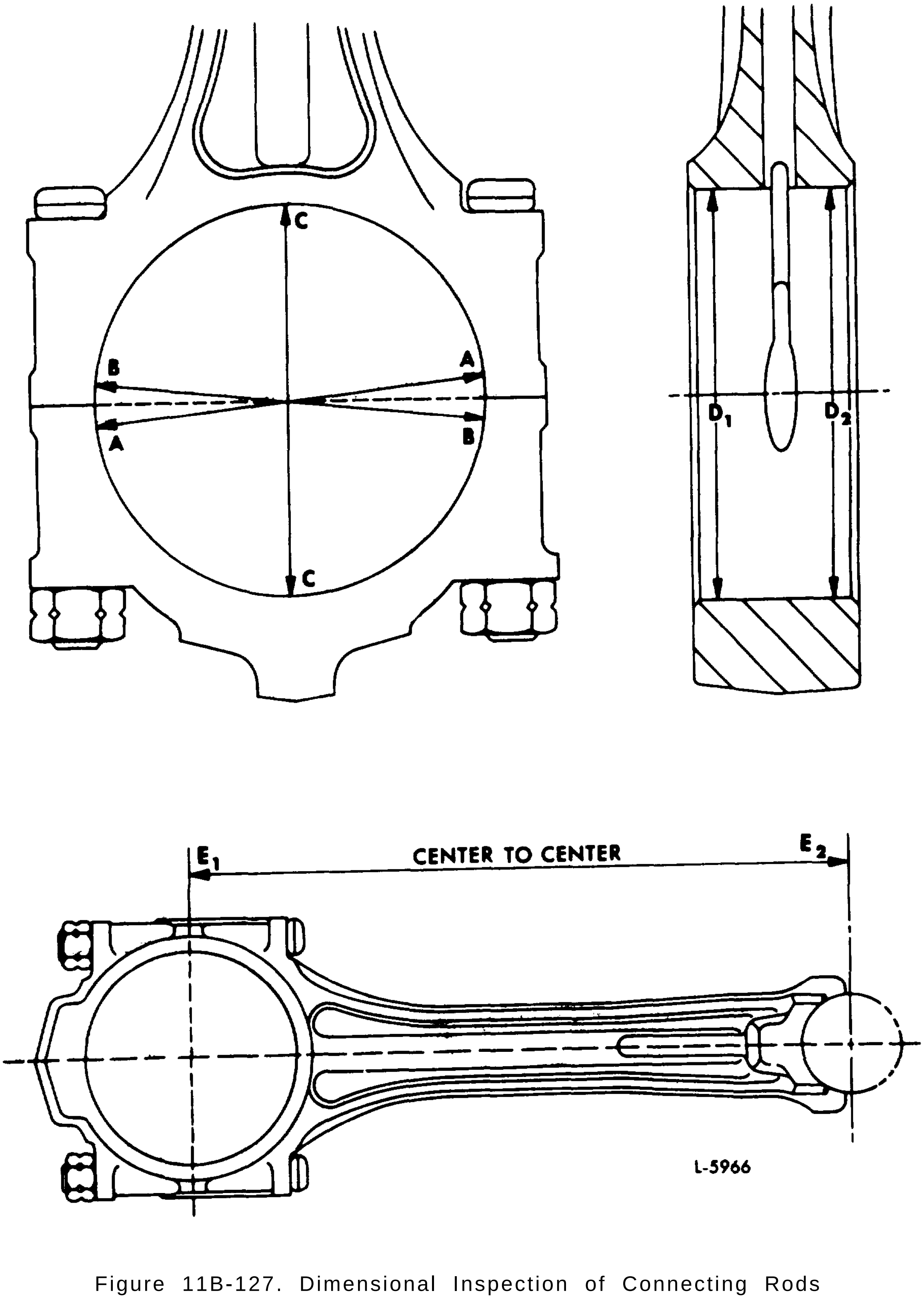


Figure 11B-127. Dimensional Inspection of Connecting Rods not recommended as it could result in very rapid bushing wear. A new piston pin has a diameter of 1.4996" to 1.5000". Replace the piston pin if it is worn to a diameter of 1.4980" or less.

Assemble the Connecting Rod Piston

Refer to "Assemble Piston" on page 11B-73 for assembly of the connecting rod to the piston.

CONNECTING ROD BEARINGS

Description

The connecting rod bearing shells (Figure 11B-128) 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.

Various types of bearings have been used. Currently, multiple layer copper-lead coplate or aluminum triplate bearings are in use. These bearings have an inner surface called the matrix, of copper-lead or aluminum. A thin deposition of babbitt is then plated onto the matrix. This babbitt overlay has excellent resistance to friction, corrosion and scoring tendencies which, combined with the materials of the matrix, provides improved load carrying characteristics. These bearings are identified by the satin silver sheen of the babbitt when new and a dull gray after being in service.

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 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.

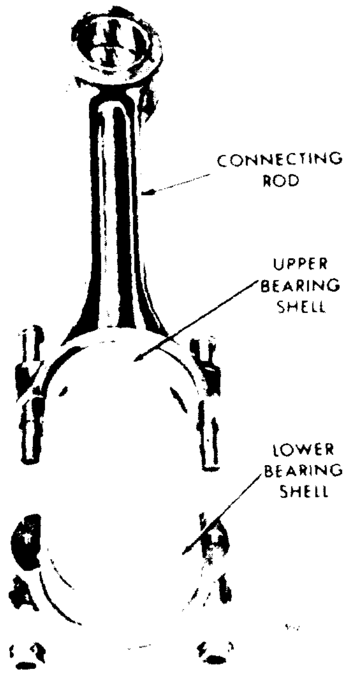


Figure 11B-128. Connecting Rod and Bearing Shells

Remove Bearing Shells

The connecting rod bearing caps are numbered 1, 2, 3, etc., with matching numbers stamped on the connecting rods. When removed, each bearing cap and the bearing shells must 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. Remove the lubricating oil pump and pump inlet and outlet pipes.

NOTE

> 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.

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" on page 11B-82.

5. Install the bearing shells and bearing caps before another connecting rod bearing is removed.

Inspection

Bearing failures may result from deteriorations (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 overheating. If any of these defects are present, the bearings must be discarded. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristic 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 attachment J 4757, as described under "Inspection" on page 11B-57. The minimum thickness of a worn standard connecting rod bearing shell should not be less than 0.1530" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of 0.1548" to 0.1553". The dimensions of undersize bearings are shown in the following table.

Bearing Size	*New Bearing Thickness	Minimum Worn Thickness
Standard	.1548"/.1553"	.1530"
.002" Undersize	.1558"/.1563"	.1540"
.010" Undersize	.1598"/.1603"	.1580"
.020" Undersize	.1648"/.1653"	.1630"
.030" Undersize	.1698"/.1703"	.1680"

*Thickness 90° from parting line of bearing.

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 bearing (refer to "Shop Note - Troubleshooting" on page 11B-121). The maximum connecting rod bearing-to-journal clearance with used parts is 0.006".

Before installing the bearings, inspect the crankshaft journals.

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 0.010", 0.020" and 0.030" undersize for service with reground crankshafts. To determine the size bearings required, refer to "Crankshaft Grinding" on page 11B-49. Bearings which are 0.,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.

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 lb-ft (81-95 Nm) torque (lubrite nut) or 65-75 lb-ft (88-102 Nm) torque (castellated 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 and the oil inlet and outlet pipes.

NOTE

> If shims were used between the oil pump body and the main bearing caps, install the shims in exactly the same location from which they were removed.

7. Install the oil pan, using a new gasket.

8. Refer to Section 11H and fill the crankcase to the proper level on the dipstick.

If new bearings were installed, operate the engine on the run-in schedule outlined in this subsection.

CYLINDER LINER

Description

The replaceable cylinder liner (Figure 11B-129 on page 11B-84) is accurately machined and heat treated to provide a long wear 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 is used with pistons equipped with three compression rings and a fire ring (top ring groove).

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 (Figure 11B-129 on page 11B-84). 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 persist 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 a cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaner must be serviced regularly according to the surroundings in which the engine is operating.

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 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 "Remove Piston and Connecting Rod" on page 11B-71.

2. Remove the cylinder liner with tool J 1918-02 as follows:

Figure 11B-129. Cylinder Liner

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 (see Figure 11B-130).

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.

Inspect Used Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly

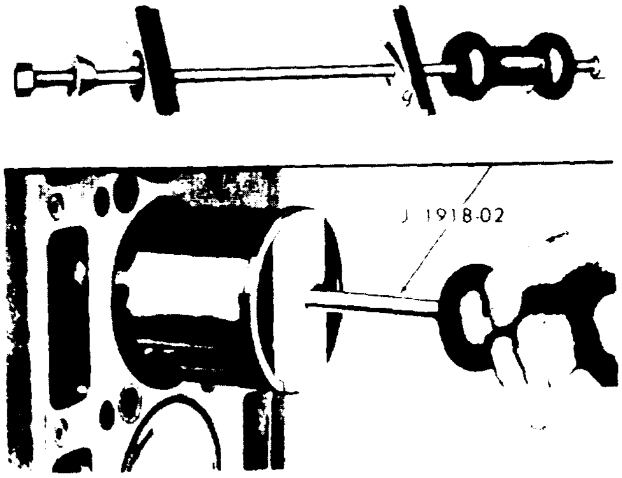


Figure 11B-130. Removing Cylinder Liner

cleaned and then checked for:

Cracks
Scoring
Poor contact on outer surface
Flange irregularities
Inside diameter
Outside diameter
Out-of-round
Taper

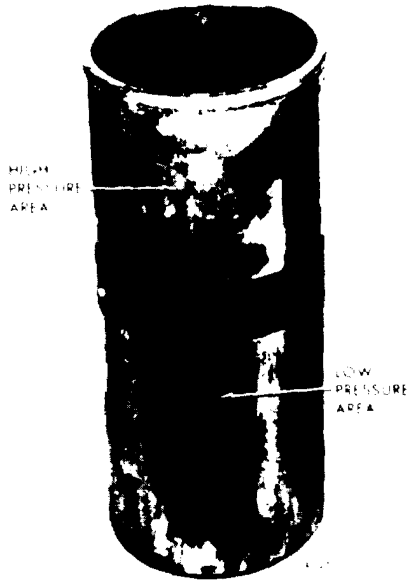


Figure 11B-131. High and Low Pressure Contact Areas on Cylinder Liner

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 (see Figure 11B-131 on page 11B-84).

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 cause 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 (Figure 11B-132) due to the rubbing action of the piston rings which result after long periods of operation. Unless this glaze is removed, the time required to seat new piston rings will be lengthened.

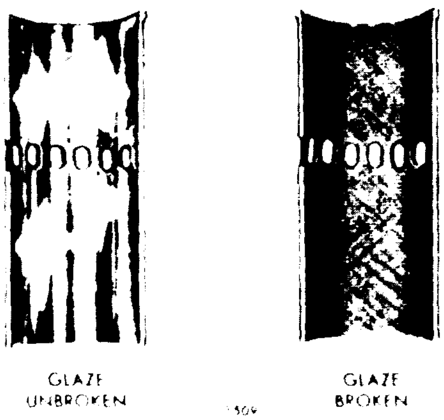


Figure 11B-132. Glaze Surface of Cylinder Liner

2. Remove the ridge (Figure 11B-133 on page 11B-86) 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 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). 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 J5902-01, 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 at a 45° 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.

Liner Measurement

Measure the block bore and the outside diameter of the liner. If the liner-to-block clearance (with used parts) exceeds 0.0025" or 0.001" press fit, it will be necessary to bore the block for an oversize liner.

Install the liner in the proper bore of the cylinder block. Measure the inside diameter of the liner at the various points shown in Figure 11B-134 on page 11B-86. Use cylinder bore gauge J 5347-01, which has a dial indicator calibrated in 0.0001" increments. Set the cylinder bore gauge on zero in master

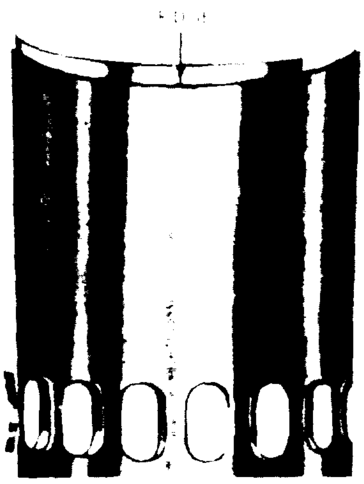


Figure 11B-133. Cylinder Liner Ridge Due to Wear

ring gauge J 5580-1. Also check the liner for taper and out-of-round. It is not necessary to measure the inside diameter or taper of a new liner.

NOTE

Dial bore gauge master ring fixture J 23059-01 may be used in place of the master ring gauge.

The piston liner clearance must be within specified limits. Also, the taper must not exceed 0.002" and the out-of-round must not exceed 0.0025" on a used liner. If the out-of-round exceeds 0.0025", rotate the liner 90° in the block bore and recheck.

Cylinder liners are available in 0.001", 0.005", 0.010", 0.020" and 0.030" 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.

Selection of New Cylinder Liner

The cylinder bores in a new cylinder block are classified as No. 1, 2 or 3 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 No. 1, 2 or 3 as illustrated

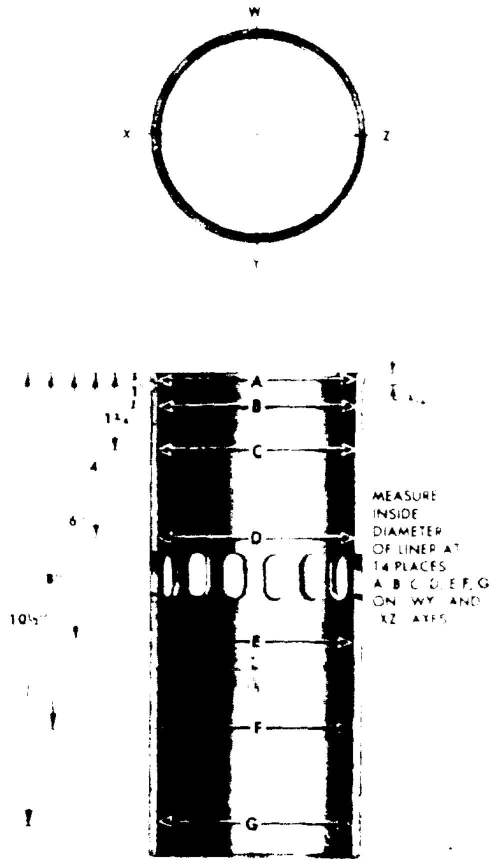


Figure 116-134. Cylinder Liner Measurement Diagram

in Figure 11B-135 on page 11B-87 and the table.

Although the block bores and liners should be measured to determine the liner-to-bore clearance, the selection of a liner is narrowed down to only those in the appropriate classification or possibly a 0.001" oversize liner.

Before installing a liner in a used cylinder block always lightly hone the block bore.

After honing the block bore, check the bore measurements to determine if a standard line or possibly a 0.001" oversize liner can be used (refer to the following tables). 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 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 0.002". If the average block bore is over 4.6285" the cylinder block should be bored oversize.

To determine what size to re-bore 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 determined by the average liner measurement taken at the three positions

EXAMPLE:

Service liner O.D. measures 4.6280"

O.D. size =	4.6280"
plus clearance =	0.0005"
bore size =	4.6285"

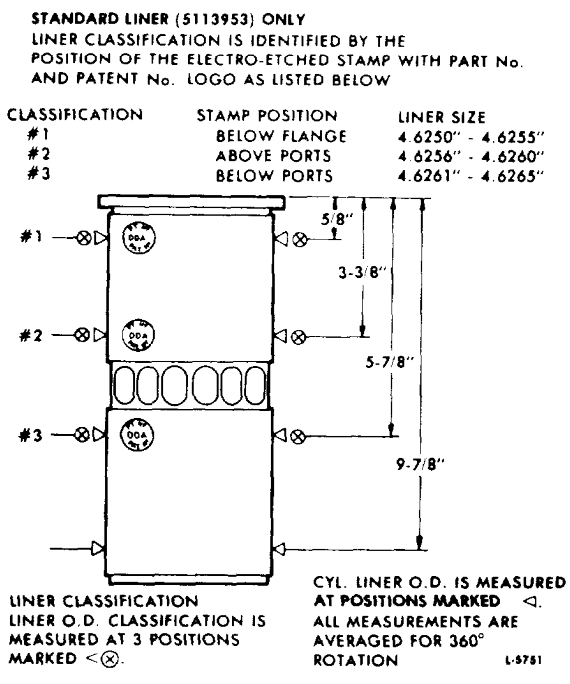


Figure 11B-135. Cylinder Liner Classification

Then, 4.6285" + 0.001" boring tolerance will allow a bore size of 4.6285" to 4.6295" and a possible liner-to-block clearance of 0.0005" to 0.0015". The clearance tolerance is the dimensional difference between the liner O.D. and the block bore I.D..

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 (0.1795"-0.1800" thick) in the block counterbore (see Figure 11B-136 on page 11B-89).

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. 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.

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 #2	4.6250"/4.6255" 4.6256"/4.6260"	.0005"/.0015" .0000"/.0009"
#2	4.6266"/4.6270"	#2 #3	4.6256"/4.6260" 4.6261"/4.6265"	.0006"/.0014" .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 #2	117.475/117.488 mm 117.490/117.500 mm	.012/.038 mm .000/.023 mm
#2	117.516/117.526 mm	#2 #3	117.490/117.500 mm 117.503/117.513 mm	.016/.036 mm .003/.023 mm
#3	117.528/117.539 mm	#3	117.503/117.513 mm	.015/.036 mm

OVERSIZE SERVICE CYLINDER LINERS			
Service Liner Oversize	Liner Outside Diameter		Liner/Block Clearance Req'd After Boring Block
	inches	mm	
.001" (.0254 mm)	4.6280 4.6265	117.551 117.513	.0005"/.0015" (.013/.038 mm)
.005"	4.6315 4.6300	117.640 117.602	.0005"/.0015" (.013/.038 mm)
.010"	4.6365 4.6350	117.767 117.729	.0005"/.0015" (.013/.038 mm)
.020"	4.6465 4.6450	118.021 117.983	.0005"/.0015" (.013/.038 mm)
.030"	4.6565 4.6550	118.275 118.237	.0005"/.0015" (.013/.038 mm)

4. Install a cylinder liner hold-down clamp as shown in Figure 11B-137 on page 11B-89.

5. Measure the distance from the top of the liner to the top of the block with a dial indicator (see Figure 11B-137 on page 11B-89). The liner flange must be 0.045" to 0.050" below the surface of the block. However, even through all of the liners are within these specifications, there must not be over 0.002" difference in depth between any two adjacent liners when measured along the cylinder longitudinal center line.

NOTE

A 0.002" thick shim is available for adjusting the liner height. The shim must be installed underneath the liner insert. Do not cut the shim for installation. Liner inserts which are 0.0015" thicker or thinner than standard are also available for service. In addition, the 0.004" and 0.008" thinner inserts, which are provided for use with resurfaced cylinder blocks, can also be used to adjust the liner height.

6. Matchmark the liner and the cylinder block with a felt pen so the liner may be reinstalled in the same position in the

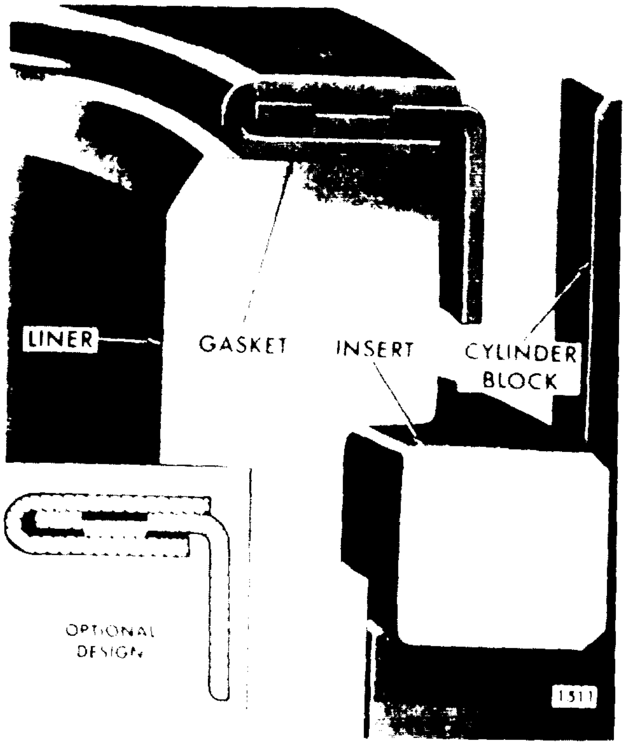


Figure 11B-136. Cylinder Liner Mounting in Block

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

Do not remove the liner insert.

Install Piston and Connecting Rod Assembly

1. With the piston assembled to the connecting rod and the piston rings in place, 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 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 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 Figure 11B-138).

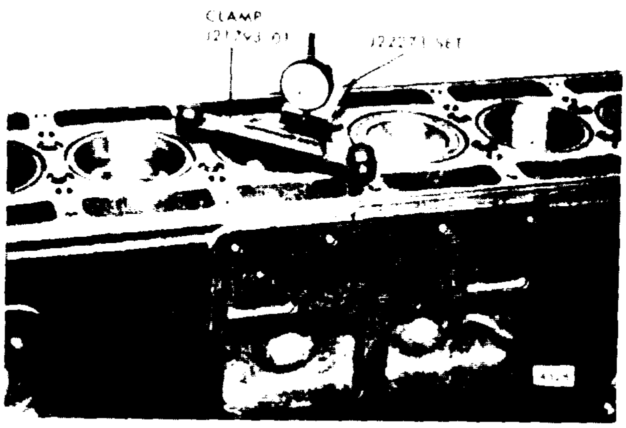


Figure 11B-137. Checking Distance of Liner Flange Below Top Face of Block

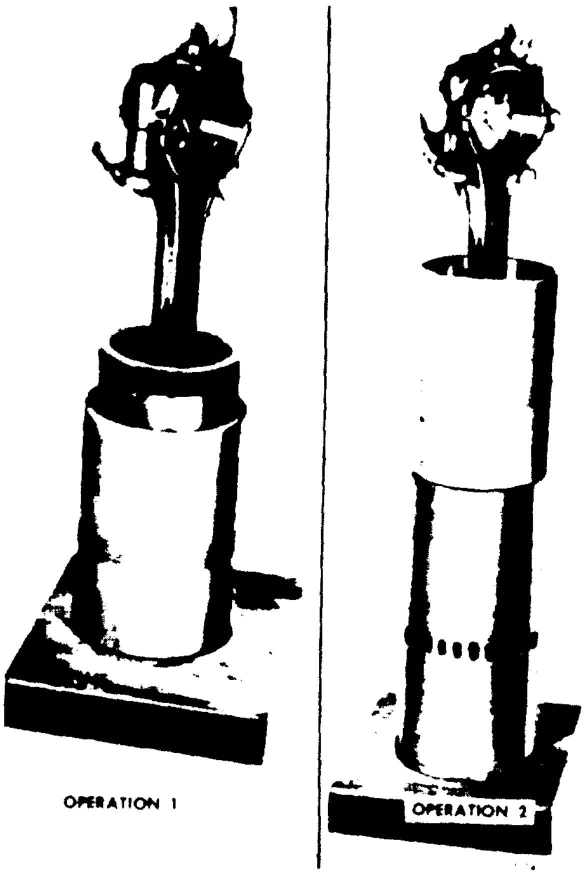


Figure 11B-138. Installing Piston in Cylinder Liner

5. 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 matchmarks on the liner (operation 2 of Figure 11B-138 on page 11B-89).

NOTE

The numbers on the side of the connecting rod and cap (Figure 11B-139) 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.

6. 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. Therefore, extra care must be taken during the loading operation to prevent ring breakage.

7. Remove the connecting rod cap and the ring compressor. Then push the piston down until the compression rings pass the cylinder liner ports.

Install Cylinder Liner, Piston and Connecting Rod

After the piston and connecting rod assembly have been installed in the cylinder liner, install 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.

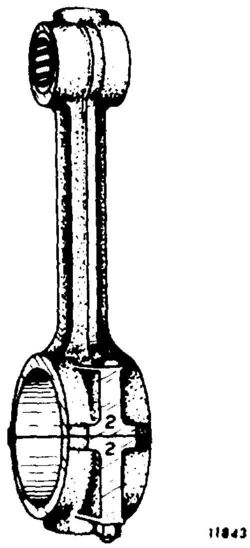


Figure 11B-139. Connecting Rod Markings

3. Install the upper bearing shell, the one with a short oil groove at each parting liner, 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 (see Figure 11B-140 on page 11B-91) so the identification number on the rod is facing the blower side of the engine 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 until the liner 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 rod adjacent to each other. Tighten the connecting rod bolt nuts to 60-70 lb-ft

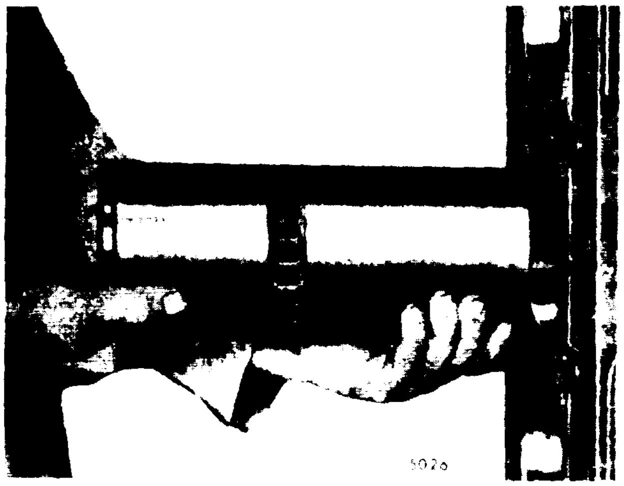


Figure 11B-140. Installing Cylinder Liner in Cylinder Block

(81-95 Nm) torque (lubrite nut) or 65-75 lb-ft (88-102 Nm) torque (castellated nut).

NOTE

Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut.

8. Check the connecting rod side clearance. The clearance must be 0.006” to 0.012”.

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 “Cylinder Head” on page 11B-14. 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 Section 11H 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 piston, rings, cylinder liners or bearings were installed, operate the engine on the run-in schedule given in this subsection.

ENGINE BALANCE AND BALANCE WEIGHTS

Description

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 unbalance 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 produces 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. When 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 unbalance 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 desire couple effective only in a vertical plane.

The balance weights consist of two eccentric weights at each end of the engine.

The front balance weights are keyed to the front end of the camshaft and the balance shaft (Figure 11B-141 on page 11B-92). Balance weights are of one piece construction.

Remove Front Balance Weights

1. Remove the balance weight cover.

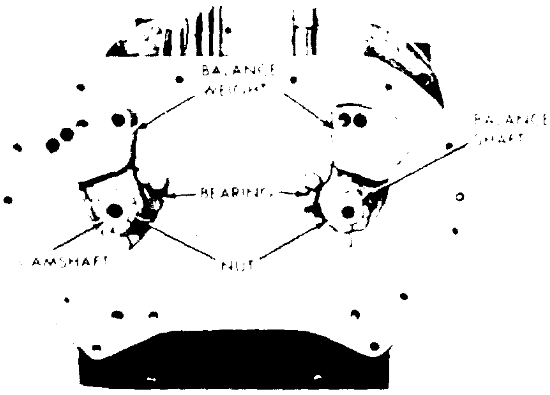


Figure 11B-141. Front Balance Weight Mounting

2. Place a block of wood between the balance weights to prevent rotation (see Figure 11B-142 on page 11B-92).

3. Loosen the balance weight retaining nut on the camshaft and balance shaft with a 1-1/2" socket wrench and remove the nuts and internal tooth lock washers.

4. Force the balance weight off the end of each shaft with two heavy screwdrivers or pry bars between the heads of the bearing retaining bolt and the balance weight (see Figure 11B-143).

Inspection

Clean all of the parts thoroughly with fuel oil and dry them with compressed air.

If the thrust surface (side facing the camshaft) of the balance weight hub is

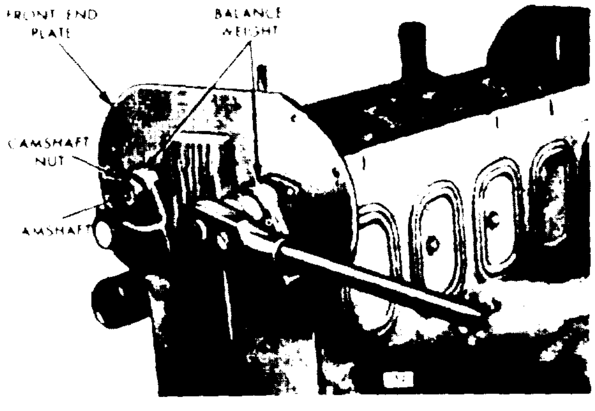


Figure 11B-142. Loosen Nut on Camshaft or Balance Shaft

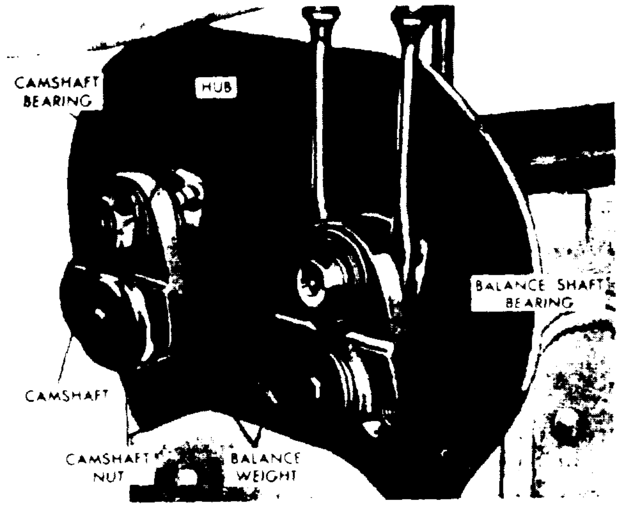


Figure 11B-143. Removing Balance Weight Assemblies

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 0.0005" to 0.0035" with new parts and 0.006" with used parts. The clearance between the weight and the hub should be from 0.010" to 0.023".

Install Front Balance Weights

1. Install Woodruff keys in the keyways at the front end of the camshaft and the balance shaft.

2. Align the keyway in the balance weight hub with the key in the shaft and slide the balance weight on the camshaft.

3. Install the balance weight on the balance shaft in the same manner.

4. Slip an internal tooth lock washer over the end of each shaft. Start the nuts on both shafts.

5. Place a block of wood between the balance weights as shown in Figure 11B-142 and tighten the retaining nuts to 300-325 lb-ft (407-441 Nm) torque.

6. Install the balance weight cover, using a new gasket.

GEAR TRAIN AND ENGINE TIMING

Gear Train

DESCRIPTION. A completely enclosed train of five helical gears is located at the rear end of the engine as shown in Figure 11B-144. 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 camshaft gears.

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 "O" 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 gear train end, the right hand gear, has left hand helical teeth (see Figure 11B-144).

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 matchmarks stamped on the crankshaft gear and the camshaft gear as shown in Figure 11B-144.

However, 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 gear. Then

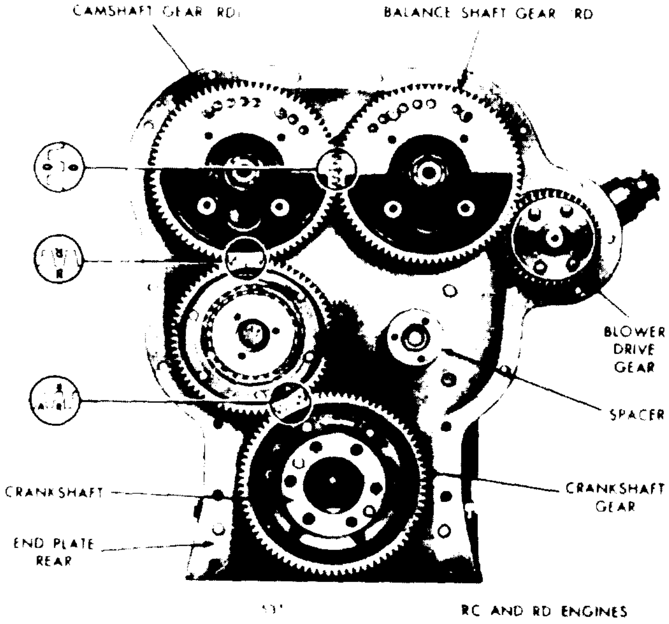


Figure 11B-144. Gear Train and Timing Marks

check whether the "R" timing mark on the crankshaft is aligned with the "R" on the idler gear and record this information for reassembly purposes. This engine is set at standard timing.

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 whining 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 helix steel gear train is from 0.003" to 0.008" with new parts and 0.010" 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. However, 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.

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 support. The idler gear bearing is pressure lubricated by oil passages in the idler gear hub which connect to the oil gallery in the cylinder block.

Engine timing

GENERAL. The correct relationship between the crankshaft and camshaft 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 is offset. The camshaft gear can also be mounted 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 Figure 11B-144 on page 11B-93.

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 below.

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 to 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 Subsection 11C.

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 0.001” 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.

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 shown in Figure 11B-145 on page 11B-95. The pointer should extend over the vibration damper.

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 0.010”.

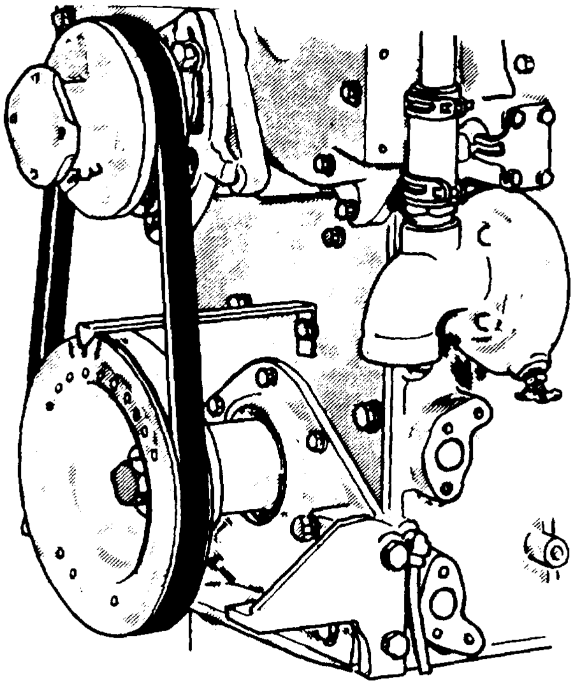


Figure 11B-145. Pointer Installation for Marking Top-Dead Center

11. Scribe a line on the vibration damper 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 indicator to zero. Turn the crankshaft until the indicator reading is 0.010”.

14. Scribe a second line on the vibration damper 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 Figure 11B-145. Remove the indicator and rod from the engine.

NOTE

> If the crankshaft pulley retaining bolt has loosened, tighten it to the specified torque.

16. Install the injector as outlined in Subsection 11C. Then refer to 11H 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. Re-install the dial indicator so the indicator spindle rests on top of the injector follower (Figure 11B-146 on page 11B-96). 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. The correct timing should be 0.230”; retarded timing should be 0.197” and advanced timing should be 0.262”.

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.

CAMSHAFT, BALANCE SHAFT AND BEARINGS

Description

The camshaft and the balance shaft are located just below the top of the cylinder block (see Figure 11B-147 on page 11B-96) and each may be located on either side of the engine as required by engine rotation and accessory arrangement. The camshaft actuates the exhaust valve and injector operating mechanism.

The accurately ground cams ensure efficient, quiet cam follower roller action. The 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 counterbore in the top of the cylinder block.

washers bear against thrust shoulders on the shafts.

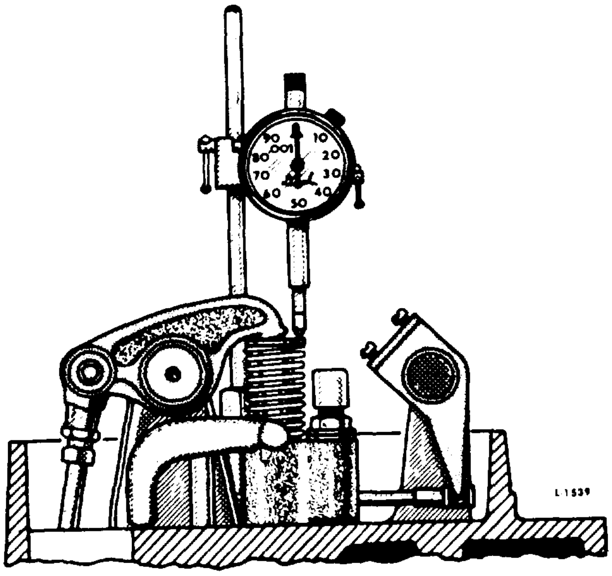


Figure 11B-146. Checking Engine Timing by Measuring Injector Depression

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 balance shaft, the gear thrust load is absorbed by two thrust washers, one on each end of the rear end shaft bearings. 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 (see Figure 11B-148 on page 11B-97), nut, nut retainer, retainer bolt and lock washers. The drive gears are attached to the rear end of the shafts on all engines.

To help maintain engine balance, a balance weight is installed on the front end of each shaft.

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 bearing (see Figure 11B-149 on page 11B-97). Oil from the passage in the camshaft is

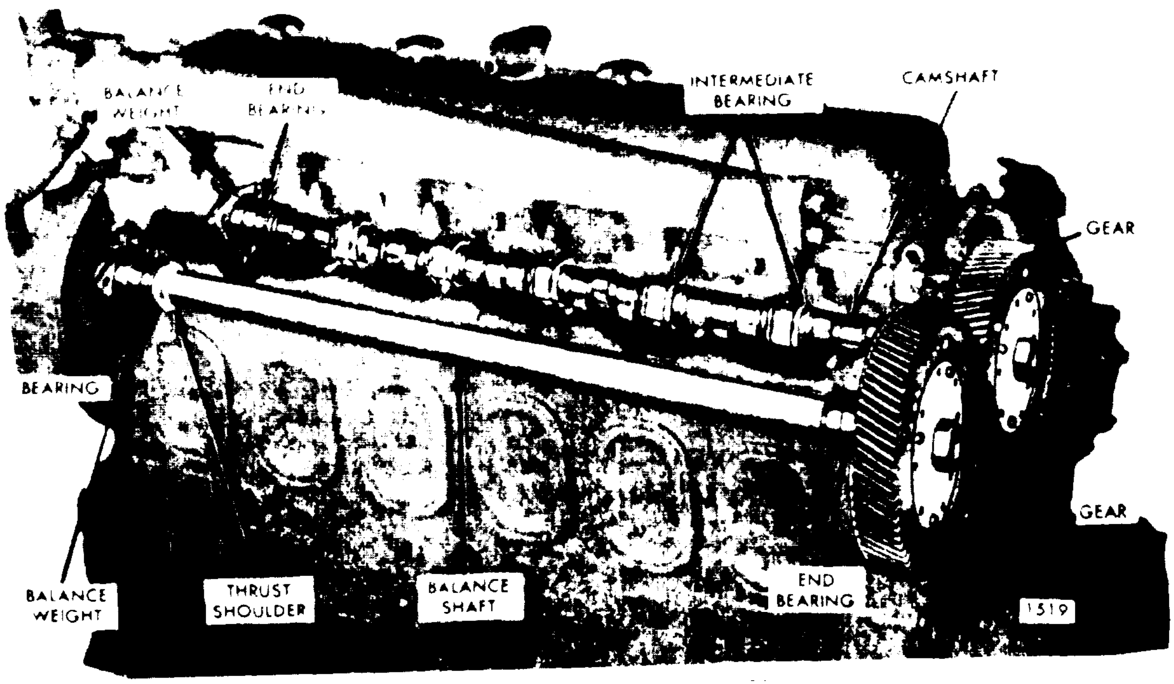


Figure 11B-147. Camshaft and Balance Shaft Assemblies

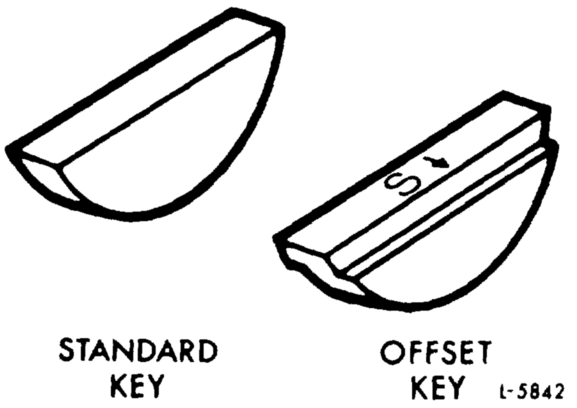


Figure 11B-148. Woodruff Keys for Camshafts

forced through the milled slots in the bearing and then out the grooves to furnish 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.

Remove Camshaft or Balance Shaft

Whenever an engine is being completely reconditioned or the camshaft, gears, bearings or thrust washers need replaceing, 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.

3. Mount the engine on an overhaul stand. Be sure the engine is securely mounted on the overhaul stand before releasing the lifting sling (see Figure 11B-5 on page 11B-3).

4. Remove the cylinder head.

5. Remove the flywheel and flywheel housing.

6. Remove the front balance weight cover and place a wood block between the balance weights (see Figure 11B-150) or wedge a clean rag between the camshaft

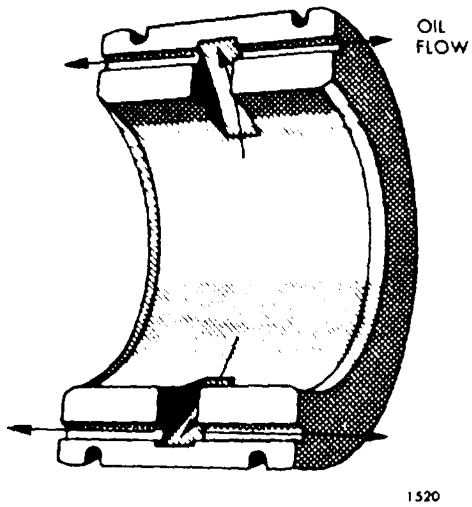


Figure 11B-149. Camshaft Intermediate Bearing

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 lock washer from the balance weight end of each shaft.

9. Remove the front balance weights.

10. Remove the lock screws that secure the camshaft intermediate bearings.

11. Rotate the gears as required to reveal the end bearing retaining bolts. Remove the bolts as shown in Figure 11B-151 on page 11B-98.

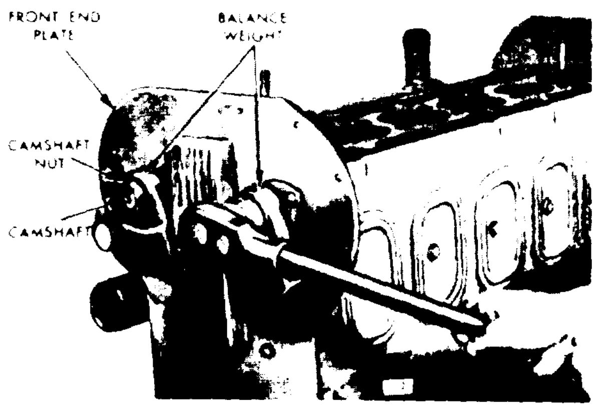


Figure 11B-150. Loosening Nut on Camshaft or Balance Shaft

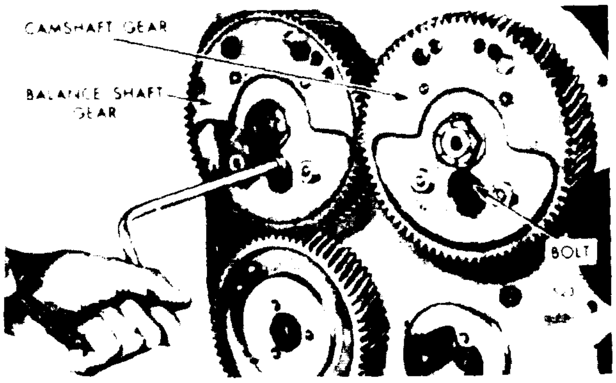


Figure 11B-151. Removing or Installing Shaft Bearing Retainer Bolts

12. Withdraw the camshaft bearing and gear assembly and the balance shaft and gear from the rear end of the cylinder block.

13. The cam and balance shaft front end bearings 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.

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 all of the accessories and assemblies that are necessary to facilitate the removal of the flywheel housing hole cover over 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 (see Figure 11B-150 on page 11B-97).

5. Remove the gear nut retainer after removing the bolts.

6. Loosen and remove the nut at each end of the camshaft.

7. Remove the front balance weights.

8. Remove the lock screws that secure the camshaft intermediate bearings.

9. Remove the three bolts that secure the camshaft bearing to the front end plate.

10. 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 (Figure 11B-152 on page 11B-99 and Figure 11B-153 on page 11B-99).

11. Turn the center screw of the puller clockwise to disengage the camshaft from the camshaft gear.

NOTE

> Do not remove the puller or 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 (also the thrust washer) securely in place and in alignment which will aid in the reinstallation of the camshaft.

12. Remove the front bearing from the camshaft. Then pull the camshaft and intermediate bearing from the cylinder block.

Disassemble Camshaft and Balance Shaft

1. Remove the gear from the shaft.

2. Slide the rear bearing (and the thrust washer) 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 cylinder of the camshaft end plug with a 31/64" drill (carboloy tip).

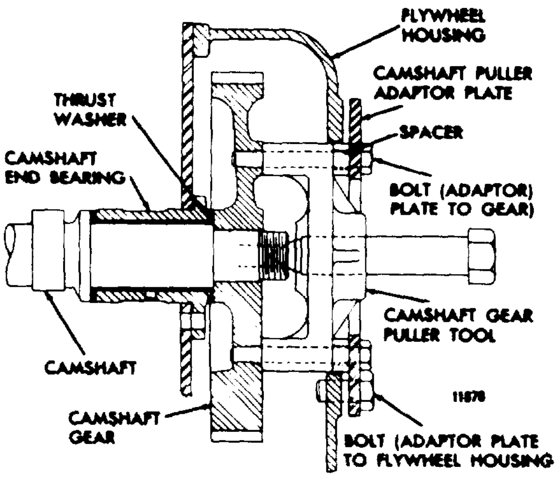


Figure 11B-152. Removing Camshaft with Puller

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 the 3/8"-16 adaptor J 6471-2 into the plug. Then attach slide hammer J 2619-5 to the adaptor. Remove the plug by striking the weight against the handle.

H. Insert a 0.375" 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 plugs as outlined in steps A through G.

Inspection

Soak the camshaft in clean fuel oil. then, run a wire brush through the oil

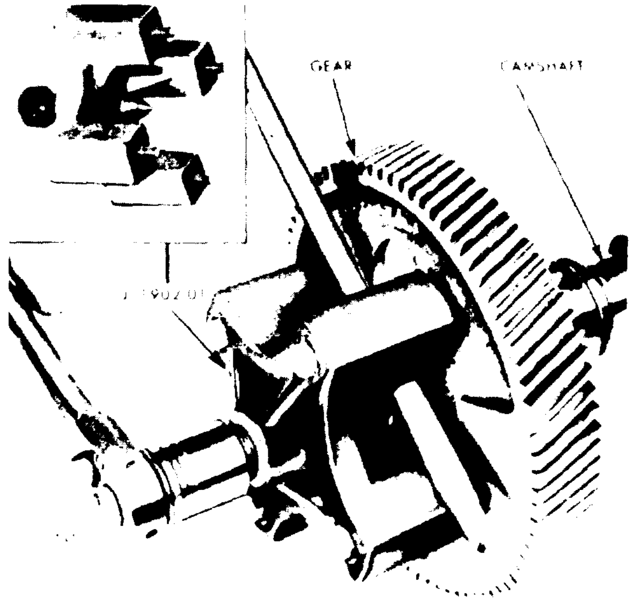


Figure 11B-153. Removing Camshaft Gear

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. Also inspect the camshaft keyways and threads for damage.

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

The camshaft can be in or out of the engine during this inspection.

1. With a tapered leaf set of feeler gauges (0.0015" - 0.0100") 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 (see Figure 11B-154 on page 11B-100).

2. If the flats measure less than 0.003" in depth and there are no other defects the camshaft is satisfactory for service.

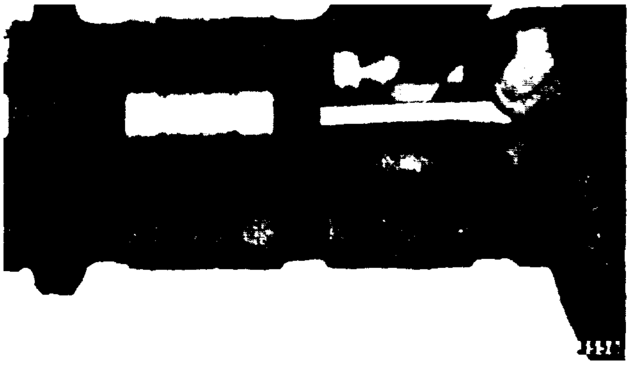


Figure 11B-154. Checking Cam Lobe Wear

3. A slightly worn 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 on the end bearing surfaces. Runout should not exceed 0.002".

Examine both faces of each camshaft rear end bearing and thrust washer. Also, examine the 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 preventative and blow out the oil passages with compressed air.

New standard size thrust washers are 0.120" to 0.122" thick. The clearance between the thrust washer and the thrust shoulder of the camshaft is 0.004" to 0.012" with new parts or a maximum of 0.018" with used parts. Excessive clearance may be reduced by using thrust washers which are 0.005" or 0.010" oversize.

When the thrust surfaces of a camshaft or balance shaft are ground undersize, special care must be taken as follows:

1. Leave a 0.031" to 0.094" radius between the bearing surface of the thrust collar shoulder and the bearing surface of the camshaft (see Figure 11B-155)

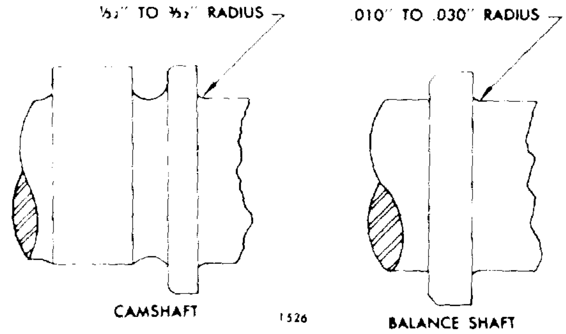


Figure 11B-155. Cam and Balance Shaft Journal Fillets

2. Leave a 0.010" to 0.030" radius between the bearing surface of the thrust collar shoulder and the bearing surface of the balance shaft (see Figure 11B-155).

Use a fillet gauge to measure the specified radii.

Examine the faces of the shaft end bearings and any other surface which comes into contact with the thrust washers. Parts that are badly marred must be placed; parts with slight scratches may be cleaned up with an oil stone.

NOTE

> If a new camshaft is to be installed, steam clean it to remove the rust preventative and blow out the oil passages with compressed air.

Inspect the bushings in the shaft end bearings. Replace the bushings or end bearing assemblies if they are worn excessively or the bushings have turned within the bearing. New bushings must be finished bored to 20 rms finish after installation and tested for the correct press fit. The correct press fit is indicated if the bushing does not move when a 2000 pound (8.9 kN) end load is applied. This test is of special importance with engines that operate at high (2300 RPM) speeds. The inside diameter of the bushings must be square with the rear face of the bearing within 0.0015" total indicator reading and concentric with the outside diameter of the bearing retainer within 0.002" total indicator reading. The bushings must project from 0.045" to

0.055” from each end of the bearing (see Figure 11B-157 on page 11B-102).

The clearance between the camshaft and balance shaft end journals and the end bearing bushings is 0.0025” to 0.004” with new parts or a maximum of 0.006” with used parts. End bearings are available in 0.010” or 0.020” undersize for use with shafts that are worn or have been reground and the clearances exceed the specified limits.

Replace excessively scored or worn camshaft intermediate bearings. The clearance between the camshaft journals and the intermediate bearings is 0.0025”: to 0.005” with new parts or a maximum of 0.009” with worn parts. Camshaft intermediate bearings are available in 0.010” and 0.020” undersize for use with worn or ground shafts in which the clearances exceed the specified limits. Examine the intermediate bearing lock screws and the tapped holes in the block. Damaged holes in the cylinder block may be blocked, redrilled and tapped. Discard lock screws with damaged threads.

Assemble Camshaft and Balance Shaft

Refer to Figure 11B-156 and assemble the camshaft and balance shaft as follows:

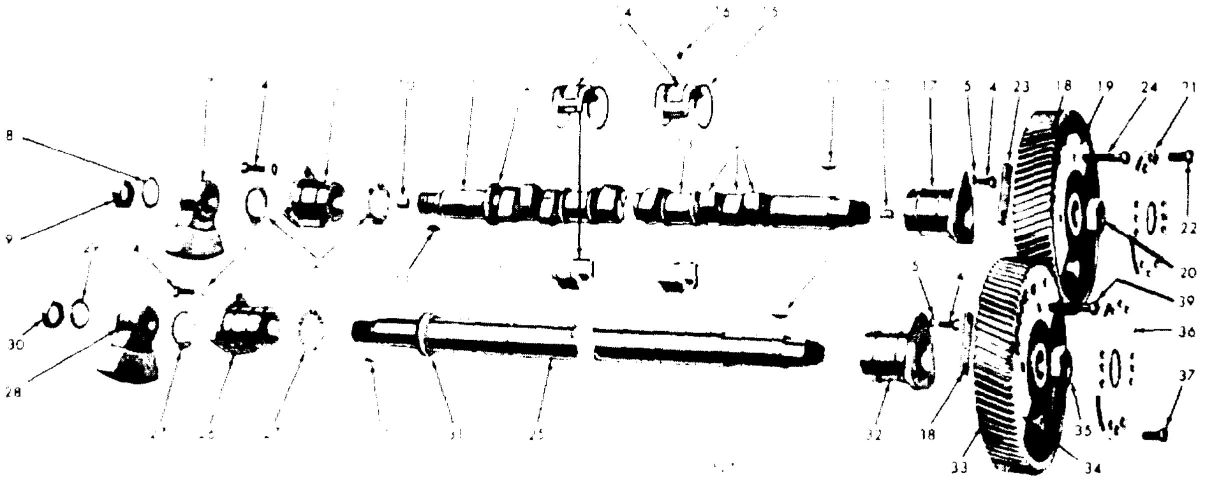
1. Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940” to 2.060” (see Figure 11B-158 on page 11B-103).

2. Apply grease to the steel face of each end thrust washer. Then place a thrust washer against each end of the camshaft and balance shaft rear bearings. Be sure the steel face of the thrust washers are next to the bearing.

3. 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.

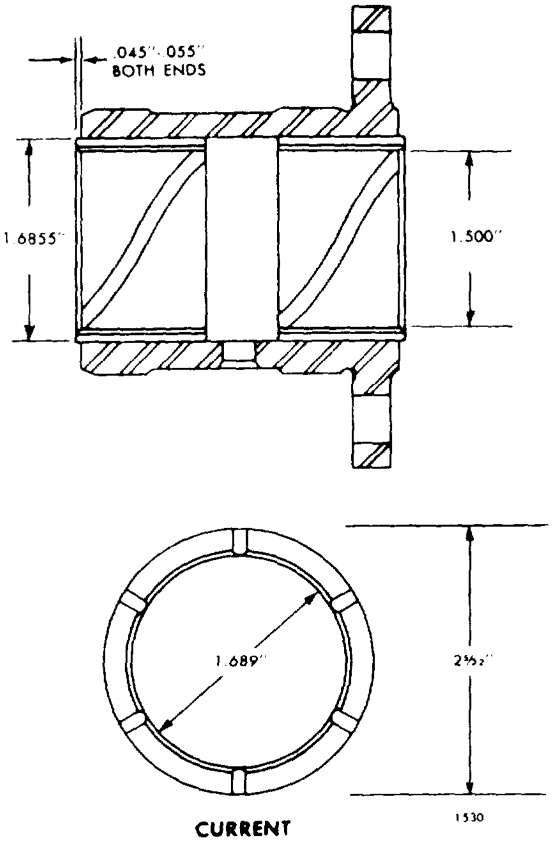
4. Install the gears on the shafts.

5. Lubricate the camshaft intermediate bearing journals. Then place the two halves of each intermediate bearing on a camshaft journal and lock the halves to-



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

Figure 11B-156. Camshaft and Balance Shaft Parts



CURRENT

Figure 11B-157. Comparison of End Bearings and Thrust Washers

gether 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.

Install Camshaft and Balance Shaft

1. insert the front end of the camshaft into the opening on the side opposite the blower. 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.

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 Figure 11B-144 on page 11B-93 and slide the camshaft gear in place.

3. Secure the camshaft rear end bearing to the cylinder block with the three bolts and lockwashers. Rotate the camshaft gear as required to install the bolts through the hole in the gear web (see Figure 11B-151 on page 11B-98). Tighten the bolts to 30-40 lb-ft (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 Figure 11B-144 on page 11B-93 and slide the balance shaft gear in place.

6. Secure the balance shaft rear end bearing. Use the same procedure as outlined for the camshaft rear end bearing.

7. Install the camshaft and balance shaft front end bearings with the bolts and lockwashers. Tighten the bolts to 35-40 lb-ft (47-54 Nm) torque.

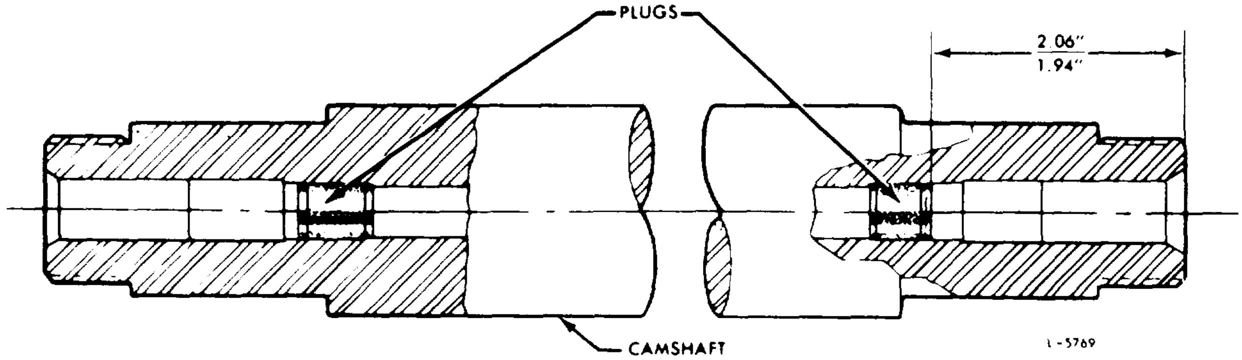


Figure 11B-158. Camshaft Plug Installation

NOTE

Install the front bearings with care to avoid dislodging the thrust washers. Do not hammer the bearings into the cylinder block.

8. 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 screw and tighten them to 15-20 lb-ft (20-27 Nm) torque.

CAUTION

When the intermediate bearings are locked into position with the lock screw, the bearing must have slight movement in the block bore.

9. Install the front balance weights on the shafts.

10. Place an internal tooth lock washer on the end of each shaft and start the nuts on both shafts.

11. Use a wood block (Figure 11B-150 on page 11B-98) 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 lb-ft (407-441 Nm) torque.

12. Install the camshaft and balance shaft gear nut retainers with bolts and lockwashers. Tighten the bolts to 35-39 lb-ft (47-53 Nm) torque.

13. Check the clearance between the thrust washer and the thrust shoulder of both the camshaft and balance shaft. The specified clearance is 0.004" to 0.012" with new parts or a maximum of 0.018" with used parts.

14. Check the backlash between the mating gears. The specified backlash between new gears is 0.003" to 0.008" or a maximum of 0.010" between worn gears.

15. Install the flywheel housing and other parts or assemblies that were removed from the engine as outlined in their respective section of this manual.

16. Refill the cooling system.

Install Camshaft (Flywheel Housing and Torque Converter in Place)

1. Apply grease to the steel face of the thrust washer and install it with the steel face against the bearing.

2. 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.

3. Align the key in the shaft with the keyway in to camshaft drive gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.

NOTE

Make sure the thrust washer is in the correct position to prevent pushing the bushing into the bearing or damaging the bushing.

4. Remove the camshaft gear puller, spacers and adaptor plate. Finger tighten the gear retaining nut on the shaft.

5. Install the front end bearing with the bolts and lockwashers. Tighten the bolts to 35-40 lb-ft (47-54 Nm) torque.

6. Install the balance weight on the front end of the camshaft.

7. Start the balance weight retaining nut and lockwasher on the camshaft (Figure 11B-154 on page 11B-100). Place a wood block between the balance weights (Figure 11B-150 on page 11B-97). Tighten the gear retaining nut and the balance weight nut to 300-325 lb-ft (407-441 Nm) torque.

8. Align the holes in the camshaft intermediate bearings with the tapped holes in the top of the cylinder block. Install and tighten the lock screws to 15-20 lb-ft (20-27 Nm) torque.

9. Reinstall the parts, accessories and assemblies that were removed from the engine as outlined in their respective subsections of this section.

10. Refill the cooling system.

CAMSHAFT AND BALANCE SHAFT GEARS

Description

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 (see Figure 11B-159). Either one of the gears may be driven from the crankshaft timing gear, through an idle gear, depending upon engine rotation. 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

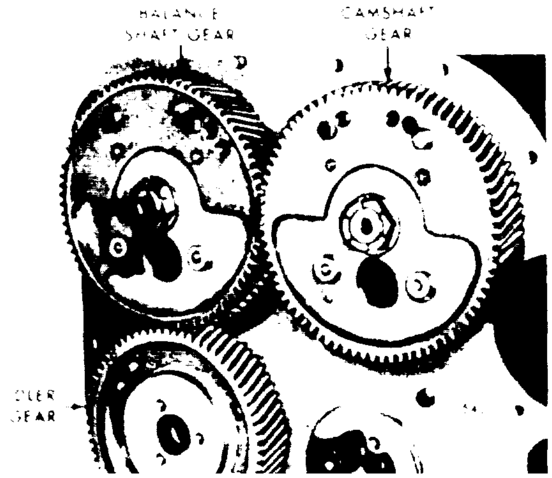


Figure 11B-159. Camshaft and Balance Shaft Gears

“R” for right hand rotation engine) are located on either the camshaft gear or balance shaft gear and the mating idler 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. A gear nut retainer, with a double hexagon hole in the center, fits over the nut and prevent loosening of the nut. The retainer is attached to the gear by bolts threaded into tapped holes in the gear. These tapped holes are also utilized in mounting an accessory drive on the camshaft or balance shaft gear.

A small balance weight is attached to the inner face of each gear. These weights are important in maintaining perfect engine balance.

Remove Camshaft and Balance Shaft Gears

1. Remove the camshaft and balance shaft from the engine as outlined in “Remove Camshaft or Balance Shaft” on page 11B-97.

2. Support the camshaft suitably in the soft jaws of a bench vice, 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 (see Figure 11B-160 on page 11B-105).

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.

Inspection

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.

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. Install the thrust washers between the end bearings and the thrust shoulders of the shafts, and between the end bearings and the gears.

NOTE

Be sure the steel face 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 form a right hand helix and on the other a left hand helix. When viewing the engine from the flywheel end, the gear with ri ght hand helical teeth is located on the left side and the gear with the 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.

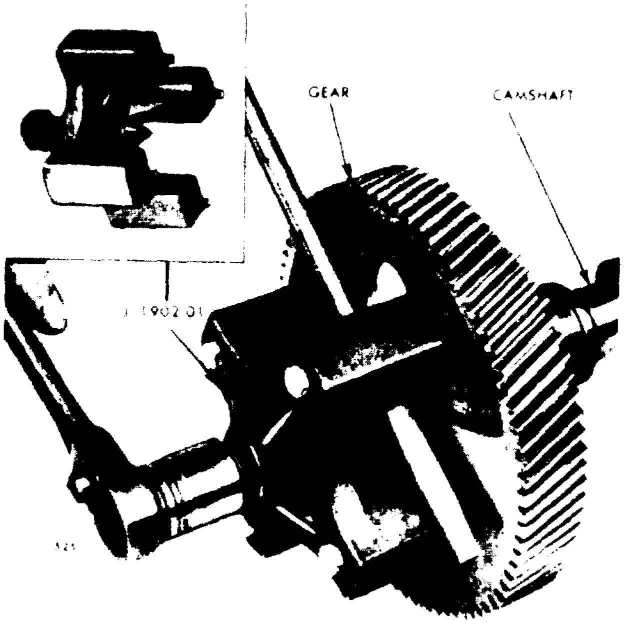


Figure 11B-160. Removing Gear (Camshaft or Balance Shaft)

5. Use gear installer J 1903 as shown in Figure 11B-161 on page 11B-106 to drive the gears on the camshaft and balance shaft.

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.

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 lb-ft (407-447 Nm) torque.

9. Secure the nuts with retainers, retainer bolts and lock washers.

10. Check the backlash between the mating gears. The backlash should be 0.003" to 0.008” with new parts or 0.010” maximum with used parts.

IDLER GEAR AND BEARING ASSEMBLY

Description

The idler gear is mounted on a double row, tapered roller bearing which, in

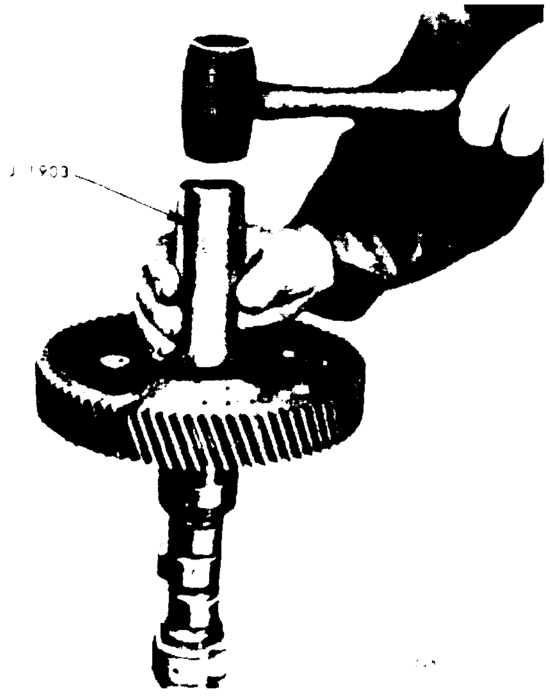


Figure 11B-161. Replacing Camshaft Gear

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.

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.

Remove Idler Gear (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.

NOTE

> 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.

2. Remove the idler gear hole spacer in the same manner if the engine is being completely reconditioned.

Disassemble Idler Gear 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 Figure 11B-163 on page 11B-108 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.

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.

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 pressure with the bearing cone or inner race supported on steel blocks as shown in Figure 11B-162. 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.

Inspection

Wash the idler gear, hub and bearing components thoroughly in clean fuel oil and dry with compressed air.

Check the idler gear hub and spacer. 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.

Assemble Idler Gear Assembly

Refer to Figure 11B-163 on page 11B-108 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 match 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 180° from the gap in the inner spacer ring.

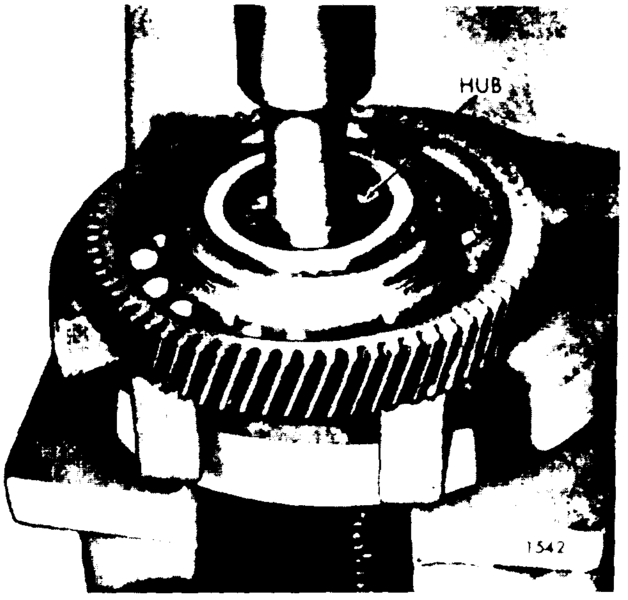


Figure 11B-162. Pressing Hub Out of Bearing

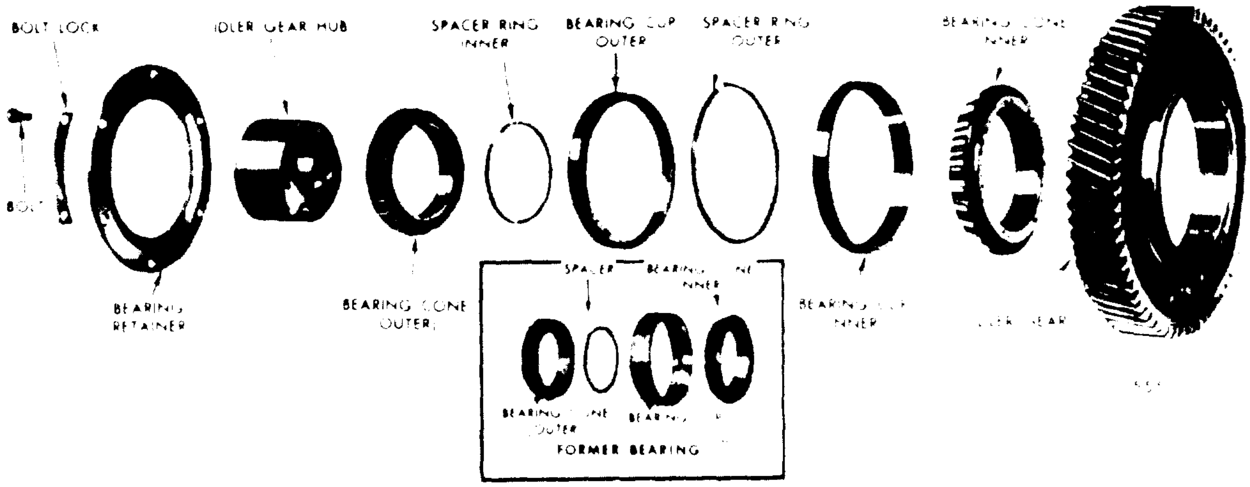


Figure 11B-163. Idler Gear Parts

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 roller properly between the cones. The bearing cones must be supported so as not to load the bearing rollers during this operation (see Figure (11B-164).

8. Before installing the gear and bearing assembly, check the pre-load.

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 tapered 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-loading is measured, in terms of pound-pull, by the effort required at the outer diameter of the gear to turn the bearing cup in relation to the bearing cones.

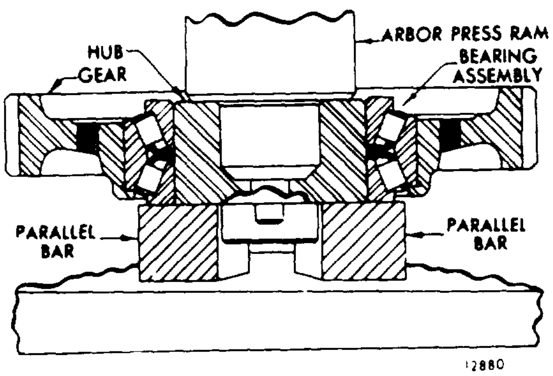


Figure 11B-164. Pressing Hub into Bearing

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

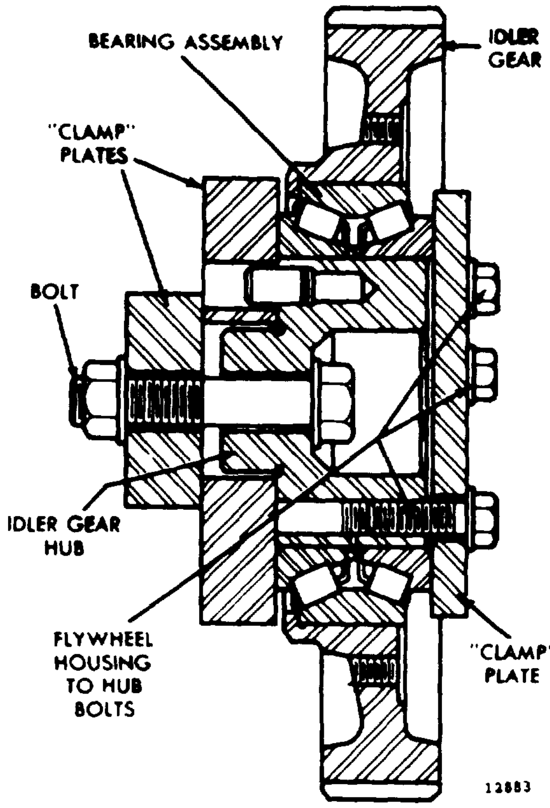


Figure 11B-165. Fixture for Testing Bearing Pre-Load

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 into the cylinder block. Tighten the bolt to 80-90 lb-ft (108-122 Nm) torque.

3. Place steel plate (lower plate shown in Figure 11B-166) 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 lb-ft (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

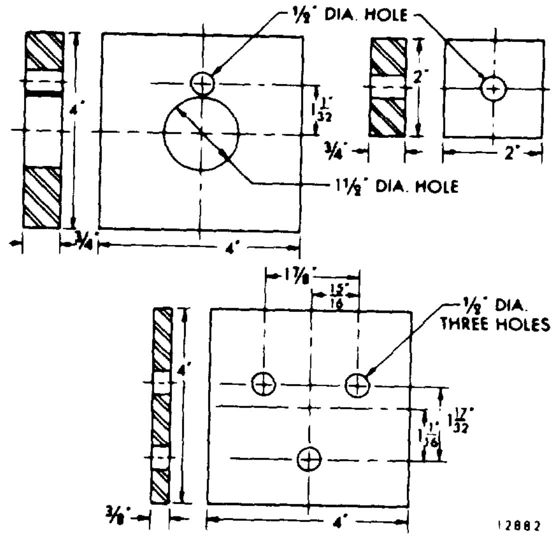


Figure 11B-166. Plates for Bearing Test Fixture

cord around the periphery of the gear several times. Attach the other end of the cord to spring scale, J 8129 (see Figure 11B-167 on page 11B-110). Maintain a straight, steady pull on the cord and scale, 90° 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 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 Figure 11B-165. Three plates (shown in Figure 11B-166) a 1/2"-13x 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, the other two plates, the cylinder block. Engine mounted conditions are simulated by tightening the nut to 80-90 lb-ft (108-122 Nm) torque and tightening the three plate-to-hub attaching bolts to 25-40 lb-ft (34-54 Nm) torque.

Check the pre-load as follows:

A. Attach the plates (two upper plates shown in Figure 11B-166) to the idler gear with 1/2"-13 bolt, washer and nuts as shown in Figure 11B-765. Tighten the bolt to 80-90 lb-ft (108-122 Nm) torque.

B. Attach the third plate to the idler gear hub with three 3/8"-16 bolts. Tighten the bolts to 25-40 lb-ft (34-54 Nm) torque.

C. Clamp the idler gear assembly and fixture in a vise (see Figure 11B-167)

D. Attach the cord to the idler gear and spring scale and check the pre-load as previously described.

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 lb-ft (33-39 Nm) torque.

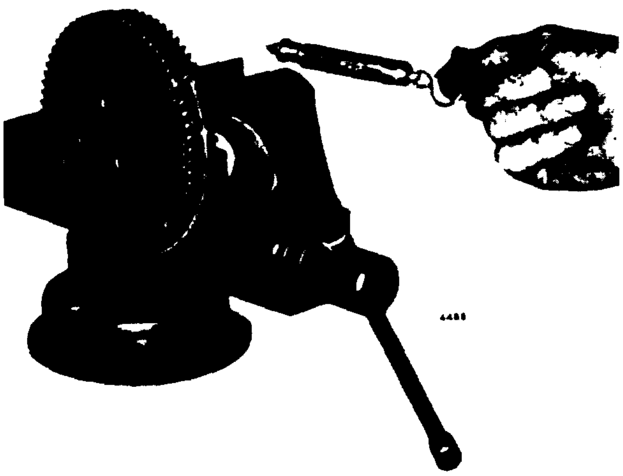


Figure 11B-167. Check Pre-Load of Idler Gear Bearing

NOTE

New locking bolts should always be used when attaching the bearing retainer to the idler gear.

2. Bend the ears of each bolt lock against the flat side of the attaching bolt heads to secure the bolts.

Install Idler Gear Assembly

1. Position the crankshaft gear and either the balance shaft or camshaft gear (depending upon engine rotation) so that the timing marks will align with those on the idler gear (see Figure 11B-144 on page 11B-93).

2. With these marks in alignment, start the idler gear into mesh with the crankshaft gear and the camshaft 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 lb-ft (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 lb-ft (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 0.002" to 0.008" between new gears and must not exceed 0.010" between used gears.

8. Install the flywheel housing.

CRANKSHAFT TIMING GEAR

Description

The crankshaft timing gear is bolted to the flange at the rear of the crankshaft and drives the camshaft gears, 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.

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft gear is press fit on the crankshaft. 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 and lock washers securing 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. The remove the gear with a suitable puller as shown in Figure 11B-168.

Inspection

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.

Install Crankshaft Timing Gear

1. Position the gear on the rear 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 “R” timing mark on the crankshaft gear tooth with the corresponding mark on the idler gear.

3. Start the six 3/8”-24 bolts with lock washers through the gear and into the crankshaft. Then draw the gear tight against the shoulder on the crankshaft. Tighten the bolts to 35-39 lb-ft (47-53 Nm) torque.

4. Check the backlash with the mating gear. The backlash should be 0.003” to 0.008” with new gears or 0.010” maximum with used gears.

5. Install a new crankshaft rear oil seal sleeve, if required.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

Description

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 Figure 11B-169 on page 11B-112 and Figure 11B-173 on page 11B-115, which insures a uniform rotation of the blower rotors. The right hand helix blower drive gear is driven by the balance shaft gear (see Figure 11B-144 on page 11B-93). The ratio of blower speed to engine speed is 1.55 to 1.

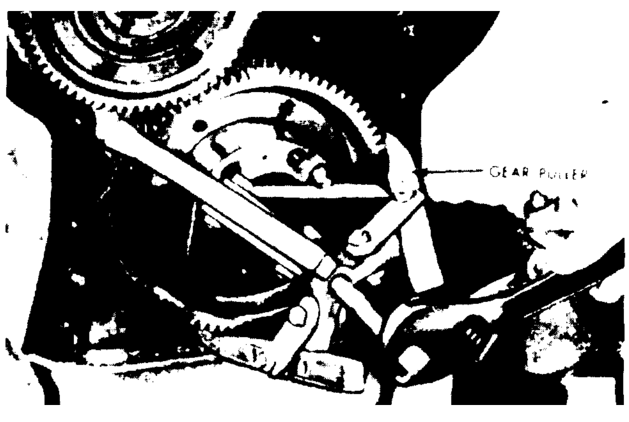


Figure 11B-168. Removing Crankshaft Timing Gear

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, Figure 11B-169).

2. Refer to Figure 11B-172 on page 11B-113 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 Subsection 11D.

A broken drive shaft indicates an unusual loading which may have been caused by a bearing failure other malfunction. Inspect the blower drive, blower rotors and the housing before replacing the drive shaft. See the blower inspection procedure in Subsection 11D.

Reverse the removal steps to install the blower drive shaft.

Remove Blower Drive Gear (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 requires service.

Before removing the blower drive gear, the blower drive shaft must be removed as previously outlined.

1. Remove the blower as outlined in Subsection 11D.

2. Remove the blower drive oil line (see Figure 11B-171 on page 11B-113).

3. Straighten the ears on lock washer (58) and loosen the drive gear hub nut (57, Figure 11B-173 on page 11B-115).

4. Remove the blower drive support attaching bolts.

47. Cover--Blower Drive
51. Seal--Drive Cover
52. Clamp--Cover Seal
53. Gear--Blower Drive
54. Hub--Drive Gear
55. Lock Ball
56. Washer--Drive Gear Hub Thrust
57. Nut--Drive Gear Hub
58. Lock Washer
59. Bearing--Drive Gear Hub
61. Support--Drive Gear Hub
63. Gasket
64. Bolt--Drive Gear Hub Support
67. Support--Drive Coupling
68. Cam--Drive Coupling
71. Retainer--Drive Coupling
72. Bolt--Drive Coupling
73. Lock Washer
75. Pipe--Drive Bearing Oil
76. Elbow--Oil Pipe
79. Shaft--Blower Drive
80. Ring--Blower Drive Shaft
81. Hub--Blower Rotor Gear
83. End Plate--Cylinder Block-Rear
91. Housing--Flywheel
92. Cover--Flywheel Housing (Small Hole)
93. Gasket--Cover
94. Bolt--3/8"-16 x 7/8"-Cover
95. Bolt--3/8"-24 x 5"-Cover
96. Lock Washer
102. Thrust Washer

Figure 11B-169. Blower Drive Gear and Support

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.

Disassemble Blower Drive Gear and Support

1. Secure the blower drive gear and support assembly in a vise with soft jaws.

2. Take out drive coupling bolts (72) and remove retainer (71) and coupling support (67, Figure 11B-173 on page 11B-115).

3. Remove drive gear hub nut (57), lock washer (58), lock ball (55) and thrust

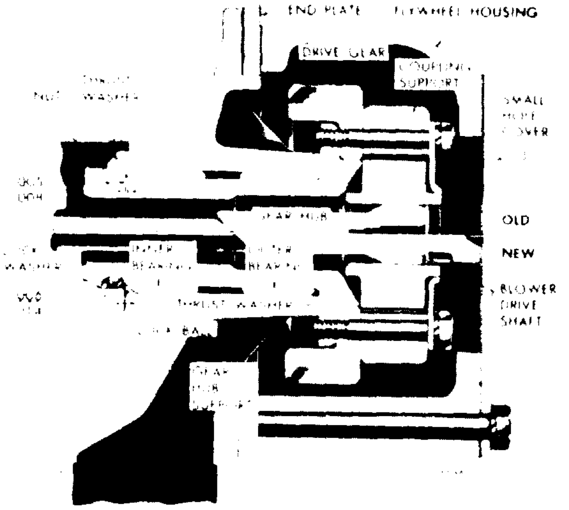


Figure 11B-170. Blower Drive Support

washer (56) and withdraw the blower drive gear hub.

4. Remove the thrust washer from the blower drive gear hub (see Figure 11B-170).

5. Press the gear hub out of the blower drive gear.

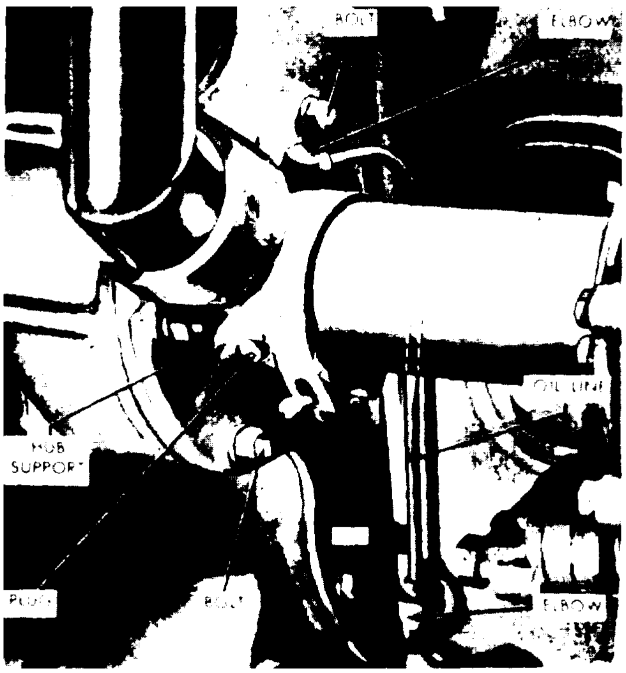


Figure 11B-171. Blower Oil Line

Inspection

Clean the parts with fuel oil and dry them with compressed air. Ensure that the oil grooves,oil holes and cavities are free of dirt.

Replace the thrust washers if they are worn or scored.

If the bearings are worn or scored excessively the drive gear hub support or bearings will have to be replaced. These bushing type bearings are diamond bored to an inside diameter of 1.6260" to 1.6265" after installation in the hub.

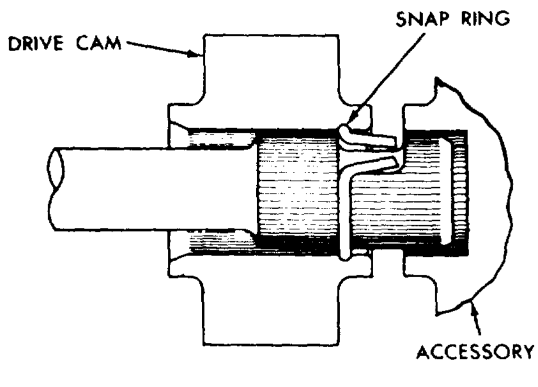
The clearance between the bearings and the hub is 0.0010" to 0.0025" with new parts and a maximum of 0.0050" with used parts.

The bearing on the gear end protrudes 0.045" to 0.055" above the surface of the face to facilitate the installation of blower thrust washer (102). The other bearing is installed with the end flush to 0.030" below the surface of the face of the support. Replacement bearings must withstand 2000 lb end load without moving, also the bearing bores must be square with the inner and outer faces of the support within 0.001" total indicator reading.

Replace the blower drive shaft if the serrations are worn or damaged.

Inspect the blower drive coupling support, cam, spring seats and spring packs. Replace worn or damaged parts.

The blower drive coupling incorporates spring seats which prevent pressure and



CURRENT LONG SHAFT AND SNAP RING

Figure 11B-172. Blower Drive Shaft Mounting wear from the spring packs on the coupling, thereby prolonging the life of the coupling. Shorter springs are required for use with the spring seats. When a spring replacement is necessary, the new springs and spring seats, available in a kit, must be installed.

Examine the blower drive gear. If the teeth are excessively worn, scored or pitted, the gear must be replaced.

Assemble Blower Drive Gear and Support

The relative location of the parts is shown in Figure 11B-173 on page 11B-115:

1. Secure blower drive gear support (61) in a vise with soft jaws.

2. Press drive gear hub (54) into drive gear (53).

3. Lubricate the drive gear hub, bearings in the support, thrust surfaces and blower drive thrust washer with engine oil.

4. Place thrust washer (102) on the protruding bearing in the gear side of the support and insert the blower drive gear hub and gear assembly.

5. Locate lock ball (55) in its place on the drive gear hub and slide hub thrust washer (56) into position over the lock ball. The thrust washer must be installed with the tapered face toward the threads on the hub.

6. Install a new lock washer (58) and finger tighten 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 lb-ft 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 as follows:

A. Place drive coupling support (67) on wood blocks as in Figure 11B-174.

B. Install spring end seats (101) and place spring seat (70) in each corner of the drive coupling support.

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 blower drive cam (68) on the installer J 1471, insert the round end of the tool between spring pack (69) and press the cam into position (see Figure 11B-174).

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 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 to ensure proper lubrications (see Figure 11B-175 on page 11B-115).

9. Install the drive coupling bolts.

Install Blower Drive Gear and Support

1. Check the clearance (Figure 11B-170 on page 11B-113) between the drive support and gear hub thrust washer before installing the blower drive gear support assembly. The clearance must be 0.006" to 0.014".

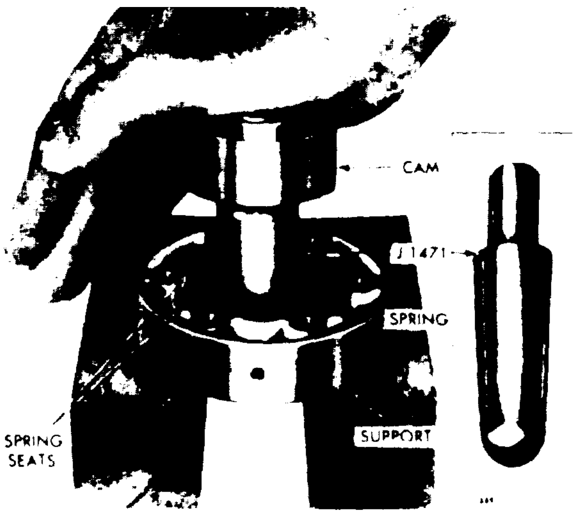
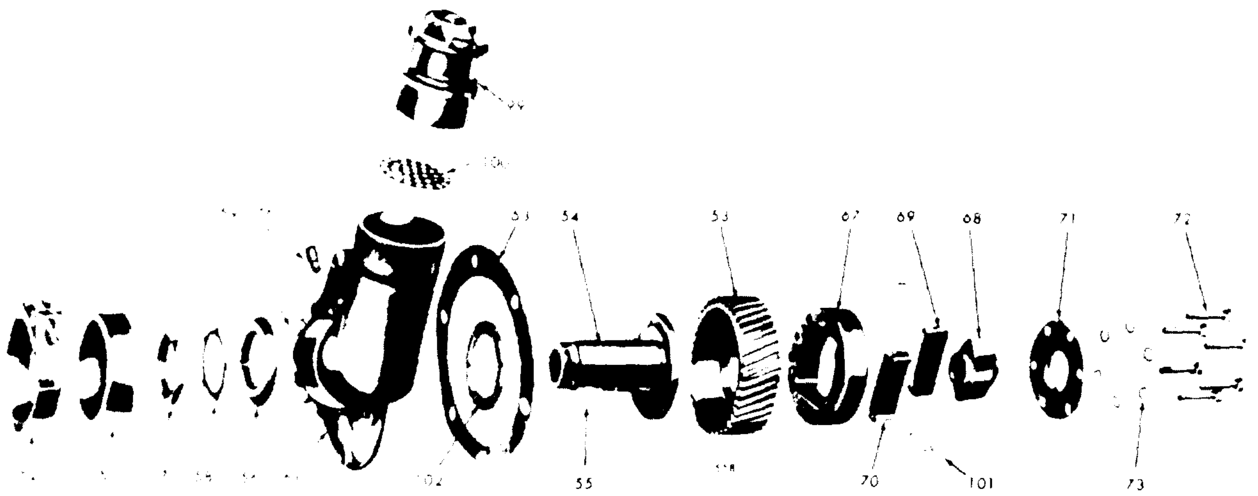


Figure 11B-174. Inserting Blower Drive Cam



51. Seal--Drive Cover
52. Clamp--Cover Seal
53. Gear--Blower Drive
54. Hub--Drive Gear
55. Lock Ball
56. Washer--Drive Gear Hub Thrust
57. Nut--Drive Gear Hub
58. Lock Washer
61. Support--Drive Gear Hub
63. Gasket
67. Support--Drive Coupling
68. Cam--Drive Coupling
69. Spring (Pack)--Drive Coupling
70. Seat--Coupling Spring
71. Retainer--Drive Coupling
72. Bolt--Drive Coupling
73. Lock Washer
76. Elbow--Oil Pipe
99. Cap--Oil Filler
100. Strainer--Oil Filler
101. Seat--Coupling Spring End
102. Washer--Thrust

Figure 11B-173. Blower Drive Gear Parts

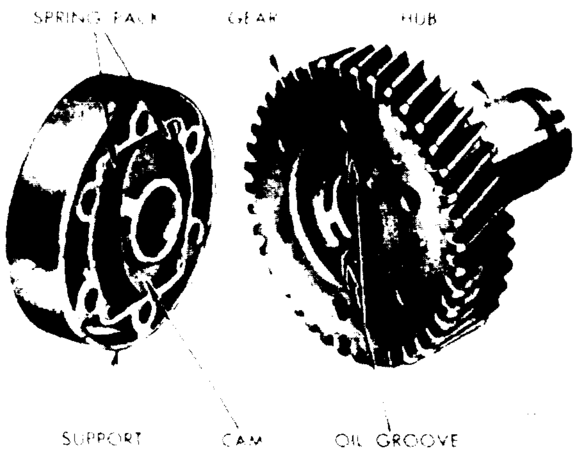


Figure 11B-175. Relation of Blower Drive Cam to Oil Grooves in Gear Hub

2. Place a new gasket (63) on the mounting face of the hub support.

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.

5. Install the blower as outlined in Subsection 11D and secure seal (61) and clamp (52) as shown in Figure 11B-173.

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.

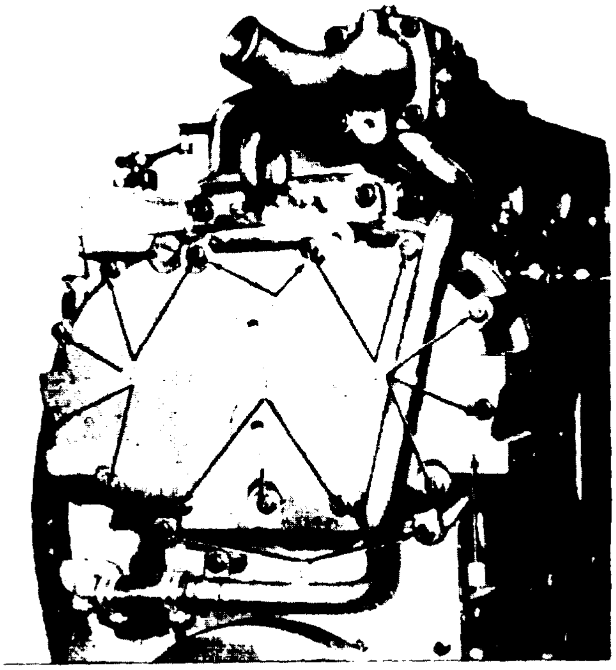
8. Re-install the flywheel and flywheel housing and install the remaining bolts that secure the blower drive gear and support assembly.

BALANCE WEIGHT COVER

Description

The front balance weight cover (Figure 11B-176 on page 11B-116) 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.



1. Cover-Balance Weight
2. Bolt-3/8-24 x 3 (to end plate)
3. Bolt-3/8-16 x 3-1/2 (to cylinder block)
4. Bolt-3/8-16 x 1-7/8 (to cylinder block)
5. Bolt-3/8-24 x 1-1/2 (to end plate)
6. Washer-Plain

Figure 11B-176. Balance Weight Cover Mounting

Remove Cover

1. Drain the cooling system.

2. Loosen the hose connections between the radiator and the engine.

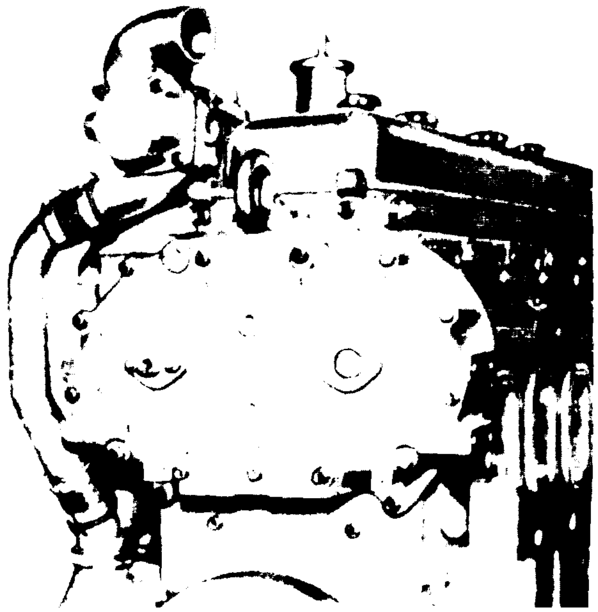


Figure 11B-177. Balance Weight Cover Tightening Sequence

3. Remove the radiator.

4. Remove the fan, fan hub and adjusting bracket.

5. Remove the fifteen bolts, lock washers and plain washers 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.

Install Cover

1. Affix a new gasket to the balance weight cover.

2. Install the cover in place and install the fifteen attaching bolts, lock washers and plain washers finger tight.

3. Refer to Figure 11B-177 and tighten the bolts to 25-30 lb-ft (34-41 Nm) torque.

4. Install the various subassemblies that were previously removed.

ACCESSORY DRIVES

Description

Accessory drives have been provided at the rear of the engines to accommodate both gear driven and belt driven accessories.

For the possible accessory drive location and rotation of the drive at a particular position, refer to Figure 11B-178 on page 11B-117.

The drive for direct gear driven accessories, such as a raw water pump, is made up of a spacer (when used), accessory drive plate and drive coupling (see Figure 11B-179 on page 11B-117).

The drive plate is bolted to the camshaft or balance shaft gear. The accessory is bolted to the flywheel housing and driven by a drive coupling which is splined to both the accessory shaft and accessory drive plate.

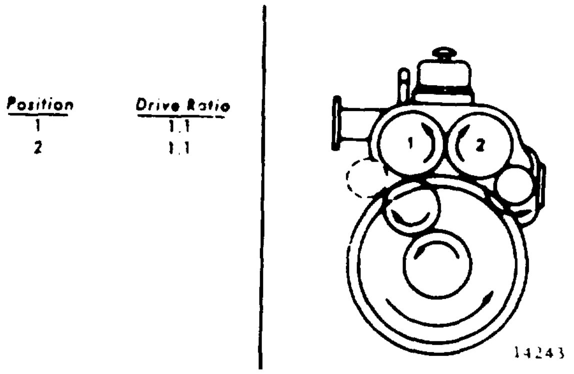


Figure 118-178. Accessory Drive Locations

Belt driven accessories, such as battery charging generators, are driven off the camshaft or balance shaft gears by a accessory drive plate, drive shaft, accessory drive retainer assembly and pulley (see Figure 11B-180 on page 11B-118). The accessory drive plate is bolted to one of the balance gears. The accessory drive shaft is splined to the drive plate at one end and supported by a bearing in the accessory drive retainer at the other end. The accessory drive retainer, which also incorporates an oil seal, is bolted to the flywheel housing. The pulley is keyed to the drive shaft which extends through the drive retainer assembly.

Remove Accessory Drive

Remove the gear driven type accessory drive as follows:

1. Remove any external piping or connections to the accessory.

2. Remove the five bolts and lock washers attaching the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing.

3. Remove the drive coupling.

4. Place a clean, lintless cloth in the flywheel housing opening, underneath the accessory drive plate, to prevent bolts from accidentally falling into the gear train. Remove the four bolts and lock washers attaching the accessory drive plate to the balance gear and remove the plate and spacer.

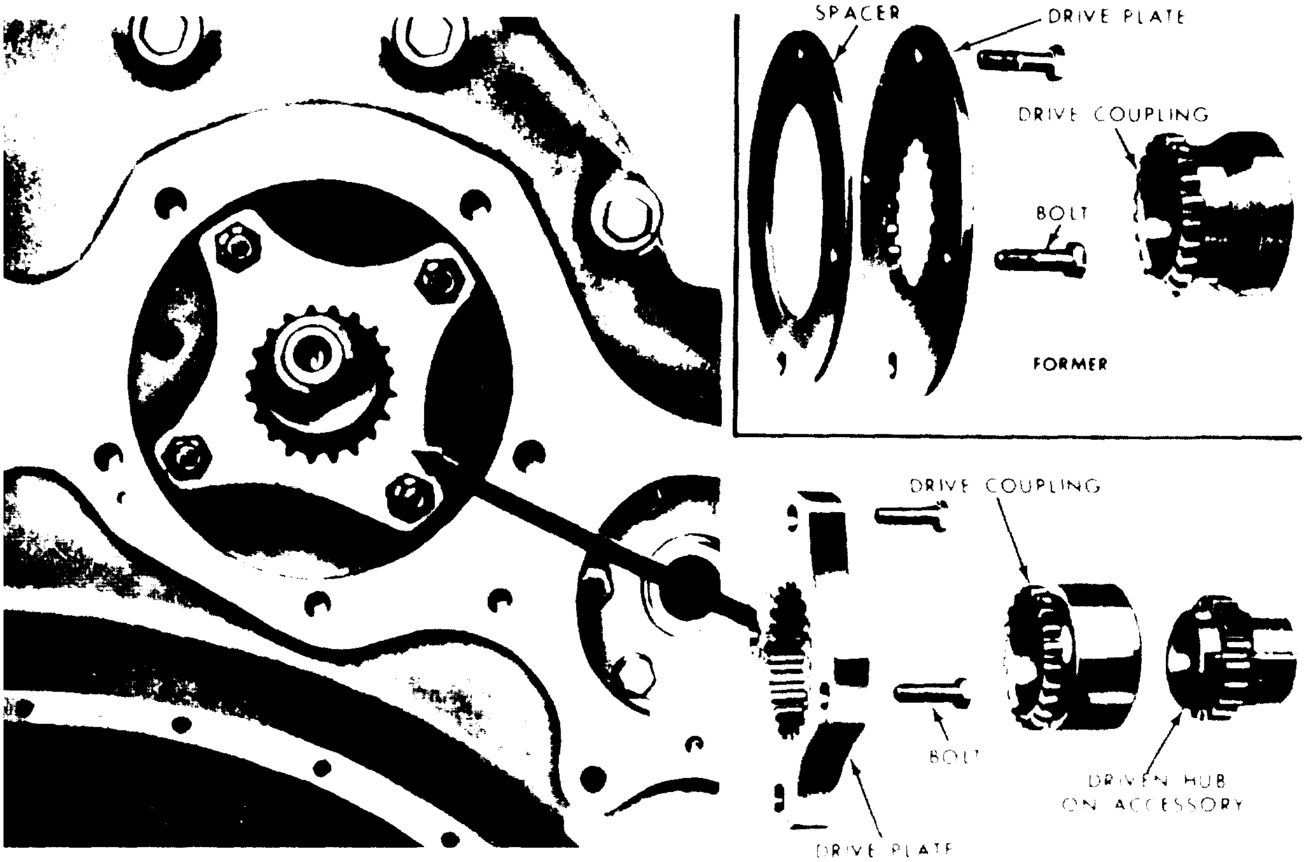


Figure 11B-179. Direct Drive Accessory Parts

Remove the drive assembly for the belt driven type accessory drive as follows:

1. Remove any external piping or connections to the accessory.

2. Loosen the accessory and slide it toward the drive pulley. Then remove the drive belt and the accessory.

3. Remove the nut (Figure 11B-180), retaining the pulley on the drive shaft.

4. Use a suitable gear puller to remove the pulley from the drive shaft. Remove the Woodruff key.

5. Remove the five bolts and lock washers which attach the drive retainer assembly to the flywheel housing. Remove the retainer assembly.

6. Remove the accessory drive shaft and drive plate in a manner similar to that

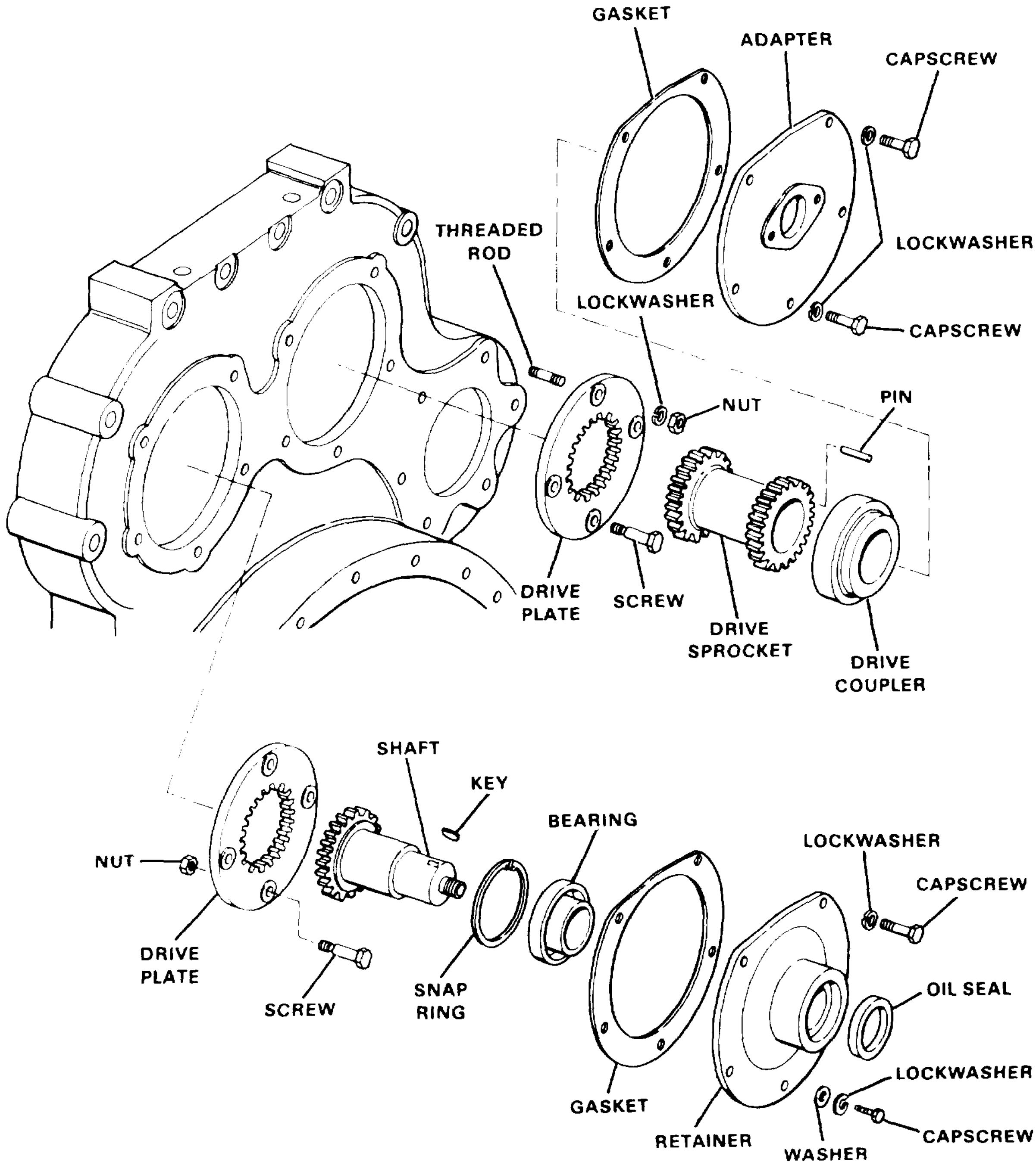


Figure 11B-180. Accessory Drives

outlined for the direct gear driven type accessory drive.

7. Remove the snap ring and ball bearing from the accessory drive shaft retainer as shown in Figure 11B-180 on page 11B-118.

Inspection

Clean the accessory drive parts with clean fuel oil (except shielded bearings) and dry them with compressed air. Examine the gear teeth of the drive shaft, drive coupling or drive plate for wear. If worn excessively, replace with new parts.

Inspect the ball bearing used to support the accessory drive shaft. Shielded bearing 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 it.

Inspect the accessory drive hub for grooving at the area of contact with the lip of the oil seal. If the hub is grooved to a point where the effectiveness of the oil seal is lost, a ring type oil seal spacer is available which serves to re-position the seal and provide a new sealing surface (see Figure 11B-181).

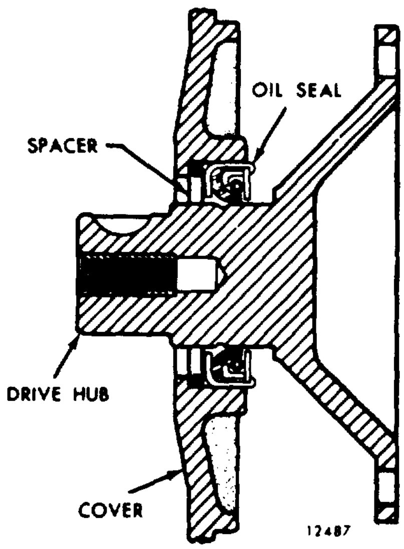


Figure 11B-181. Location of Oil Seal Spacer

Install Accessory Drive

1. Remove the old gasket material from the flywheel housing. Use care so that no gasket material falls into the gear train compartment.

2. Insert a clean, lintless cloth in the flywheel housing opening to prevent bolts from accidentally falling in the gear train. Align the bolt holes in the accessory drive plate with the tapped holes in the balance gear. Then secure the plate with four bolts and lock washers.

NOTE

> Effective with units 3A-045, 4A-007, 6A-021, 8A-003, 12A-007 and 24A-001, the tapped holes in the balance gears were changed from 5/16”-24 to 3/8”-24 threads with a corresponding change in the size of the accessory drive attaching bolts. Also, the accessory drive plate used with 5/16”-24 bolts incorporated four spacers as shown in Figure 11B-182 on page 11B-120 the current disc type spacer is separate from the accessory drive plate. The four spacers from the old drive plate may be removed and replaced by the disc type spacer for use with the current balance gears with the 3/8”-24 tapped holes.

3. If an accessory drive plate is used, refer to Figure 11B-179 on page 11B-117, Figure 11B-180 page 11B-118 and Figure 11B-182 on page 11B-120. Then align the bolt holes in the accessory drive plate with the tapped holes in the camshaft gear. Secure the drive plate with the four special shoulder bolts and lock washers. Tighten the bolts to 45-50 lb-ft (61-68 Nm) torque.

4. If a gear driven accessory is used, install the drive coupling 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; rotate it, if necessary, to align the teeth of the driven hub with those in the drive coupling. Then secure the ac-

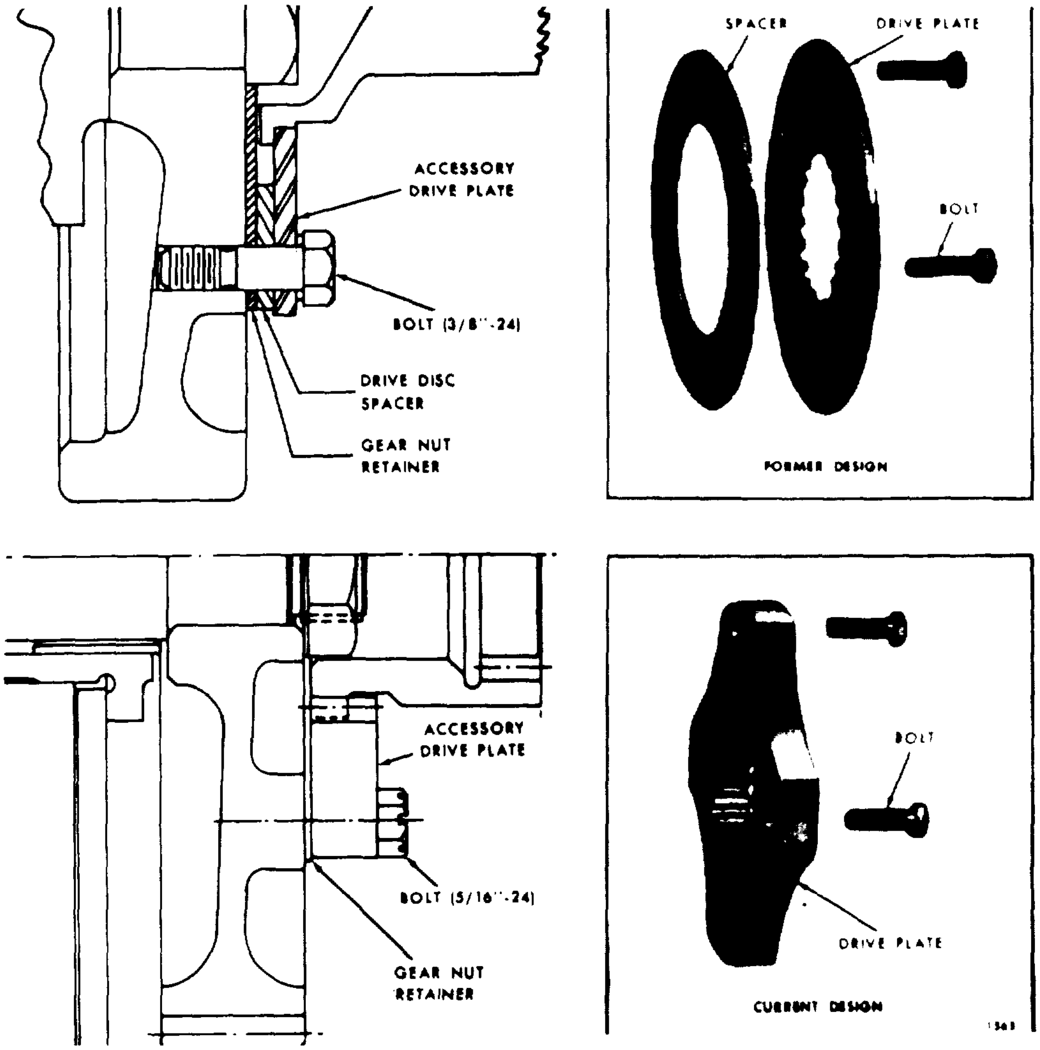


Figure 11B-182. Comparison of Current and Former Design Accessory Drive Plates

cessory to the flywheel housing with bolts and lock washers.

5. If a belt drive accessory is used, proceed as follows:

A. Place the accessory drive retainer on a bench, with the mounting flange side up. Lubricate the outside diameter of the bearing with oil. Then press or tap it (with the protruding face of the inner race facing toward the retainer) straight in until it contacts the shoulder in the retainer. Then install the lock ring.

B. Turn the retainer over and coat the bore with sealant. Then press a new oil seal into the bore of the retainer with the lip of the seal facing the bearing. Wipe any excess sealant from the retainer.

C. Turn the retainer over again, bearing side up, lubricate the drive shaft and press it in the bearing until the shoulder on the shaft contact the bearing.

D. Affix a new gasket to the mounting flange on the retainer. Then position the retainer and shaft assembly against the flywheel housing. Rotate the shaft slightly, if necessary, to permit the teeth of the shaft to mesh with the teeth in the accessory drive plate. Secure the retainer to the flywheel housing with five bolts and lock washers. Tighten the bolts to 30-35 lb-ft (41-47 Nm) torque.

E. Install the key in the shaft. Then start the pulley on the shaft and tap in in place. Install the 3/4”-16 retaining nut. Tighten the nut to 120-140 lb-ft (163-190 Nm) torque.

F. Slip the drive belts over the pulleys. The position the accessory to provide the proper tension on the belts and secure it in place.

NOTE

When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

SHOP NOTE - TROUBLESHOOTING

Shop Notes

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 to ether 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 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.

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 0.001” to 0.003”, type PR-1 (red) has a range of 0.002” to 0.006” and type PB-1 (blue) has a range of 0.004” to 0.009”.

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 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 (see Figure 11B-183 on page 11B-122).

3. Rotate the crankshaft about 30° 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. 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 strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

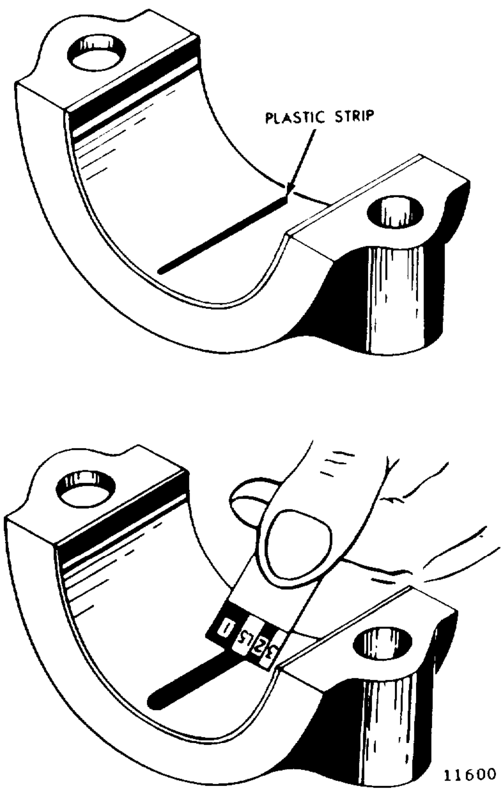
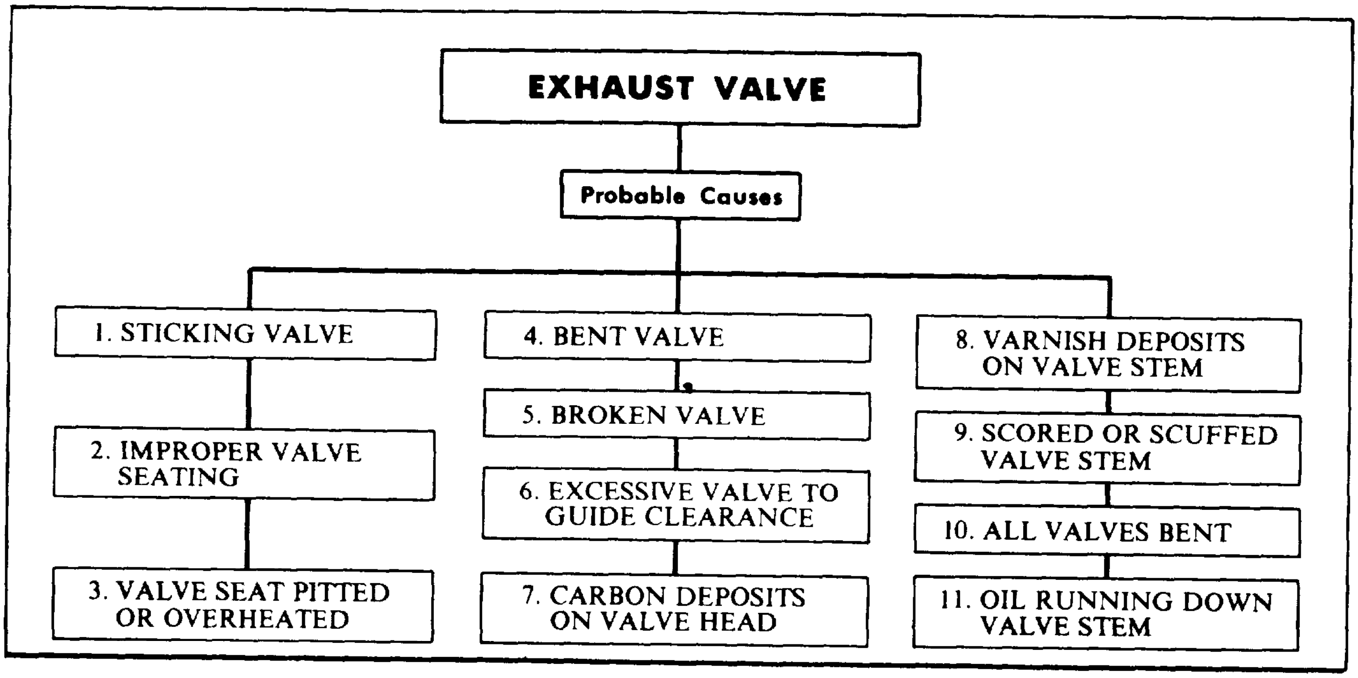


Figure 11B-183. Using Plastic Strip to Measure Clearances



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. Replace 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.

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. umn 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 judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and underslze parts

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Cylinder Block			
Block bore:			
Diameter	4.6256 "	4.6270 "	
Out-of-round		.0010 "	.0020 "
Taper		.0010 "	.0020 "
Cylinder liner counterbore:			
Diameter	5.0460 "	5.0485 "	
Depth	.4770 "	.4795 "	
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 (4 cyl.)			.0070 "
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	4.2495 "	4.2511 "	
Clearance--liner-to-block:	.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 "	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Cross-Head Pistons and Rings			
Piston crown:			
Saddle-to-crown distance:	2.6730 "	2.6800 "	
Diameter:			
At top	4.2226 "	4.2256 "	
Below both compression rings	4.2391 "	4.2421 "	
Above and below seal ring groove	3.8850 "	3.8950 "	
Above and below bearing saddle	3.2360 "	3.2370 "	
Compression rings:			
Gap (top-fire ring)	.0230 "	.0380 "	.0600 "
Gap (No. 2 and 3)	.0180 "	0430 "	.0600 "
Clearance--ring-to-groove:			
*Top (Keystone fire ring)	.0010 "	.0050 "	.0070 "
No. 2 (rectangular section)	.0100 "	.0130 "	.0220 "
No. 3 (rectangular section)	.0040 "	.0070 "	.0130 "
Seal ring:			
Gap (in skirt counterbore)	.0020 "	.0210 "	.0270 "
Clearance	.0005 "	.0030 "	.0040 "
Piston skirt:			
†Diameter	4.2428 "	4.2450 "	
Clearance--skirt-to-liner	.0045 "	.0083 "	.0120 "
Seal ring bore	3.9200 "	3.9240 "	3.9260 "
Piston pin bore	1.5000 "	1.5030 "	1.5040 "
Oil control rings:			
Gap (two rings in lower groove)	.0080 "	.0230 "	.0430 "
Gap (one ring in upper groove)	.0050 "	.0140 "	.0340 "
Gap (two rings in upper groove)	.0080 "	.0230 "	.0430 "
Clearance (lower groove)	.0015 "	.0055 "	.0080 "
Clearance (upper groove)	.0010 "	.0035 "	.0060 "
Piston Pins			
Length	3.6150 "	3.6250 "	
Diameter	1.4996 "	1.5000 "	1.4980 "
Slipper bearing (bushing):			
Thickness at center	.0870 "	.0880 "	.0860 "
Clearance (edge of bushing to groove in piston)	.0005 "	.0105 "	.0120 "
Crankshaft			
Journal diameter--main bearing	3.4990 "	3.5000 "	
Journal diameter..conn. rod bearing	2.7490 "	2.7500 "	
Journal out-of-round		.00025 "	.0010 "
Journal taper		.0005 "	.0015 "
§Runout on journals--total indicator reading:			
4 cylinder (mounted on No. 1 and No. 5 journals):			
At No. 2 and No. 4 journals		.0020 "	
At No. 3 journal		.0040 "	
Thrust washer thickness	.1190 "	.1220 "	
End play (end thrust clearance)	.0040 "	.0110 "	.0180 "

*Measured with Keystone fire ring flush with outside diameter of piston crown.

† Diameter above and below the piston pin may be 4.2414".

§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.

ENGINE PARTS (Stand Size, New)	MINIMUM	MAXIMUM	LIMITS
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.
Main Bearings			
Inside diameter (vertical axis)	3.5014 "	3.5034 "	
Bearing-to-journal clearance	.0014 "	.0044 "	.0060 "
Bearing thickness 90 ° 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--bearings-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 "

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Blower Drive Gear			
Backlash	.0030 "	.0080 "	.0100 "
Gear-to-hub fit	.0005 "press.	.001 "loose	
Support-to-end plate	.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 (current bearing)	.0060 "	.0140 "	
Cylinder Head			
Flatness--transverse			.0040 "
Flatness--longitudinal (4 cyl.)			.0080 "
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 "
Exhaust Valve Seat Inserts			
Seat width--31 °	.0468 "	.0937 "	.0937 "
Valve seat runout		.0020 "	.0020 "
Exhaust Valves			
Stem diameter (4-valve)	.3100 "	.3105 "	.3090 "
Valve head-to-cylinder head:			
30°	.023 "recess.	.006 "protr.	.038 " recess.
Valve Guides			
Height above cylinder head:			
2-valve	1.5938 "	1.5938 "	
4-valve (chamfered guide)	.8800 "	.8800 "	
4-valve (machined guide)	.6900 "	.6900 "	
Diameter--inside (4-valve)	.3125 "	.3135 "	.3140 "
Clearance--valve-to-guide (4 valve)	.0020 "	.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--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 "

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	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	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	1	No. 6 thru 1 1/2	60,000
None	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	7	1/4 thru 1 1/2	133,000
Bolts and Screws	8	1/4 thru 1 1/2	150,000
Bolts and Screws	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	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
Oil pan bolts	5/16-18	10-20	14-27
Blower drive coupling to gear hub bolt	5/16-24	20-25	27-34
Exhaust valve bridge adjusting screw lock nut	5/16-24	20-25	27-34
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	--	--
End plate 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
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
Blower drive gear hub bearing support bolts and nuts	3/8 -24	25-30	34-41
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
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

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
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
**Cylinder head bolts	5/8 -11	175-185	238-251
**Main bearing bolts (assembly)	5/8 -11		
**Main bearing bolts (boring)	5/8 -II	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
Accessory drive pulley nut	3/4 -16	120-140	163-190
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

*These specifications apply where bolts or studs are threaded into aluminum.

@75-85 lb-ft (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

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or teflon.

NPTF SIZE THREAD	TORQUE (lb-ft)	TORQUE (Nm)	NPTF SIZE THREAD	TORQUE (lb-ft)	TORQUE (Nm)
1/8	10-12	14-16	1	75-85	102-115
1/4	14-16	19-22	1-1/16	85-95	115-129
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
3/4	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 lb-ft (204-244 Nm) torque
Oil drain plug (Nylon washer)	18mm	25-35 lb-ft (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.

STUD TORQUE SPECIFICATIONS

APPLICATION	TORQUE (lb-ft)	TORQUE (Nm)	HEIGHT (±.0312 ")
Cylinder head stud	75 min.	102 min.	4.3750 "
Main bearing stud	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	..

SPRING SPECIFICATIONS

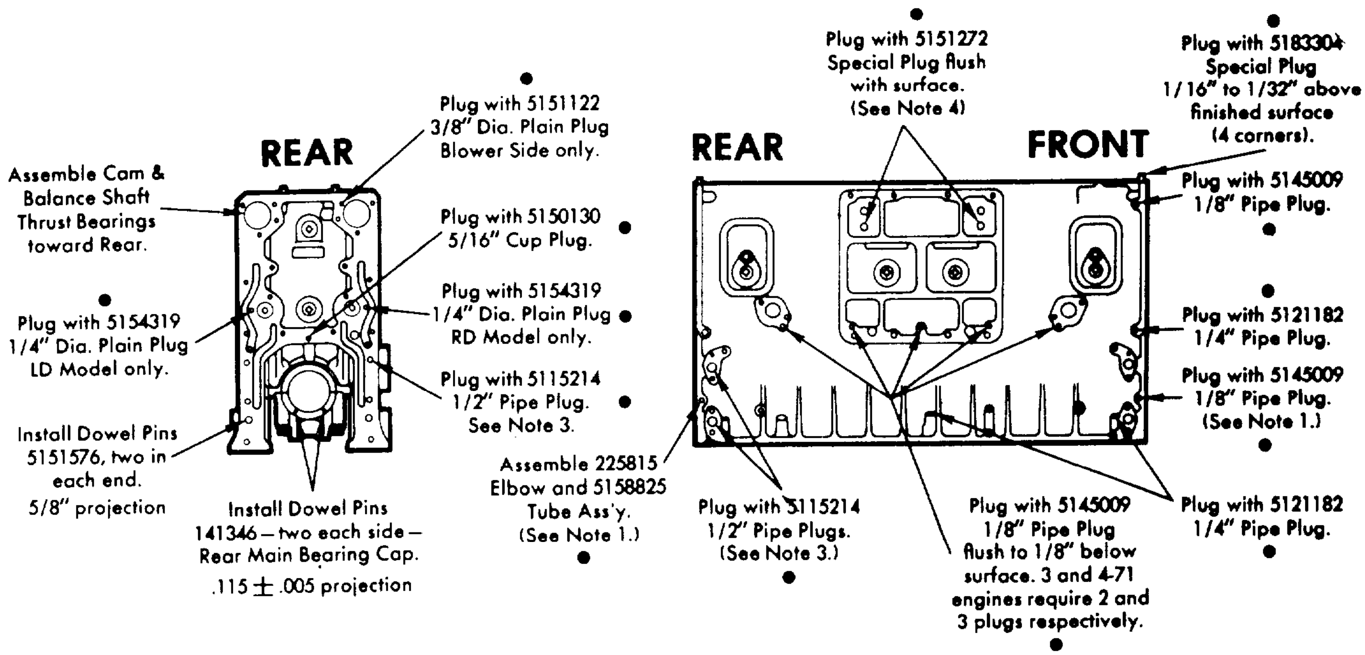
SPRING	REPLACE WHEN LOAD IS LESS THAN:
Cam follower (11 coils - .177 " wire)	172 lbs.@2.1250 "
Cam follower (11 l/2 coils - .162 "wire)	133 lbs.@2.1094 "
Exhaust valve (two-valve cylinder head)	25 lbs.@2.2000 "
Exhaust valve and bridge guide (9 3/4 coils - .135 "wire) (former)	79 lbs@1.4160 "
Exhaust valve (8 3/4 coils - .148 " wire) (current)	25 lbs.@1.8000 "

SERVICE TOOLS

TOOL NAME	TOOL NO.
Cylinder Block	
Cylinder Checking Gage and Master Ring Set	J 9353
Cylinder Hone Set (2 1/2 " to 5 3/4 ")	J 5902-01
Dial Bore Gage Master Setting Fixture	J 23059-01
Dial Indicator Set	J 22273-01
Diesel Engine Parts Dolly	J 6387
Engine Overhaul Stand	J 6837-C
Engine Overhaul Stand Adaptor Plate	J 8196
Special Plug Remover	J 21996-01
Cylinder Head	
Cam Follower Service Fixture	J 5840-01
Cylinder Head Holding Plate Set	J 3087-01
Cylinder Head Pressure Checking Tool	J 28454
Feeler Gage Set (.OO15 " 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	J 6846
Valve Guide Cleaner	J 5437
Valve Guide Installer	J 9729
Valve Guide Installer	J 21520
Valve Guide Remover	J 6569
Valve Seat Dial Gage	J 8165-2
Valve Seat Grinder	J 8165-1
Valve Seat Grinder Adaptor Set	J 6390-02
Valve Seat Insert Installer	J 6568
Valve Seat Insert Remover	J 6567-02
Valve Spring Checking Gage	J 25076-B
Valve Spring Compressor	J 7455
Crankshaft	
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

TOOL NAME	TOOL NO.
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	
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
Flywheel Housing	
Crankshaft Oil Seal Expander	J 22425
Crankshaft Oil Seal Expander (O.S. Seal)	J 4195-01
Driver Handle	J 8092
Flywheel Housing Aligning Studs (Set of 4)	J 1927-01
Flywheel Housing Concentricity Gage Set	J 9737-C
Piston. Connecting Rod and Cylinder Liner	
Connecting Rod Bolt Hole Reamer	J 28460
Connecting Rod Bushing Reamer Set	J 1686-D
Connecting Rod Holding Fixture	J 7632
Connecting Rod Spray Nozzle Remover	J 8995
Cylinder Checking Gage 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-B
Cylinder Liner Remover Set	J 1918-02
Dial Bore Gage Setting Fixture	J 23059-01
Dial Indicator Set	J 22273-01
Feeler Gage Set	J 3172
Fire Ring Groove Gage	J 24599
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 Crown Identification Gage (cross-head)	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 3272-03
Piston Ring Remover and Installer	J 8128
Piston to Liner Feeler Gage Set	J 5438-01
Seal Ring Compressor	J 23453
Camshaft	
Accessory Drive Hub Oil Seal Aligning Tool	J 21166
Blower Drive 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

CYLINDER BLOCK PLUGGING INSTRUCTIONS

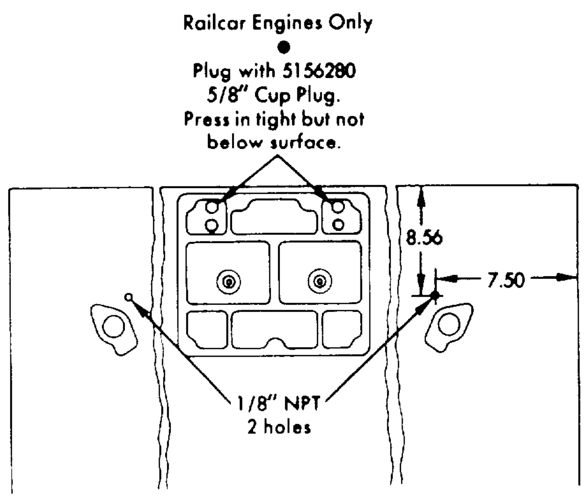


STANDARD PIPE PLUG TORQUE*

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.

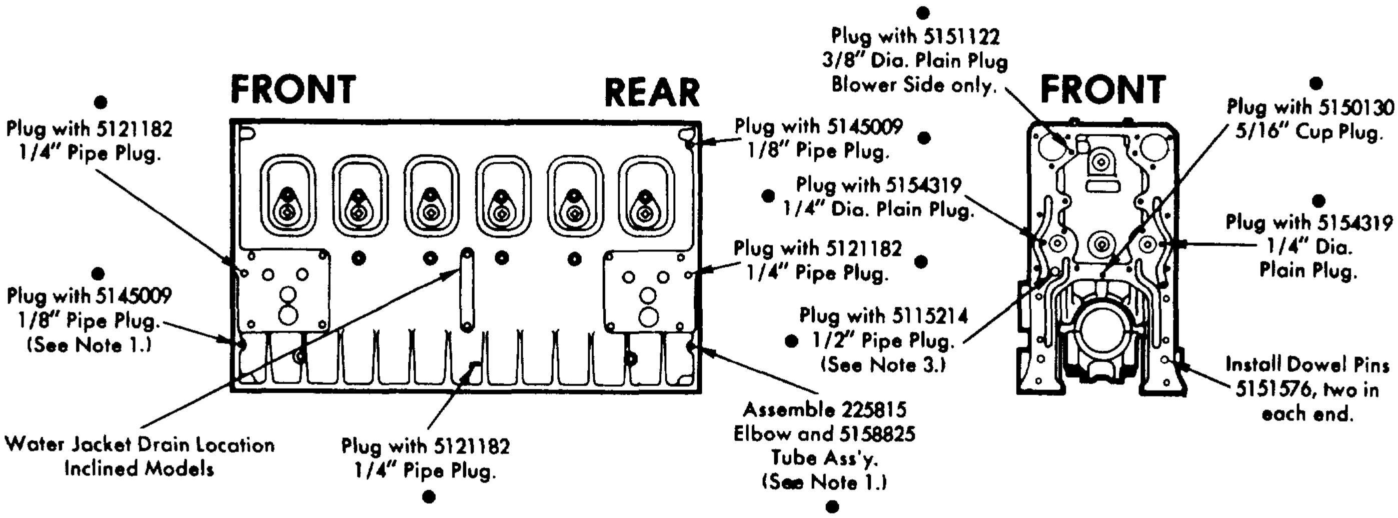
(See Note 2.)

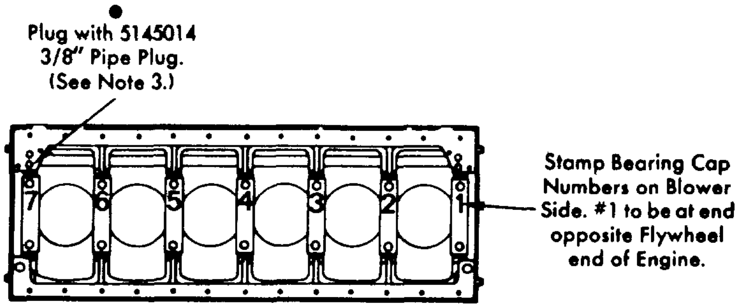


- NOTES -

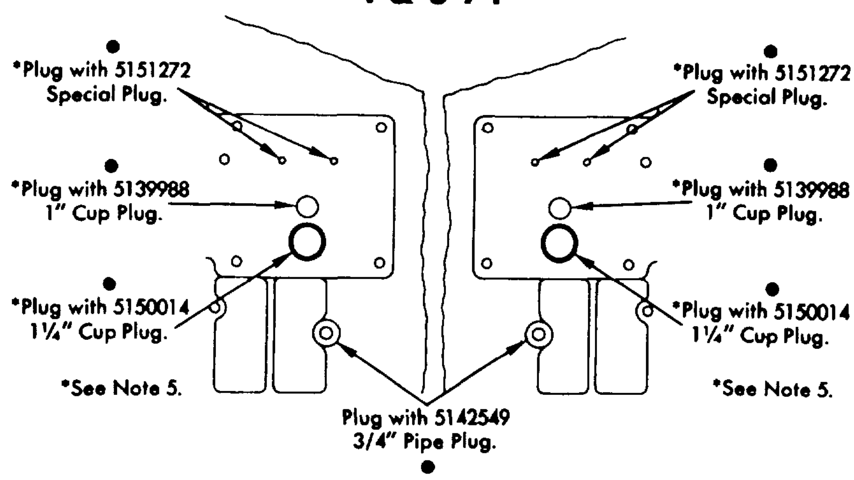
(1) Assemble 225815 Elbow and 5158825 Tube Ass'y to the front of the block for LD engine of Model 24001B ond RD engine of Model 24002B. Assembly 5145014 Plugs to rear of block on aforementioned engines, On Truck engines, assemble 225815 Elbow and 5158825 Tube Ass'y to the front and to the rear on the Blower Side. Assemble 5145009 Plugs on the opposite side of the block.

(2) Apply Loctite J-26558-92 pipe sealer or equivalent with teflon . prior to installation.





Accessory Pads 4 & 6-71



- N O T E S -

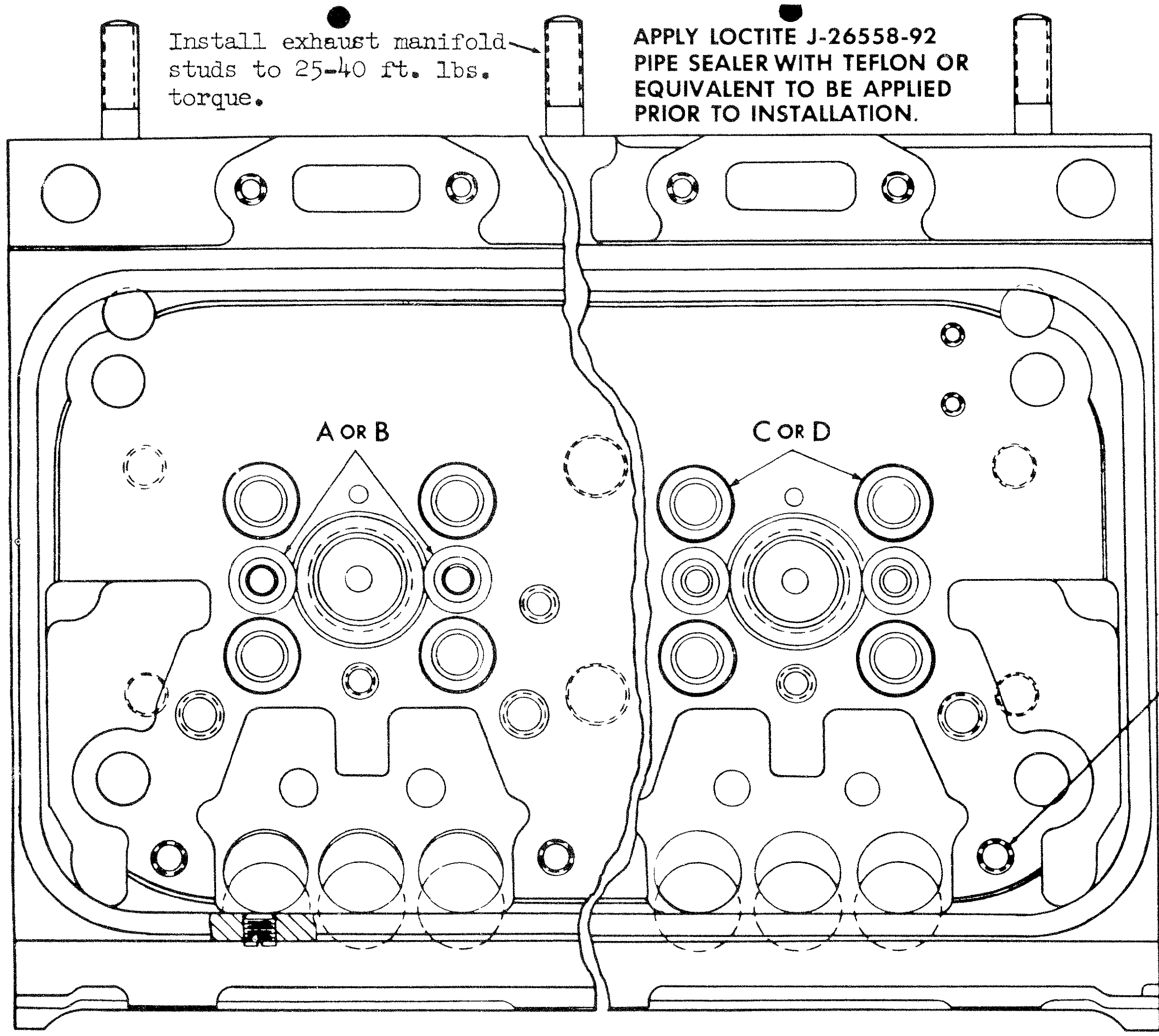
(3) Replace Oil Cooler Pad and Oil Gallery End Plugs 5115214 by Plug 5173334 and Plug 5145014 in bottom of block by 5173333 when assembling an aluminum cylinder block.

(4) Omit one 5151272 plug when using supercharged oir compressor connection.

(5) Do not install plugs when crankcase breather is to be installed on accessory pad.

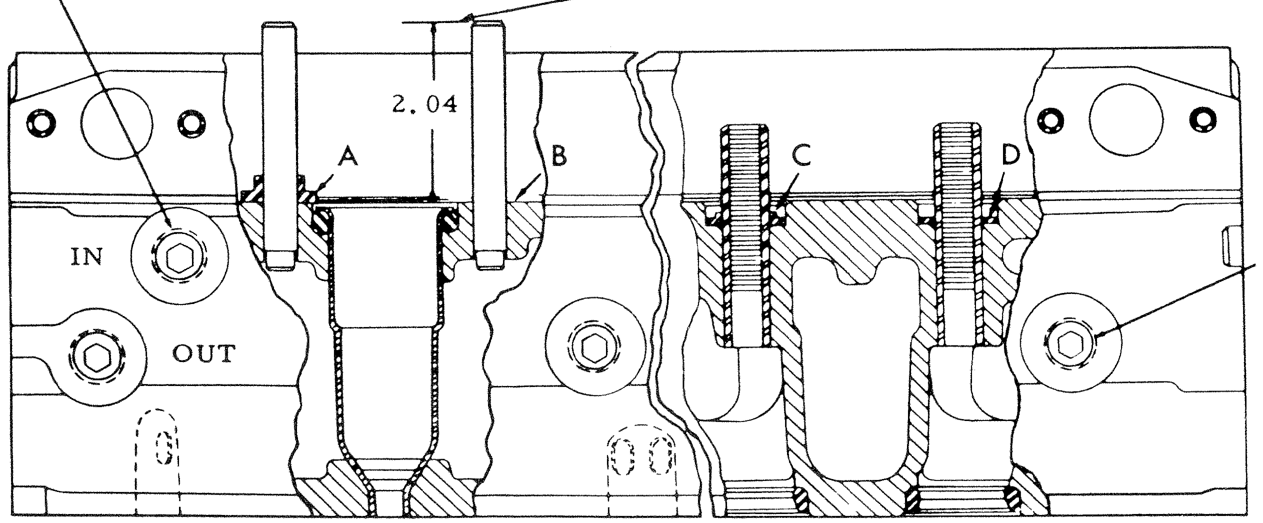
Install exhaust manifold studs to 25-40 ft. lbs. torque.

APPLY LOCTITE J-26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.



Install special 1/4 pipe plugs in all manifold end and side positions except fuel inlet and outlet positions convenient for assembly of flexible hose on in-line engines.

Bridge guides to be installed as shown.



SERIES 71 FOUR VALVE 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.

Install plug in both ends of cylinder head except on thermostat housing end(s) for 6V and 8V engines only.

Install fuel manifold connectors and washers.

A - Use with three spring design (spring under bridge).

B - Two spring design (no spring under bridge).

C - Use with .581 I.D. valve spring.

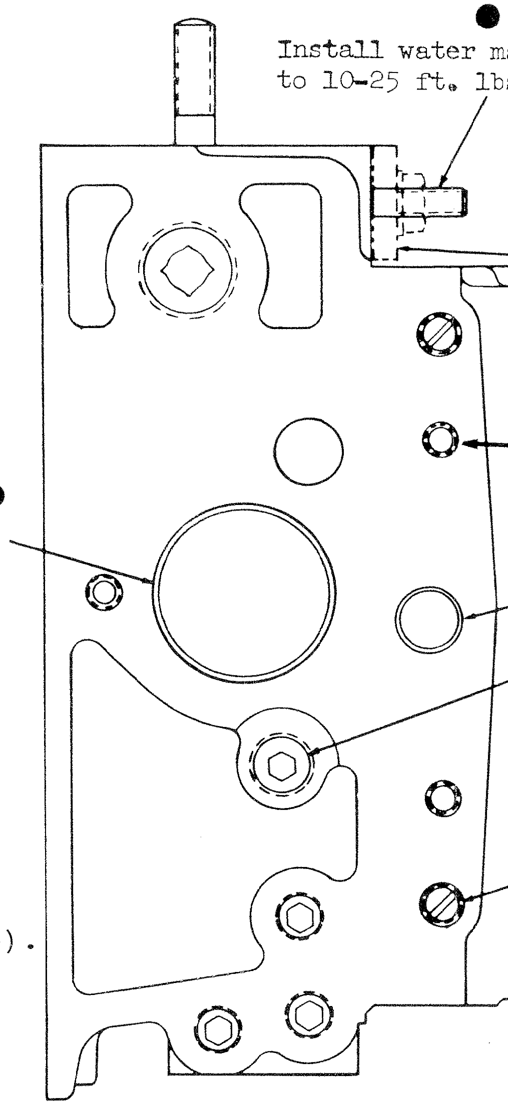
D - Use with .645 I.D. valve spring.

Install restricted (R) orifice connector in convenient location in fuel manifold outlet.

Note: Use .1065" connector (marked R10) with 90CMM injectors. Use .080" connector (marked R80, R08 or R8) with all other injectors.

Install 1/4 pipe plugs below surface of head when assembling plugs in end positions on 71 in-line engines.

Install water manifold studs to 10-25 ft. lbs. torque.



Cover plates and gaskets to be used on 6V and 8V-71 engines. Retain with lock washers and 3/8-24 Nuts.

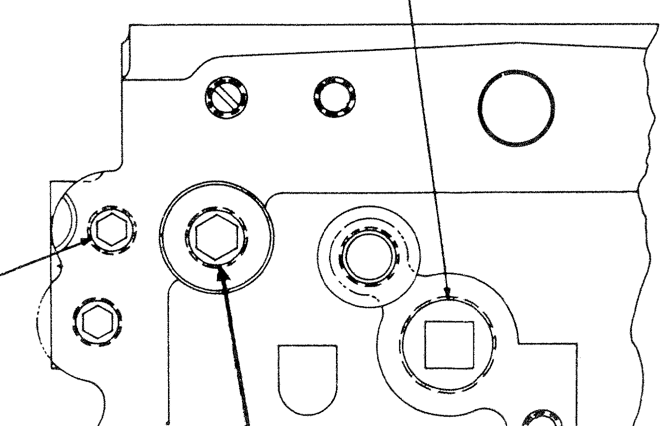
Install 3/8" headless plugs in both ends

Install plug at each end except when lifter bracket is installed.

Install 3/8"-18 plug at each end to 1/16" above surface. 7/32" rod in oil feed hole must pass inner face of plug.

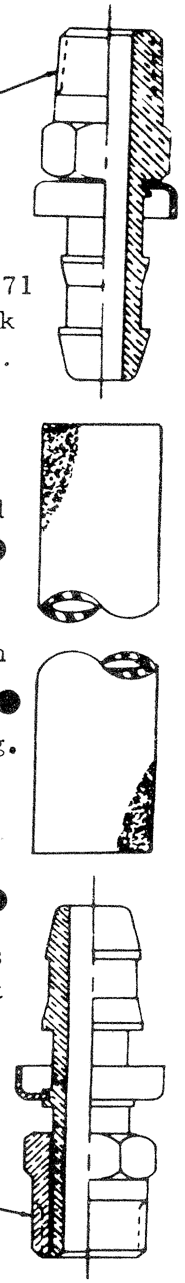
7/16-14 headless plug to be installed in two holes, both ends on V-71 engines. Install plugs on in-line engines only when lifter bracket is not used.

Before installing thermostat housings on 12V-71 engines, remove 3/4 pipe plug from front of both cylinder heads.



Install 3/8" plug.

1/4 NPTF (In Manifold)



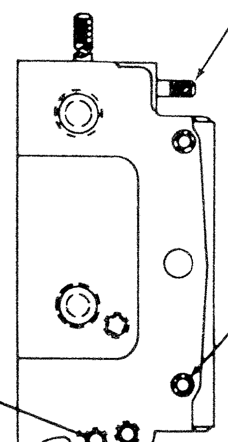
5/8-18 (In filter)

TO ASSEMBLE HOSE & FITTINGS

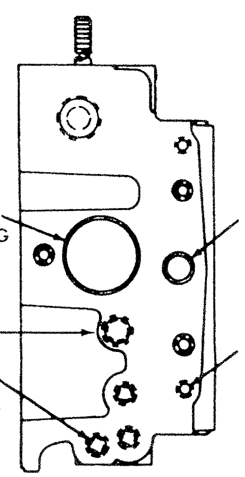
(1) Cut hose to required length. Oil inside of hose and outside of nipple.

(2) Push hose on fitting underneath protective cap.

REV. 1-81

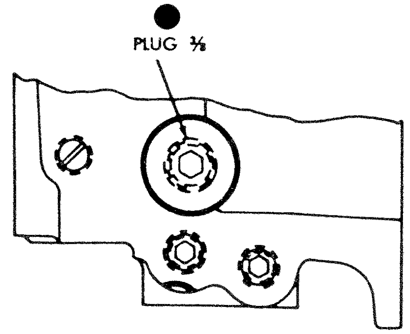


OLD STYLE HEAD
END VIEW
4-71 IN-LINE ONLY

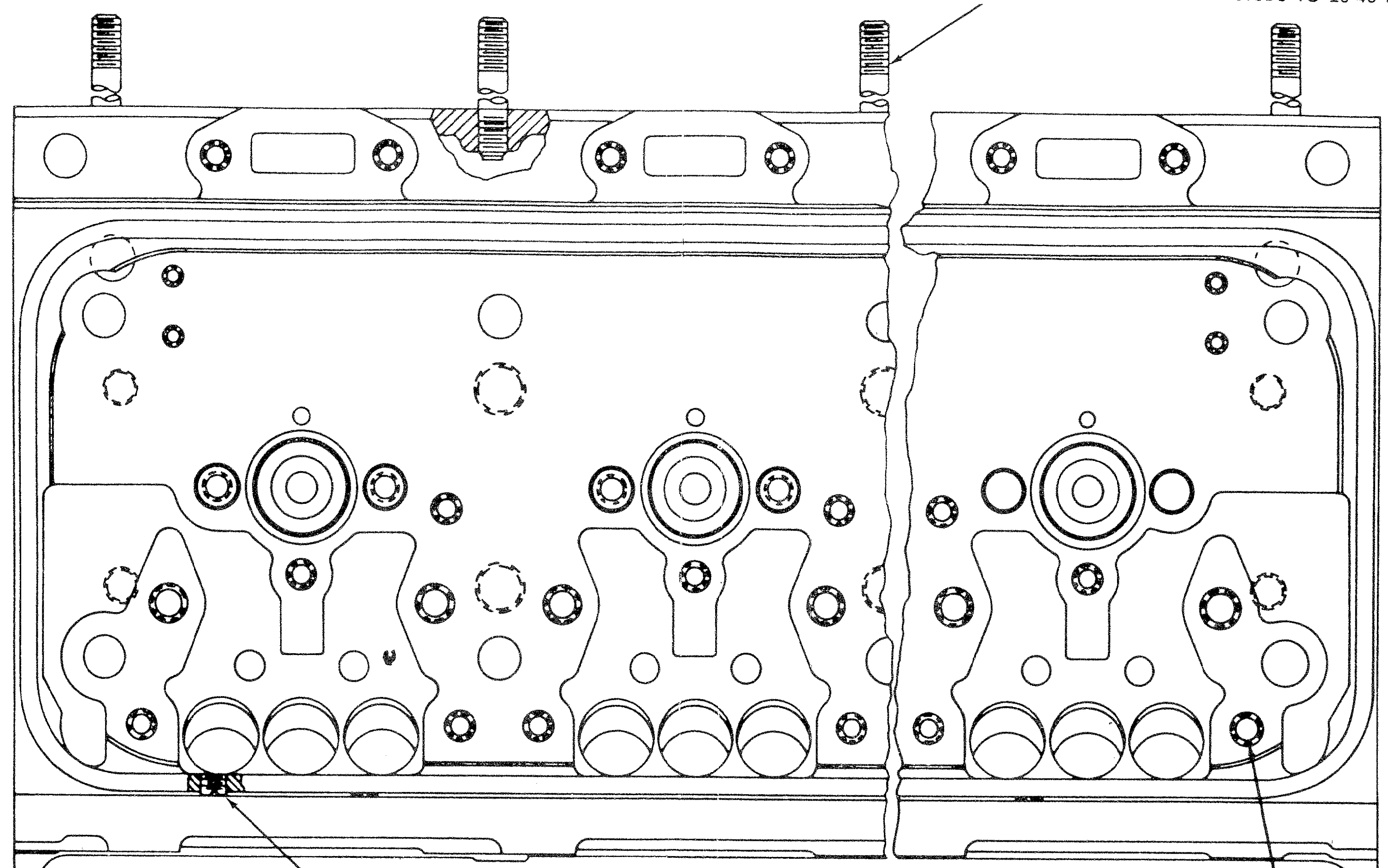


NEW STYLE HEAD
END VIEW
3-71 & 6-71 IN-LINE & 12V-71 ONLY

INSTALL 3/8"-18 PLUG AT EACH END TO 1/16" ABOVE SURFACE.
7/32" ROD IN OIL FEED HOLE MUST PASS INNER FACE OF PLUG.



NEW STYLE HEAD
END VIEW (OPPOSITE)
3-71 IN-LINE, 6V-71 & 12V-71 ONLY



STANDARD PIPE PLUG TORQUE*

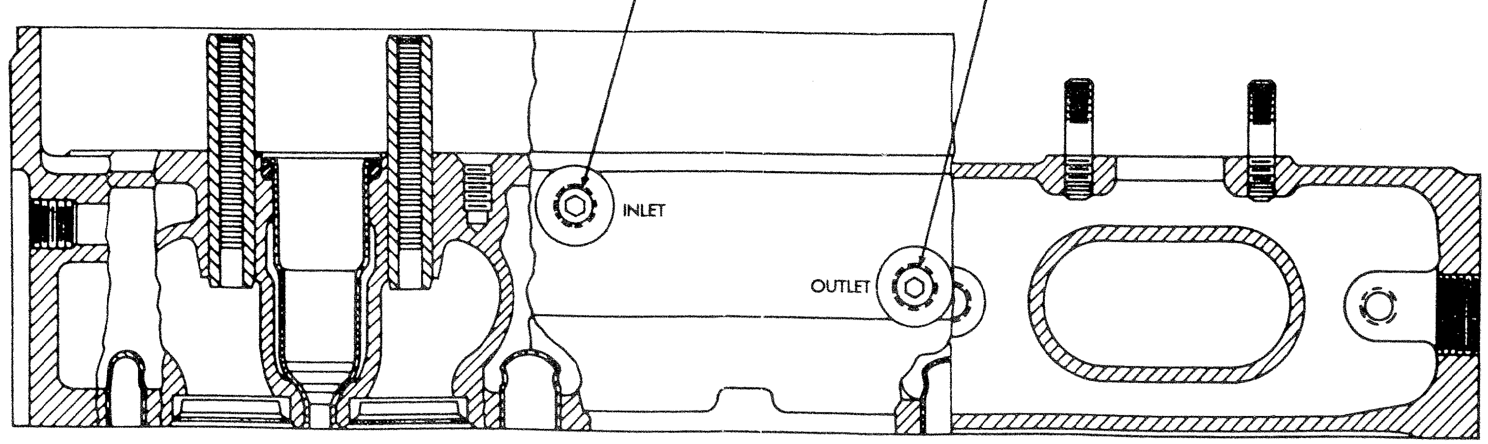
PIPE PLUG SIZE	TORQUE/FT. LBS.
1/8	10-12
1/4	14-16
3/8	18-22
1/2	23-27
3/4	33-37

*CAUTION—Do Not Over Torque Teflon Wrapped Pipe Plugs.

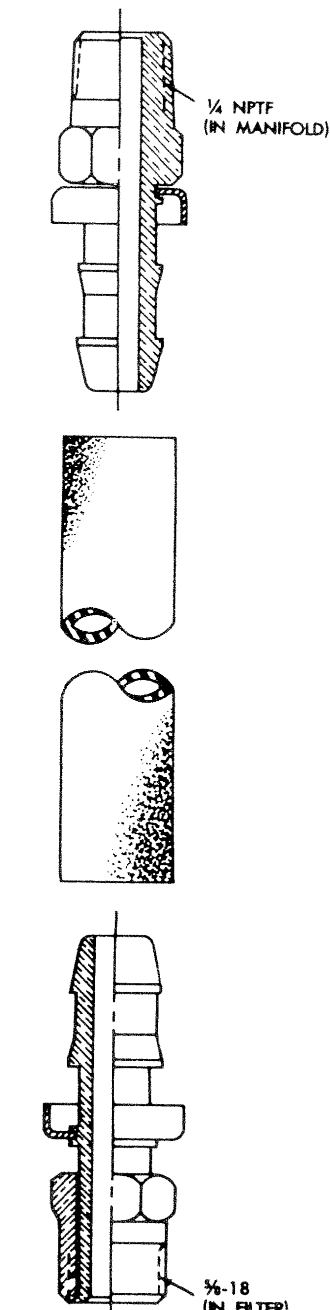
APPLY LOCTITE J-26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT TO BE APPLIED PRIOR TO INSTALLATION.

INSTALL FLEXIBLE MANIFOLD INLET HOSE IN CONVENIENT LOCATION. INSTALL SPECIAL 1/4 PIPE PLUGS IN ALL OTHER MANIFOLD END AND SIDE POSITIONS.

INSTALL RESTRICTED (R) ORIFICE CONNECTOR IN CONVENIENT LOCATION IN FUEL MANIFOLD OUTLET.



SERIES 71 TWO VALVE CYLINDER HEAD ASSEMBLY INSTRUCTIONS



TO ASSEMBLE HOSE & FITTINGS
1. CUT HOSE TO REQUIRED LENGTH. LUBRICATE INSIDE OF HOSE AND OUTSIDE OF NIPPLE.
2. PUSH HOSE ON FITTING UNDERNEATH PROTECTIVE CAP.

TABLE OF CONTENTS

SUBSECTION 11C

FUEL SYSTEM AND GOVERNOR

GENERAL

This subsection contains repair -information on the fuel injectors, variable speed mechanical governor, fuel pump and related fuel system components.

DESCRIPTION

The fuel system (Figure 11C-1) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifold (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 the 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. A check valve is 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.

FUEL INJECTOR

Description

The fuel injector (Figure 11C-2 on page 11C-2 and Figure 11C-3 on page 11C-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.

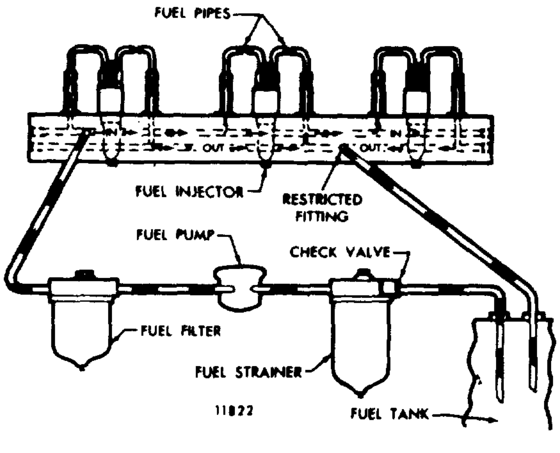


Figure 11C-1. Schematic of Fuel System

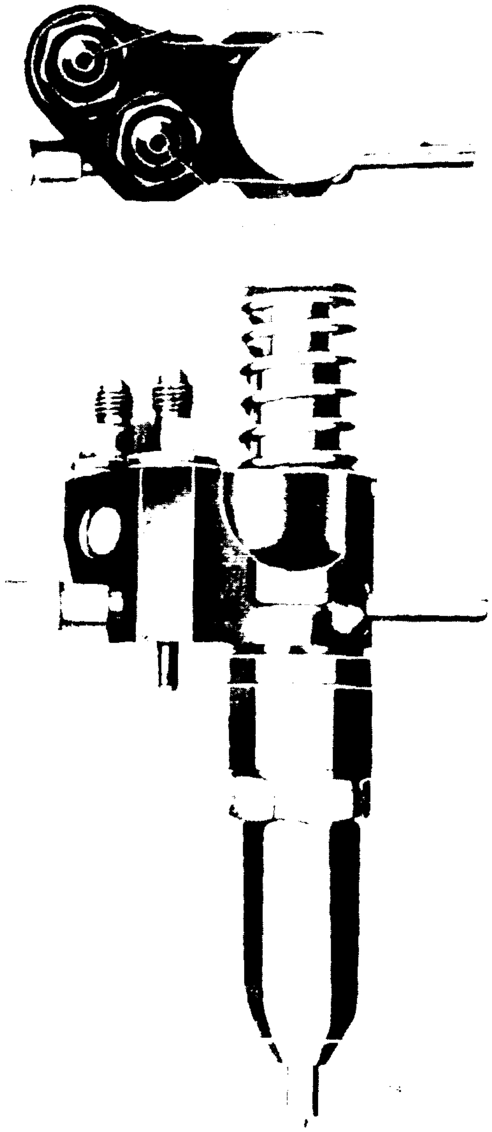


Figure 11C-2. Fuel Injector Assembly

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 11C-4 on page 11C-3 illustrates the fuel metering from no-load to full-load by rotating of the plunger in the bushing.

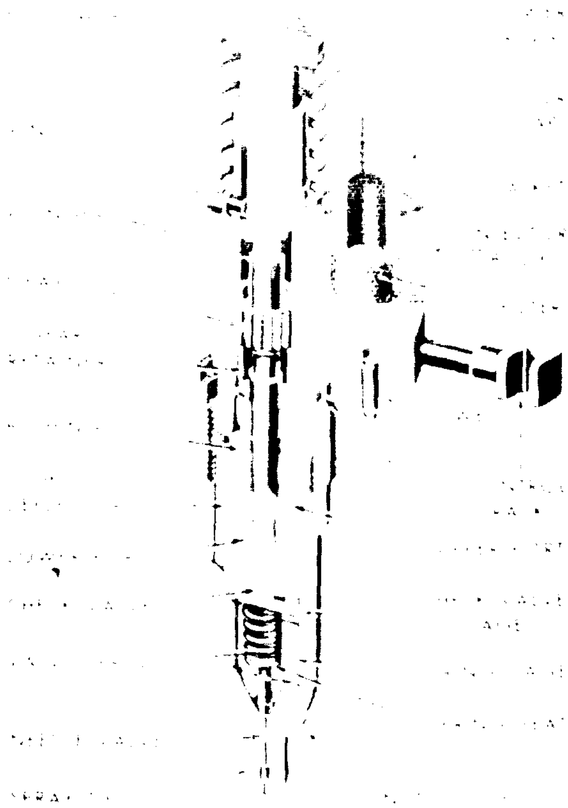


Figure 11C-3. Cutaway View of Fuel Injector

Figure 11C-5 on page 11C-3 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 Figure 11C-6 on page 11C-4 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 injector, it is imperative that the correct injector be used in the engine. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the machine.

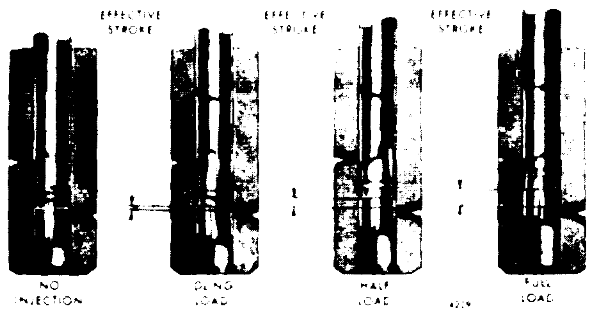


Figure 11C-4. Fuel Metering from No-Load to Full-load

NOTE

Do not intermix the needle valve injector with other type 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 (see Figure 11C-6 on page 11C-4). The identification tag indicates the nominal output of the injector in cubic millimeters.

Each injector control rack (Figure 11C-3 on page 11C-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.

Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (see Figure 11C-3 on page 11C-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 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 sprin (see Figure 11C-7 on page 11C-4). 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.

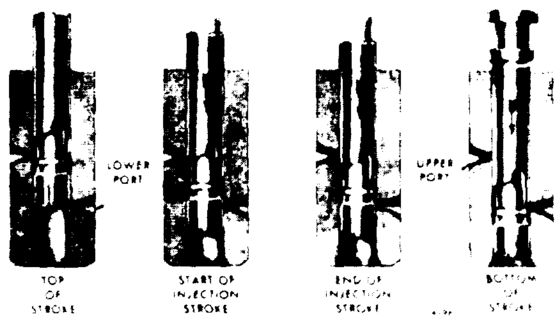


Figure 11C-5. Phases of Injector Operation

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 land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is

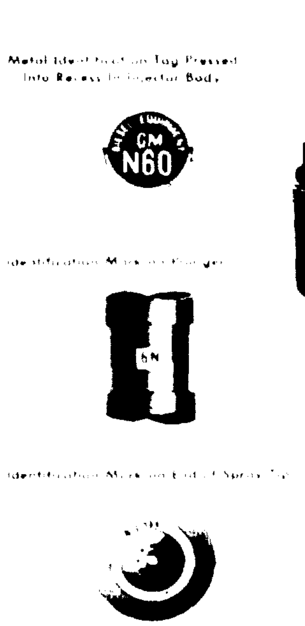


Figure 11C-6. Injector Identification Chart

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. Figure 11C-5 on page 11C-3 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 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.

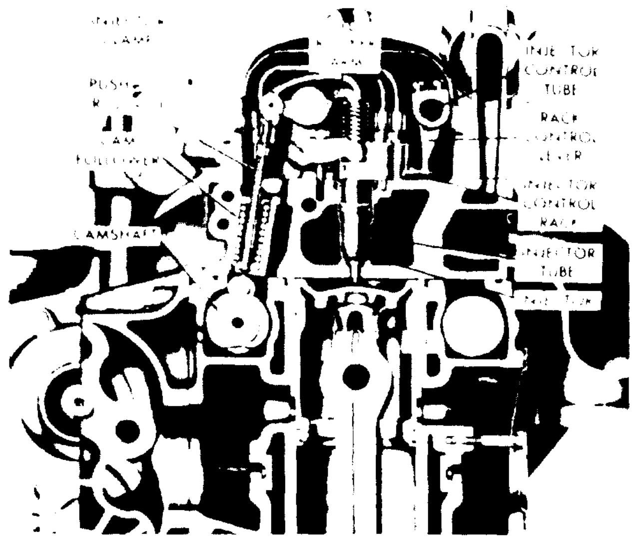


Figure 11C-7. Fuel Injector Mounting

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and than 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. Figure 11C-4 on page 11C-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.

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

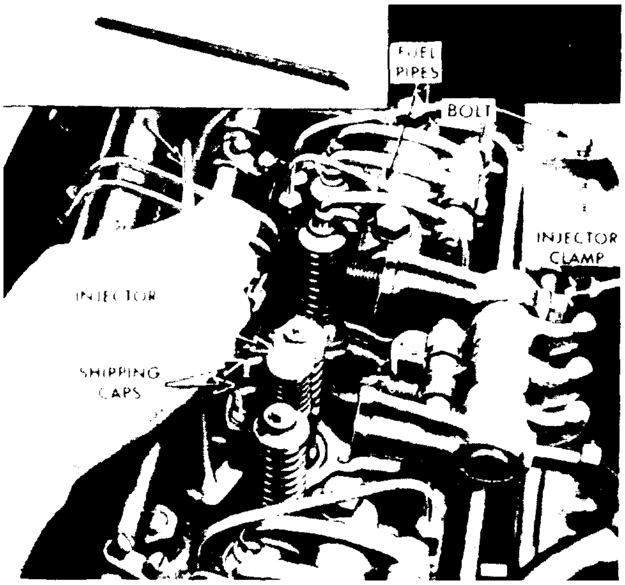


Figure 11C-8. Removing Injector from Cylinder Head

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 of fuel filters and clean, water-free fuel are the keys to trouble free operation of the injectors.

Due to the close tolerances of various 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 prevent 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 of 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 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 filters while the injector is in the engine. Replace the filters 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.

3. Whenever an injector has been removed and reinstalled or replace in an engine, make the following adjustments as outlined in Subsection 11H.

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 preventative (See Section VI of 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 plugs on both filter caps immediately after filling. Store the injector in an upright position to prevent test oil leakage.

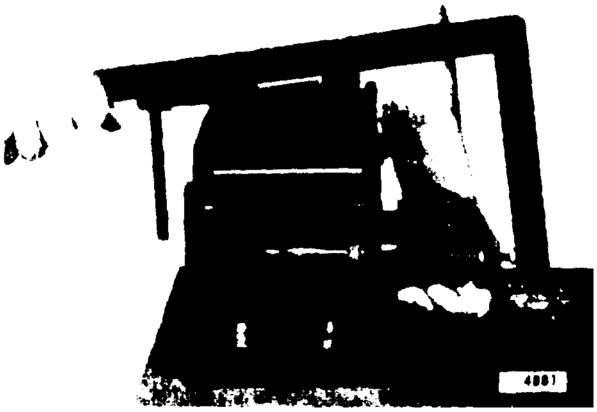


Figure 11C-9. Check Rack and Plunger for Free Movement

NOTE

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.

Remove Injector

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes from both the injector and the fuel connectors (see Figure 11C-7 on page 11C-4).

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 arm in line horizontally.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (see Figure 11C-8 on page 11C-5).

5. Remove the injector clamp bolt, special washer and clamp.

6. Loosen the inner and outer adjusting screws 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.

Test Injector

GENERAL. Use the following procedures to test the fuel injectors:

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 determine 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 tests outlined 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 following tests.

INJECTOR CONTROL RACK AND PLUNGER MOVEMENT TEST. Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Figure 11C-9 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 Figure 11C-9 on page 11C-6 until the follwer 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 is not free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts.

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. Supprt 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 (see Figure 11C-10). 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 (Figure 11C-11 on page 11C-8), replace the plunger and bushing assembly.

5. Reinstall the plunger, follower and spring.

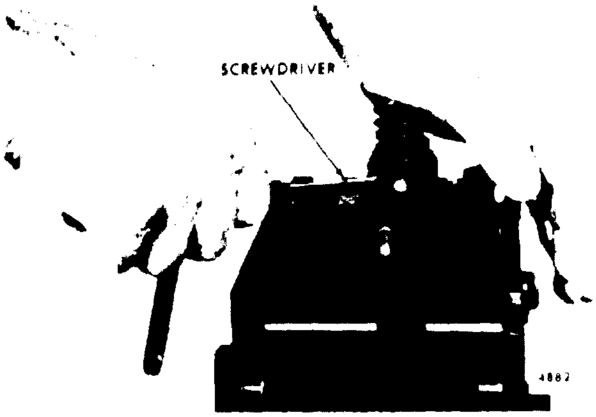


Figure 11C-10. Removing Injector Follower Stop Pin

INSTALLING FUEL INJECTOR IN TESTER J 23010

1. Select the proper clamping head (Figure 11C-12 on page 11C-8). Position it on the clamping post and tighten the thumb screw into the lower detent position (see Figure 11C-13 on page 11C-8).

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

4. Locate the adaptor plate on top of the support bracket by positioning the 3/8”

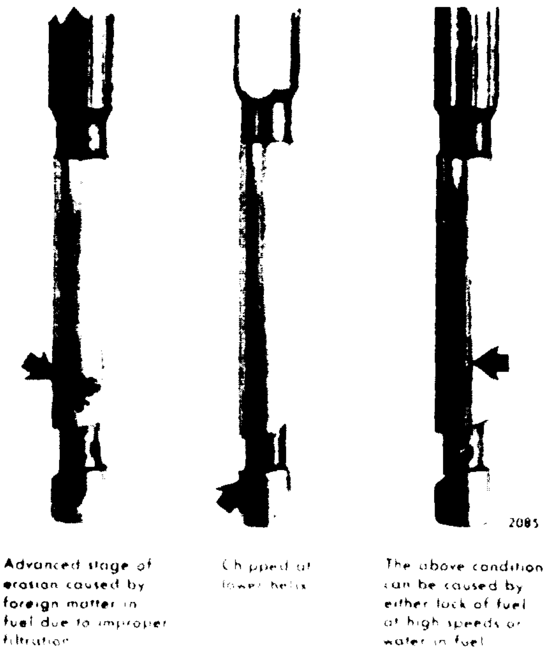


Figure 11C-11. Unusable Injector Plungers

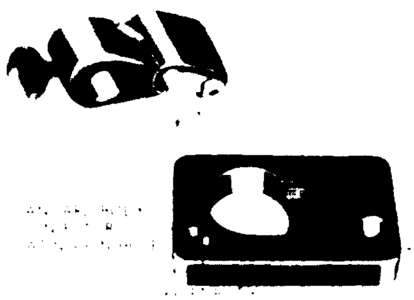


Figure 11C-12. Injector Test Clamping Heads

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 (see Figure 11C-12).

6. Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

CLAMPING THE FUEL INJECTOR. Refer to Figure 11C-14 on page 11C-9 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)

1. Align the clamp head nylon seals over the injector filter caps (see Figure 11C-13).

2. Back off the Thru-Flow valve about half-way to allow the self aligning nylon seals to seat properly during the clamping operation.

3. 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.

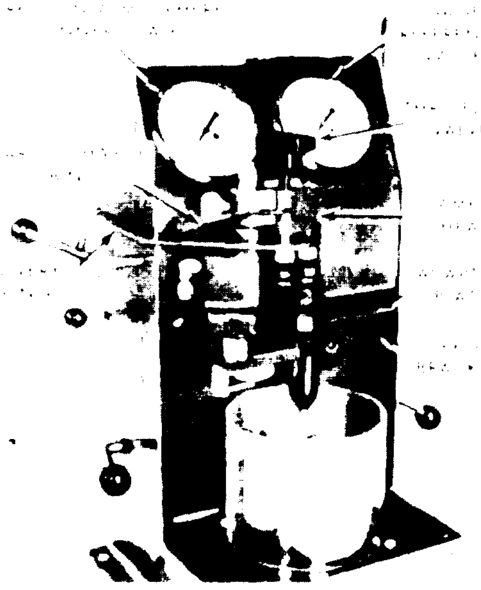


Figure 11C-13. Injector Installed in Tester J 23010

NOTE

The Thru-Flow valve should still turn freely. If it does not, turn the valve counterclockwise until it rotates freely and reapply clamping pressure.

Excessive force on lever 1 during clamping can damage the seals in the valves operated by levers 4 and 5.

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.

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.

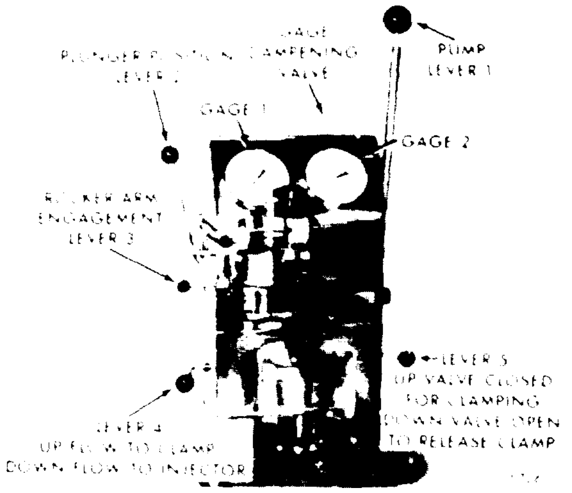


Figure 11C-14. Injector in Position for Testing with J 23010

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. The injector follower should be depressed rapidly (40 to 80 strokes per minute) to simulate operation in the engine. Observe the spray pattern to see that all spray orifices are open and dispersing the test oil evenly. The beginning and ending of injection should be sharp and the test oil should be finely atomized with no drops of test oil forming on the end of the tip.

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. Reference values 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.

INJECTOR HIGH PRESSURE TEST. This test checks for leaks at the filter cap gasket, 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.

3. Operate pump lever 1 to build up to 1600 to 2000 psi (11,024-13,780 kPa) on gauge 1. Check for leakage at the injector filter cap gaskets, body plugs and injector nut seal ring.

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 700psi (4,823 kPa).

5. Move lever 4 to the up position.

6. Time the pressure drop between 450 to 250 psi (3,100 to 1,723 kPa). If the pressure drop occurs in less than 15 seconds, leakage is excessive.

Refer to "Troubleshooting" on page 11C-50 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" on page 11C-13.

UNCLAMPING THE INJECTOR. Unclamp the injector as follows:

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.

NEEDLE VALVE TIP TEST. Assemble 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 (see Figure 11C-15).

3. Tighten the injector nut.

4. Mount the adaptor and assembled injector parts in the support bracket (adaptor plate not needed). Refer to Figure 11C-16 on page 11C-11.

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 23010-167.

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.

INSTALLING ADAPTOR AND TUBE ON TESTER

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 (see Figure 11C-16 on page 11C-11).

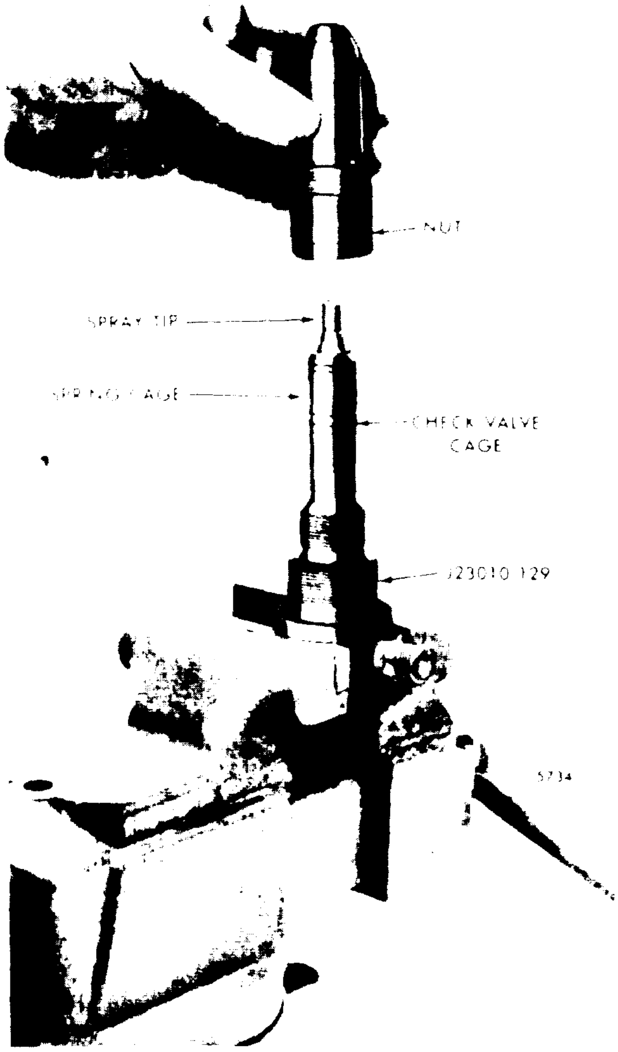


Figure 11C-15. Injector on Tip Test Adaptor

NOTE

Use the fuel injector clamping procedure to clamp adaptor J 23010-167 in the injector tester.

SPRAY TIP TEST

1, Move lever 4 down and operate the pump lever 1 rapidly with smooth even strokes (40 strokes per minute) simulating the action of the tip functioning in the engine (see Figure 11C-14 on page 11C-9).

2. Note the pressure at which the needle valve opens on gauge 1. The valve should open between 2200 and 3200 psi (15,158 and 22,048 kPa). The opening and closing action should be sharp and produce a normal finely atomized spray pattern.

If the valve opening pressure is below 2200 psi (15,158 kPa) 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 2200-3200 psi (15,158-22,048 kPa,), proceed to check for spray tip leakage as follows:

A. Actuate pump lever 1 several times and hold the pressure at 1500 psi (10,335 kPa) 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.

NEEDLE VALVE LIFT TEST. To measure the needle valve lift, use tool J 9462-01 as follows (see Figure 11C-17):

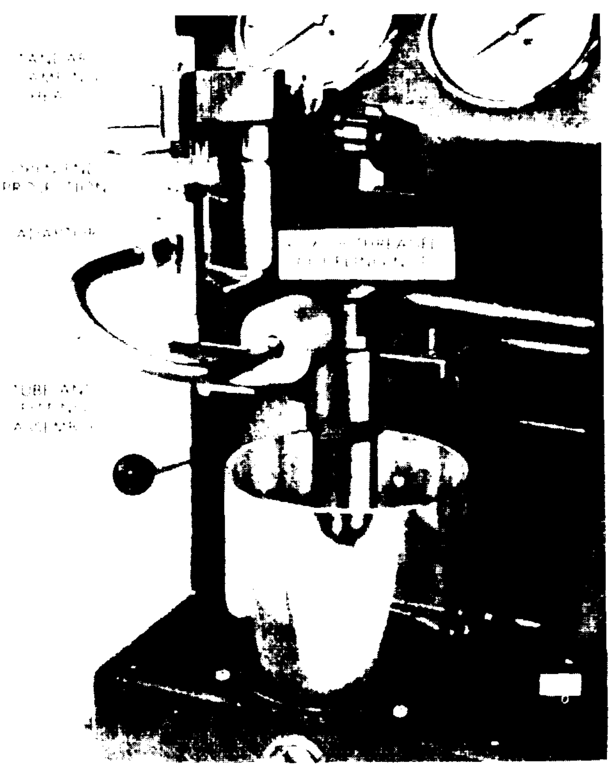


Figure 11C-16. Adaptor and Tube on Injector Tester

Figure 11C-17. Checking Needle Valve Lift

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 0.008" to 0.018". If it exceeds 0.018", the tip assembly must be replaced. If it is less than 0.008", 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 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. Reassemble the injector as outlined under "Assemble Injector" on page 11C-19 and check the injector output with calibrator J 22410.

NEEDLE VALVE TIP TEST WITH AUXILIARY TESTER

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 (see Figure 11C-18 on page 11C-12).

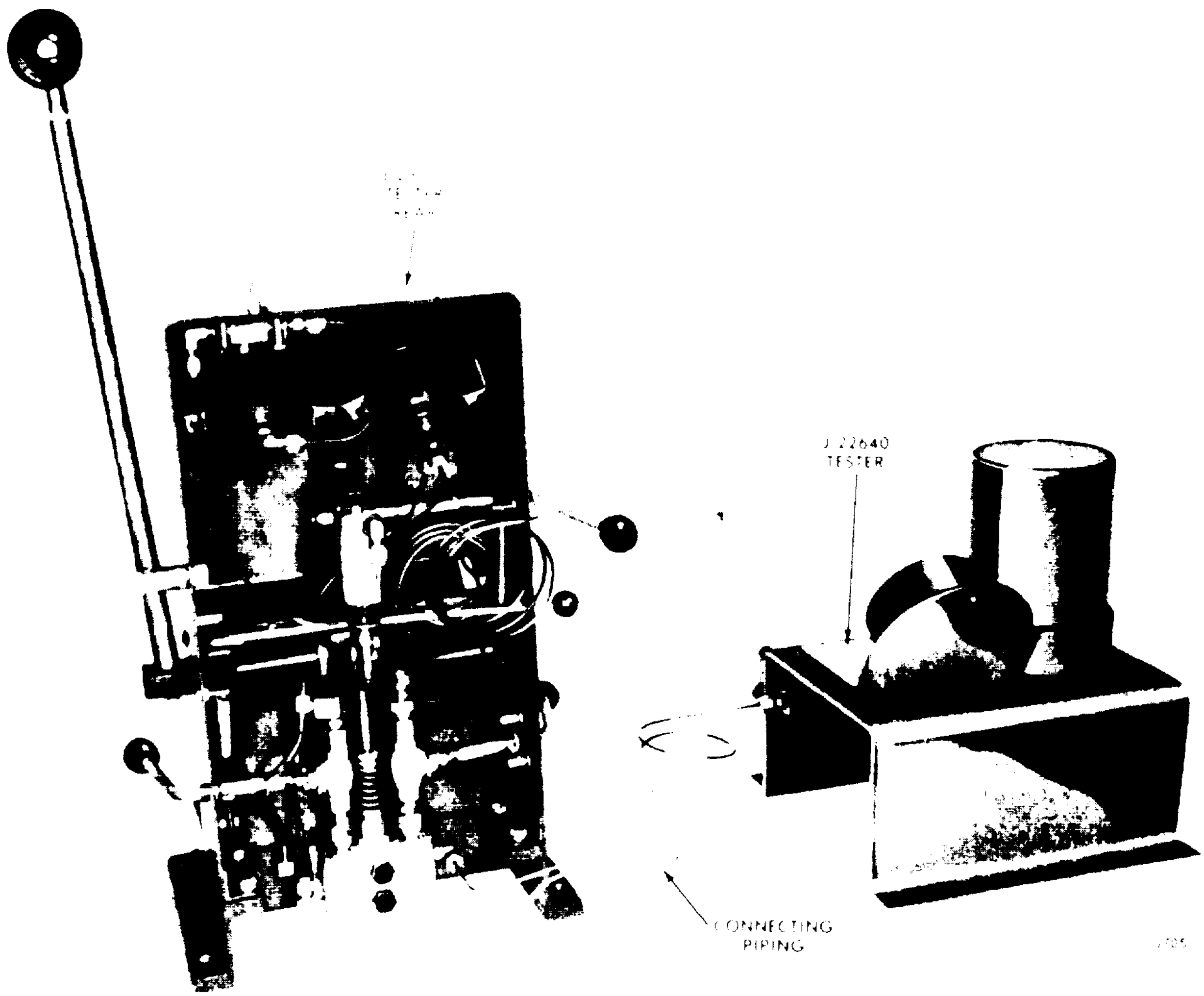


Figure 11C-18. Injector Needle Tester with Auxiliary Tester J 22640

2. Assemble cleaned injector parts, including the check valve cage, spring, spring cage and spray tip assembly, on the auxiliary tester J 22640 (see Figure 11C-19 on page 11C-13).

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 rapidly with smooth even strokes (40 strokes per minute) simulating the action of the tip functioning in the engine. Note the pressure at which the test oil delivery occurs. Test oil delivery should occur between 2200 and 3200 psi (15,158 and 22,048 kPa). The beginning and ending of delivery should be sharp and the test oil should be a finely atomized spray.

If the valve opening pressure is below 2200 psi (15,158 kPa) 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 2200-3200 psi (15,158-22,048 kPa), proceed to check for spray tip leakage as follows:

A. Actuate the pump lever several times and hold the pressure at 1500 psi (10,335 kPa) for 15 seconds.

B. Inspect the spray tip for leakage. There should be no fuel droplets, al-

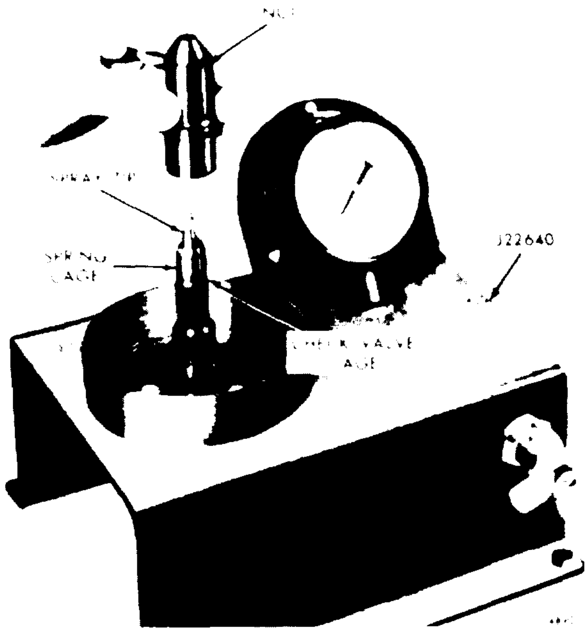


Figure 11C-19. Injector Parts on Auxiliary Tester

though a slight wetting at the spray tip is permissable.

Perform the needle valve lift test.

FUEL OUTPUT TEST. Perform the injector fuel output test in calibrator J 22410

When injectors are removed from an engine for fuel output testings 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.

Before removing an injector from the engine, note the direction of 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 (Figure 11C-20) depends on the adaptor being used and the direction of fuel flow through the injector.

CALIBRATOR J 22410. To check the fuel output, operate the injector in calibrator J 22410 as follows (see Figure 11C-21 on page 11C-14):

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).

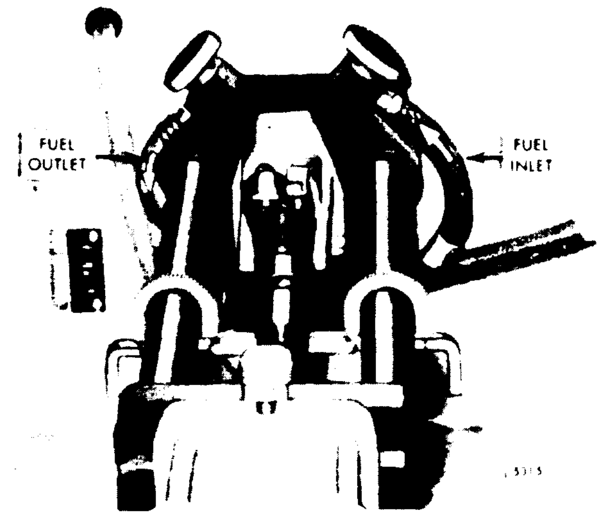


Figure 11C-20. Position of Calibrator Fuel Flow Pipes

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 (Figure 11C-22 on page 11C-14) on the calibrator is preset to 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 the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

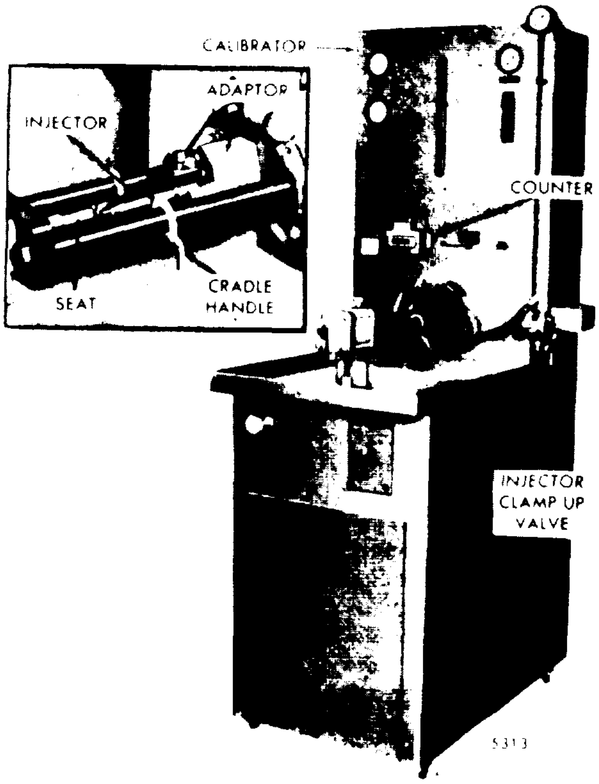


Figure 11C-21. Injector in Calibrator J 22410

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.

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. Obeserve the vial reading. The vial reading should be a minimum of 71 and a maximum of 76. If the quantity of fuel in the vial does not fall within these limits, refer to “Troubleshooting” on page 11C-50 for the cause and remedy.

The calibrator may be used to check and select a set of injectors with will inject the same amount of fuel in each cylinder

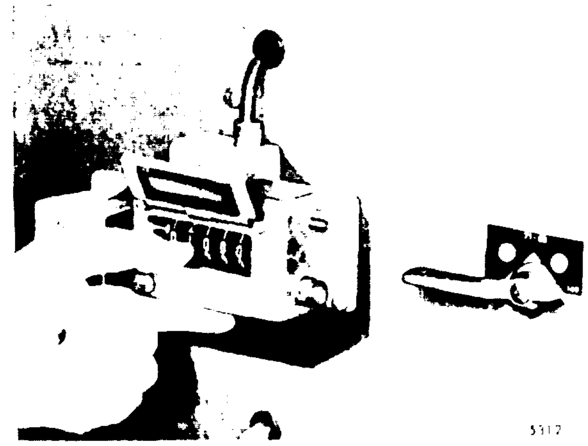


Figure 11C-22. Setting Calibrator Stroke Counter

at a given throttle setting, thus resulting in a smooth running, well balanced engine.

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.

Disassemble Injector

If required, disassemble an injector as follows:

1. Support the injector upright in injector holding fixture J 22396 (Figure 11C-23 on page 11C-15) and remove the filter caps, gaskets and filters.

NOTE

Whenever a fuel injector is disasasembled, discard the filters and gaskets and replace with new filters and gaskets.

2. Compress the follower spring as shown in Figure 11C-12 on page 11C-8. Then raise the spring above the stop pin with a screw driver and withdraw the pin. Allow the spring to rise gradually.

3. Refer to Figure 11C-24 on page 11C-15 and remove the plunger follower, plunger and spring as an assembly.

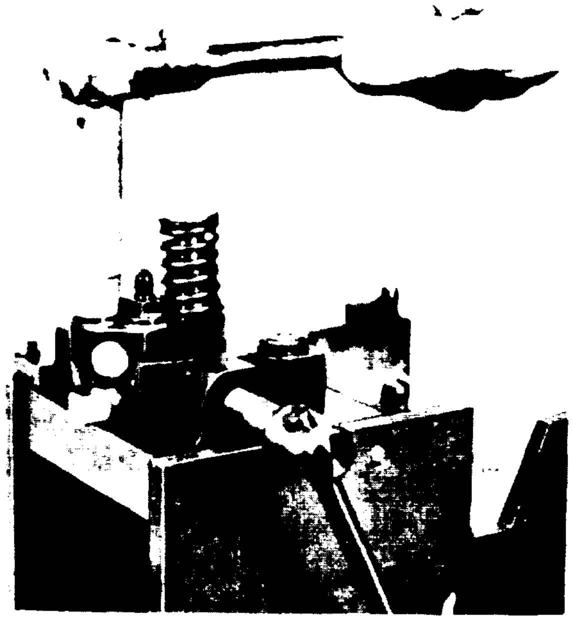


Figure 11C-23. Removing or Installing Filter Cap

4. Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (see Figure 11C-25 on page 11C-16).

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 Figure 11C-26 on page 11C-16.

6. Refer to Figure 11C-36 on page 11C-21 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. Withdrawn the injector control rack from the injector body. Also remove the seal ring from the body.

Figure 11C-24. Removing or Installing Plunger, Follower and Spring

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.

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 (see Figure 11C-27 on page 11C-17).

NOTE

> 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.

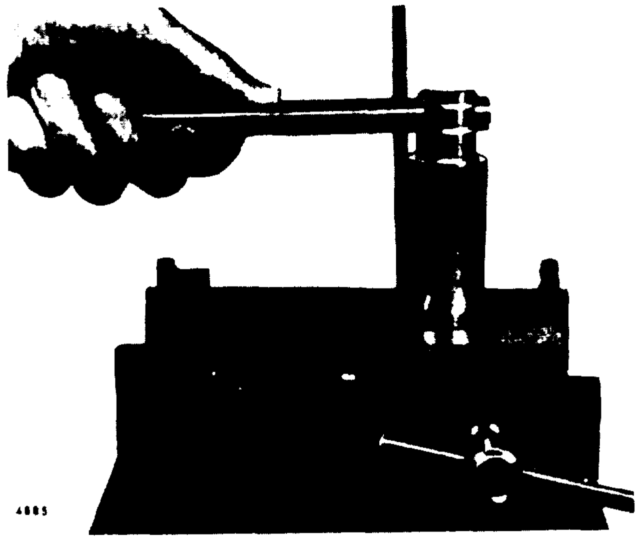


Figure 11C-25. Removing Injector Nut

Wash the tip in fuel oil and dry it with compressed air. Clean the spray tip orifice with pin vise J 4298-1 and the proper size tip cleaning wire. Use wire J 21460 to clean 0.0055" diameter holes and wire J 21461 to clean 0.006" diameter holes (see Figure 11C-28 on page 11C-17).

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.

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.

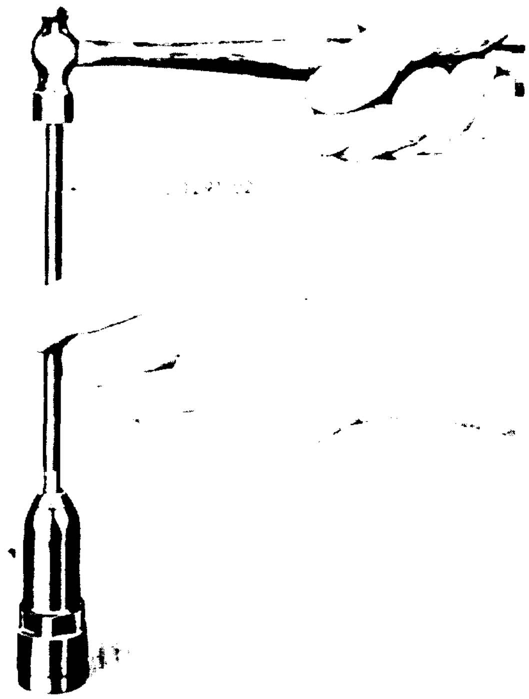


Figure 11C-26. Removing Spray Tip from Injector

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 compressed air.

Carefully insert reamer J 21089 in the injector body (see Figure 11C-29 on page 11C-18). 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 0.375" 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

Figure 11C-27. Cleaning Injector Spray Tip

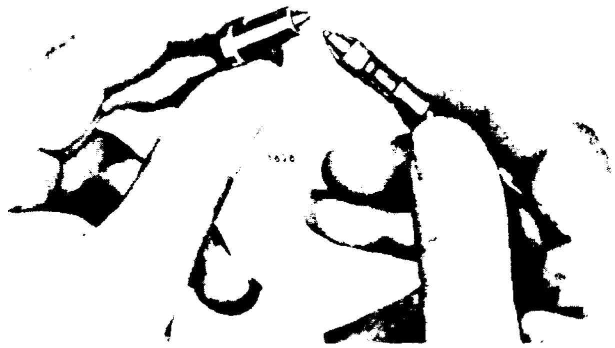


Figure 11C-28. Cleaning Spray Tip Orifices

(see Figure 11C-30 on page 11C-18). 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.

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 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 receptacle containing clean fuel oil.

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.

Inspect both ends of the spill deflector for sharp edges or burrs which could treate 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 (0.142" diameter) 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".

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 comsumption 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, errosion, 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 Busing 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

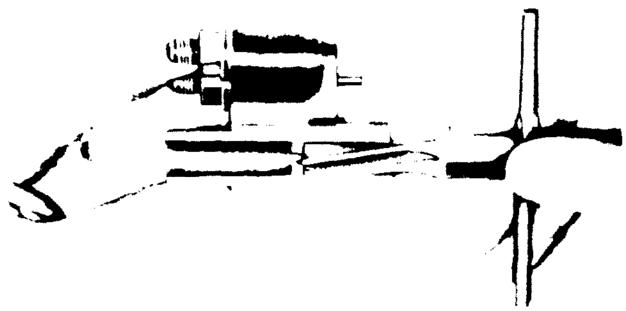


Figure 11C-29. Cleaning Injector Body Ring

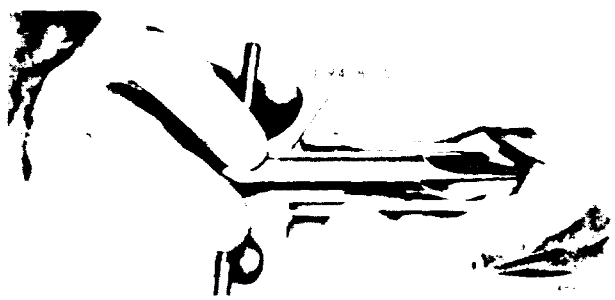


Figure 11C-30. Cleaning Injector Nut Spray Tip Seat

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 Figure 11C-31 on page 11C-19. Examine the sealing surfaces with a magnifying glass as shown in Figure 11C-32 on page 11C-19 for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks erosion, cracks, shipping 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.

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.

NOTE

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 arrow in Figure 11C-31 on page 11C-19. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

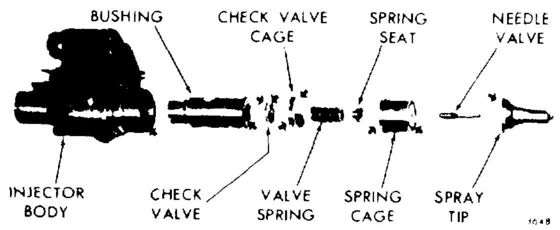
NOTE

The sealing surface of spray tips is precision lapped by a new process which leaves the surface with a dull satin like finish. It is not recommended to lap the surface of the new current spray tip.

Lapping Injector Parts

Lap the sealing surfaces indicated in Figure 11C-31 on page 11C-19, to the dimensions shown in the chart attached to the figure, as follows:

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.



Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163" – .165"
Check Valve	.022"
Valve Spring Cage	.602"

Figure 11C-31. Sealing Surfaces which may Requ'ire Lapping

2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.

3. Place the parts to be lapped on the block as shown in Figure 11C-33 on page 11C-20 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 parts. Do not lap excessively.

5. 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 parts in cleaning solvent and dry it with compressed air.

6. Place the dry parts 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 parts in this manner gives it the "mirror" finish required for perfect sealing.

7. Wash all of the lapped parts in clean fuel oil and dry them with compressed air.

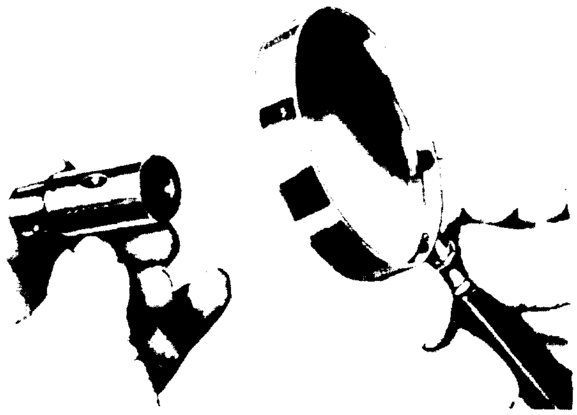


Figure 11C-32. Examining Sealing Surface

Assemble Injector

Use an extremly 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 Figure 11C-34 on page 11C-20 through Figure 11C-37 on page 11C-22 for the proper relative position of the injector parts, then proceed as follows:

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 (see Figure 11C-37 on page 11C-22).

NOTE

> 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.

2. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps to 65-75 lb-ft (88-102 Nm) torque with a 9/16" deep socket (see Figure 11C-23 on page 11C-15).

3. Purge the filters after installation by directing compressed air or fuel through the filter caps.

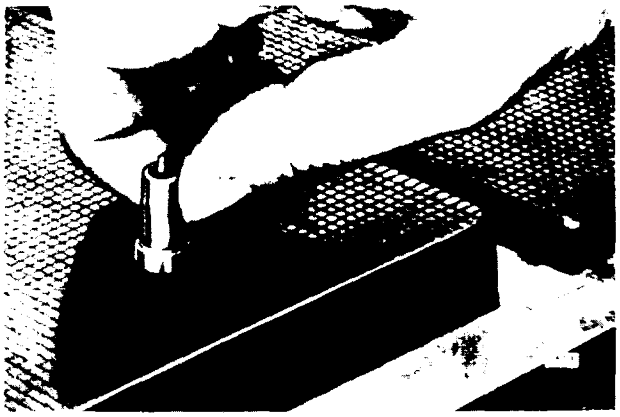


Figure 11C-33. Lapping Spray Tips on Lapping Blocks

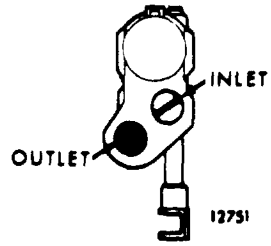


Figure 11C-34. Location of Filter in Injector Body

4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

ASSEMBLE RACK AND GEARS. Refer to Figure 11C-36 on page 11C-21 and note the drill spot marks on the control rack and gear. The 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.

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.

ASSEMBLE SPRAY TIP, SPRING AND CHECK VALVE. Refer to Figure 11C-36 on page 11C-21 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.

NOTE

Wet the seal ring with test oil and install the ring all the way down past the threads and onto the shoulder of the injector body. This will prevent the seal from catching in the threads and become shredded.

A new injector nut seal ring protector (J 29197) is now available to install the seal ring. Use the following procedure when installing the seal ring with the new protector:

A. Place the new seal ring and protector in a container with a small amount of injector test oil.

NOTE

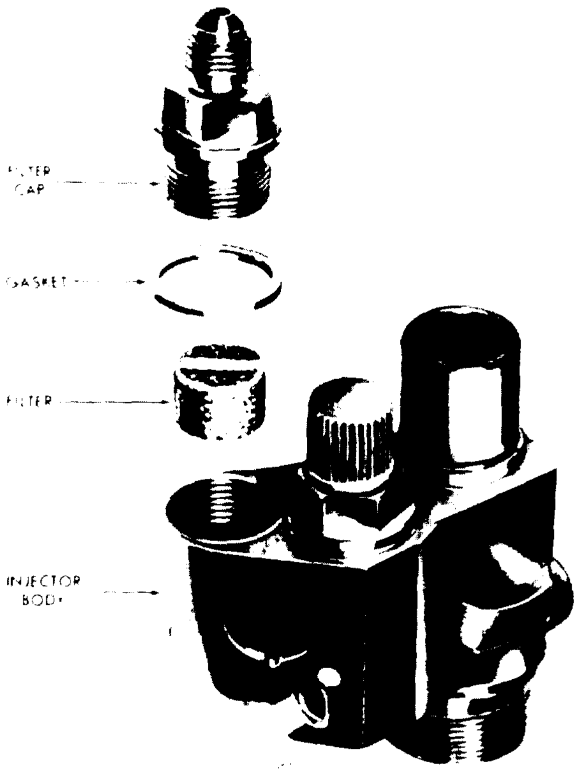
Lubrication of the seal ring and protector is important to assure proper installation of the seal ring.

B. Support the injector body, bottom end up, in the injector holding fixture J 22396.

C. Place the lubricated protector over the threads of the injector body. Place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

D. Remove the protector.

3. Install the spill deflector over the barrel of the bushing.



11C-35. Details of Injector Filters and Caps

4. Place the check valve (without the 0.010" hole) centrally on top of the bushing. Then place the check valve cage over the check valve and against the bushing.

5. Insert the spring seat in the valve spring, then insert the assembly into the spring cage, spring seat first.

6. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

7. Insert the needle valve, tapered end down, inside of the spray tip (see Figure 11C-3 on page 11C-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.

8. 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 (see Figure 11C-38 on page 11C-22). 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.

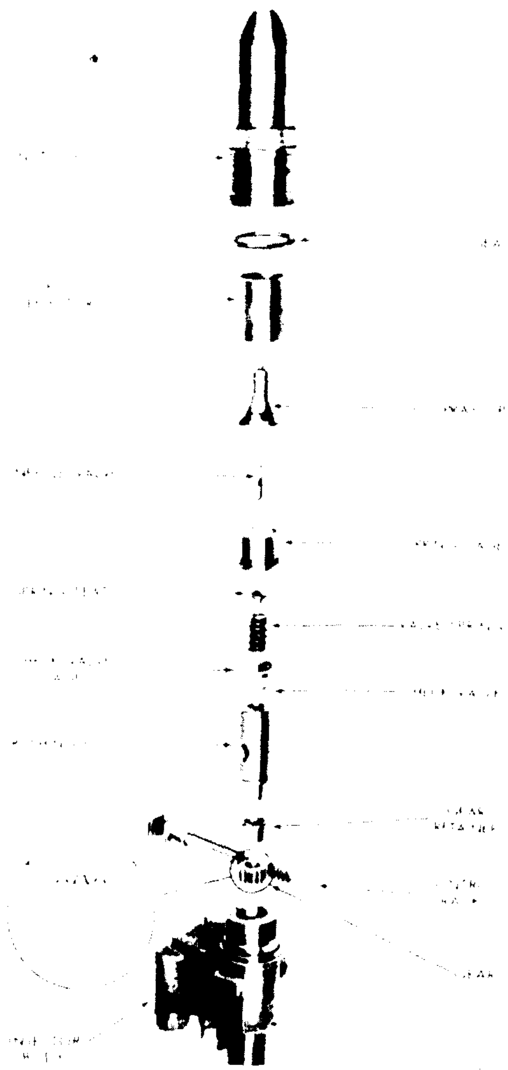


Figure 11C-36. Detailed Parts of Injector

9. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 75-85 lb-ft (102-115 Nm) torque, as shown in Figure 11C-39 on page 11C-23.

10. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut which may allow assembly on the body without extruding the seal and forcing it out of the body-nut crevice.

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.

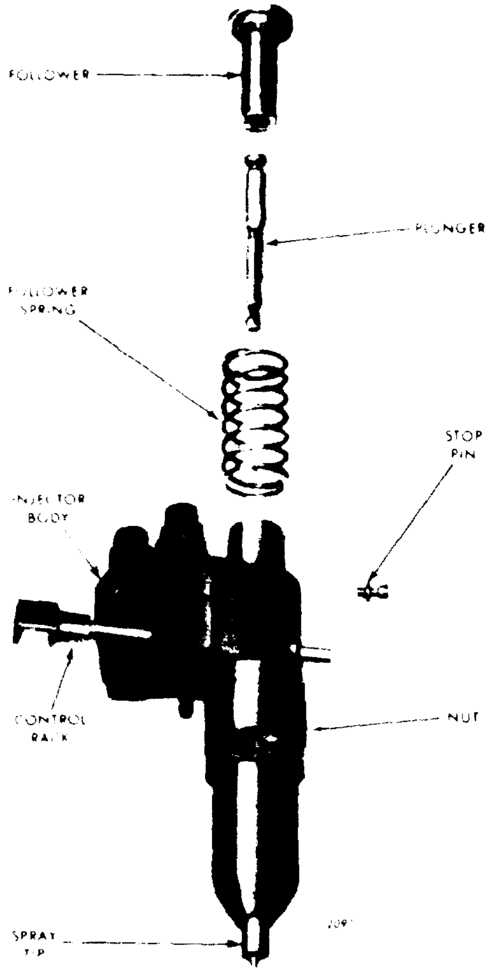


Figure 11C-37. Injector Plunger and Follower

ASSEMBLE PLUNGER AND FOLLOWER

1. Refer to Figure 11C-37 on page 11C-22 and slide the head of the plunger in 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 Figure 11C-40 on page 11C-23 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 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.

Figure 11C-38. Tightening Injector Nut by Hand

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 29584 as shown in Figure 11C-41 on page 11C-24 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 run out exceeds 0.008", remove the injector from the gauge. Loosen the injector nut, center the spray tip and tighten the nut to 75-85 lb-ft (102-115 Nm) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

TEST RECONDITIONED INJECTOR. Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) as outlined under "Test Injector" on page 11C-6.

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.

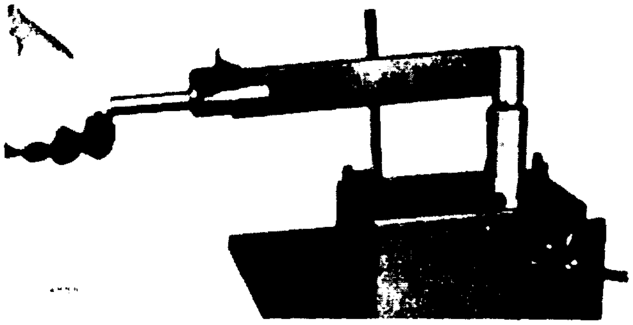


Figure 11C-39. Tightening Injector Nut with Torque Wrench

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 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 Figure 11C-7 on page 11C-4 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 lb-ft (27-34 Nm) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

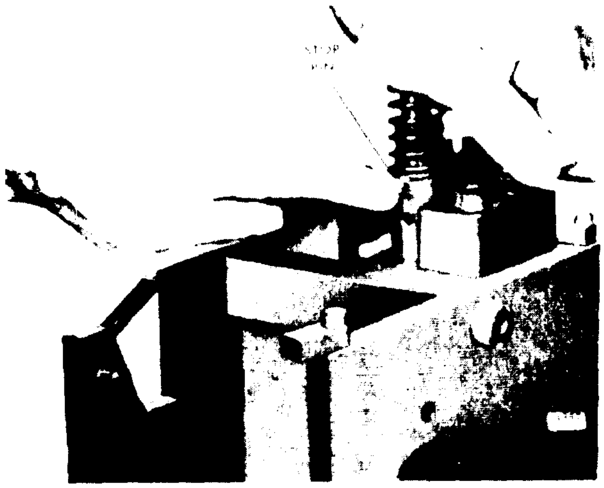


Figure 11C-40. Installing Injector Follower Stop Pin

NOTE

Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm bracket to the cylinder head by tightening the bolts to the torque specified at the end of this subsection.

NOTE

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 lb-ft (16-20 Nm) torque. 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 (refer to “Pressurize Fuel System - Check for Leaks” on page 11C-49).

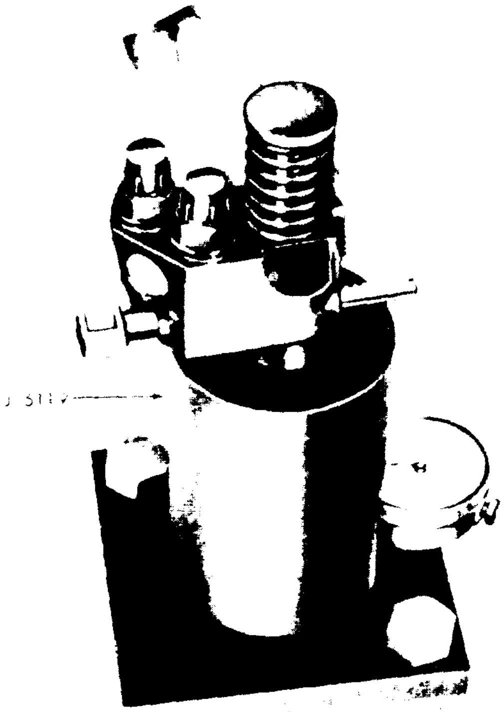


Figure 11C-41. Checking Injector Tip Concentricity

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 breather 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 oil a coating 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 is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectars. Reinstall the rocker cover. Then drain the lubricating oil and change the oil filter elements. Refer to Section III and refill the crankcase to the proper level with the recommended grade of oil.

6. Perform a complete engine tune-up as outlined in Section 11H. 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.

FUEL INJECTOR TUBE

Description

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Figure 11C-42 on page 11C-25. 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.

NOTE

Do not use methoxy propanol based antifreeze in the cooling system of the engine.

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 new injector hole tube swaging tool J 28611 is now available.

Before removing the fuel injector, pressurize the cooling system at the radiator to verify the injector 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.

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.

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 (see Figure 11C-42).

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.

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 installer J 5286-4 in the injector tube. Then insert the pilot J 5286-5 through the small opening of the injector

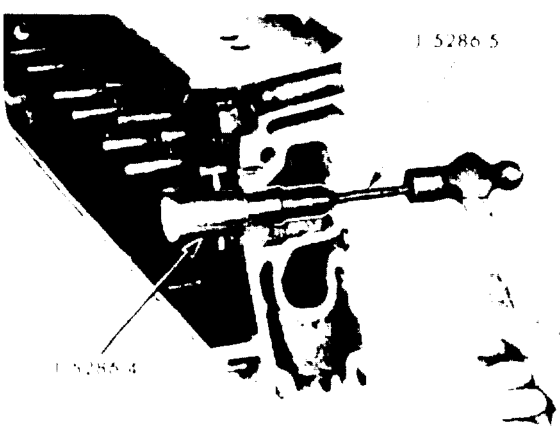


Figure 11C-42. Removing Injector Tube

Figure 11C-43. Installing Injector Tube

tube and thread it into the tapped end of the installer (see Figure 11C-43).

3. Slip the injector tube into the injector bore and drive it in place as shown in Figure 11C-43. 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 bottom side up, remove the pilot and thread the upsetting die J 5286-5 into the tapped end of the installer (see Figure 11C-44 on page 11C-26).

B. Then, using a socket and torque wrench, apply approximately 30 lb (41 Nm) torque on the upsetting die.

C. Remove the installing tools and ream the injector tube as outlined below.

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 Figure 11C-45 on page 11C-26, 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 Figure 11C-46 on page 11C-27,

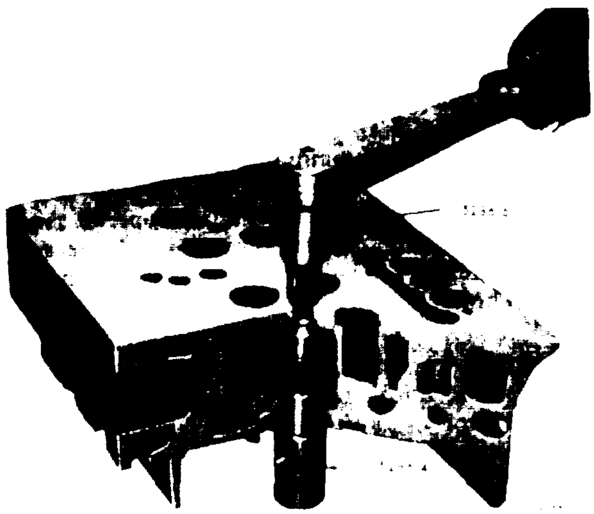


Figure 11C-44. Upsetting Injector Tube

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

The reamer should be turned in a clockwise direction only, both when inserting and when withdrawing the reamer, because movement in the opposite direction will dull the cutting edge of the flutes.

1. Ream the injector tube for the injector nut and spray tip. With 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 (withdraw the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Figure 11C-45). 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.

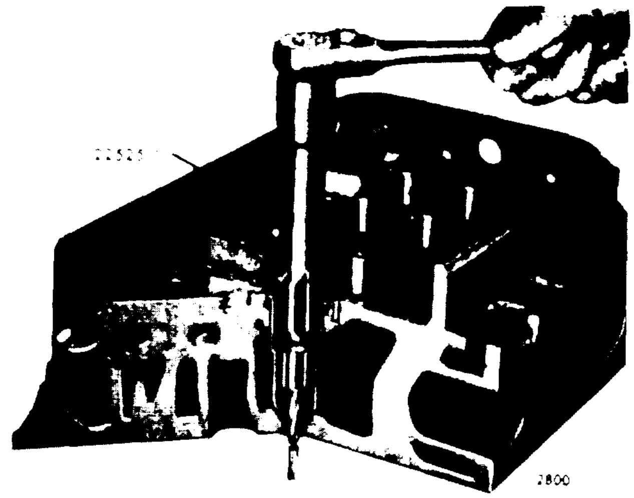


Figure 11C-45. Reaming Injector Tube for Body Nut and Spray Tip

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 0.005" 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 Figure 11C-47 on page 11C-27.

Install gauge J 25521 in injector tube. Zero the sled gauge dial indicator J 22273 to the fire deck. Gauge J 25521 should be flush to ±0.014" with the fire deck of the cylinder head (see Figure 11C-48 on page 11C-27).

NOTE

Any fire deck resurfacing work must be done prior to final injector tube gaging.

With the first reaming operation com - pleted and the injector tube spot-faced, wash the interior of the injector tube with clean solvent and dry it with com-

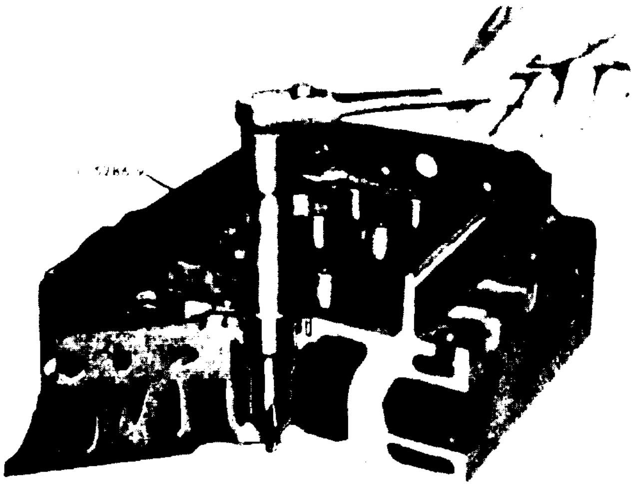


Figure 11C-46. Reaming Injector Tube for Injector Nut

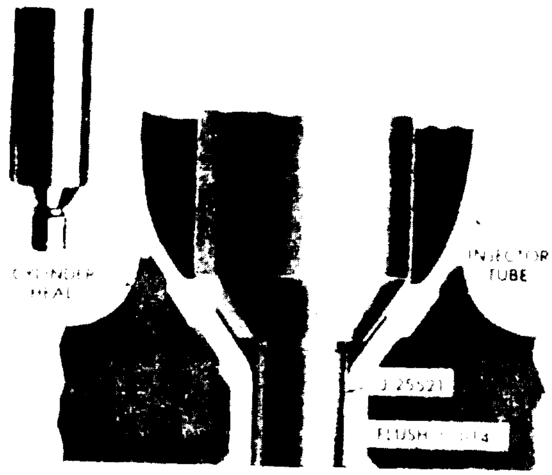


Figure 11C-48. Measuring Relationship of Gauge to Fire Deck

press 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 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.

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 ±0.014" with the fire deck of the cylinder head shown in Figure 11C-48. Then wash the interior of the injector tube with clean solvent and dry it with compressed air.

FUEL PUMP

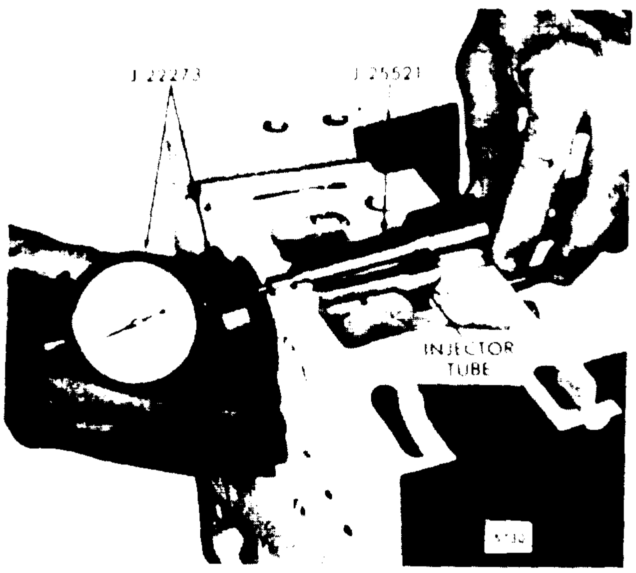


Figure 11C-47. Measuring Injector Seat Bevel Seat

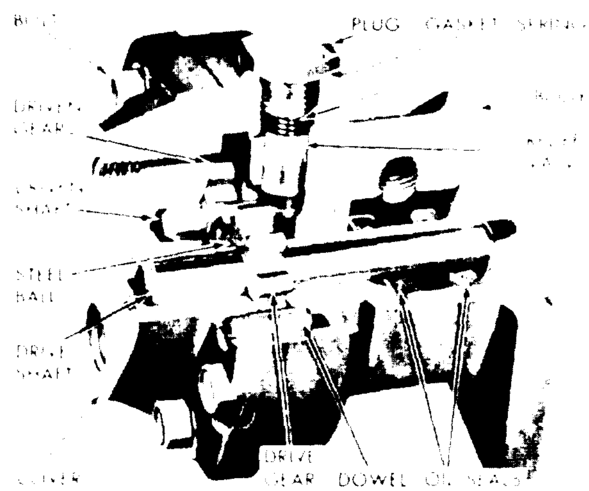


Figure 11C-49. Typical Fuel Pump

Description

The positive displacement gear-type fuel pump (Figure 11C-49) transfers fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purge 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 prevent 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 Figure 11C-50 on page 11C-29.

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 fiat 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 (see Figure 11C-51 on page 11C-29). 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” provide 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, shaft, body and cover.

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 (see Figure 11C-52 on page 11C-30). The oil seals are installed with the lips of the seals facing toward the flanged end of the pump body. A small hole “E” (Figure 11C-51 on page 11C-29) 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.

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 excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

The drive and driven
line-to-tine to 0.001" press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft (see Figure 11C-50 on page 11C-29).

A spring loaded relief va ve 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).

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

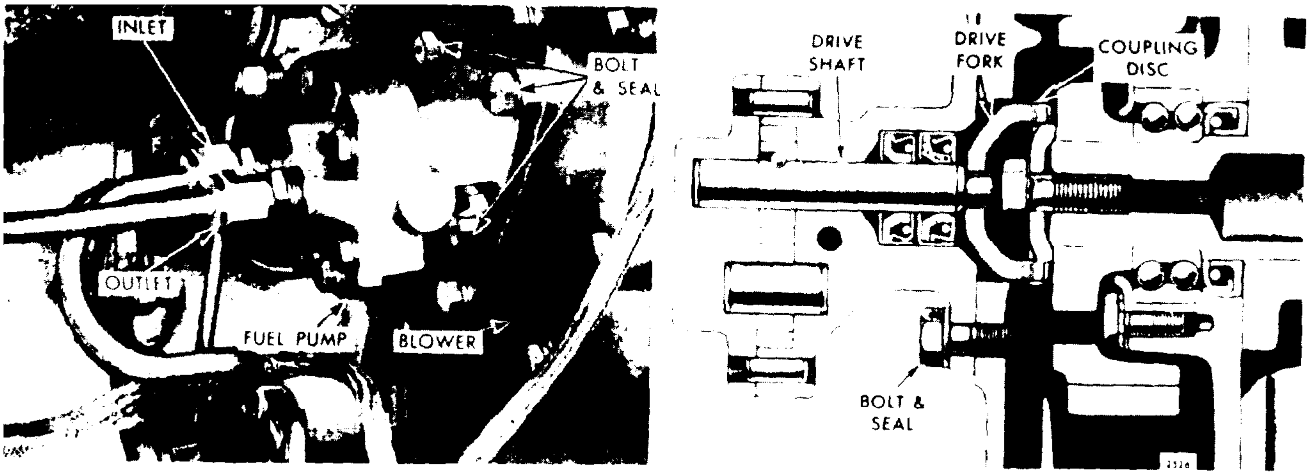


Figure 11C-50. Typical Fuel Pump Mounting and Drive

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 65 to 75 psi (448 to 517 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold as shown at the end of this subsection.

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 withdrawn the pump from the blower.

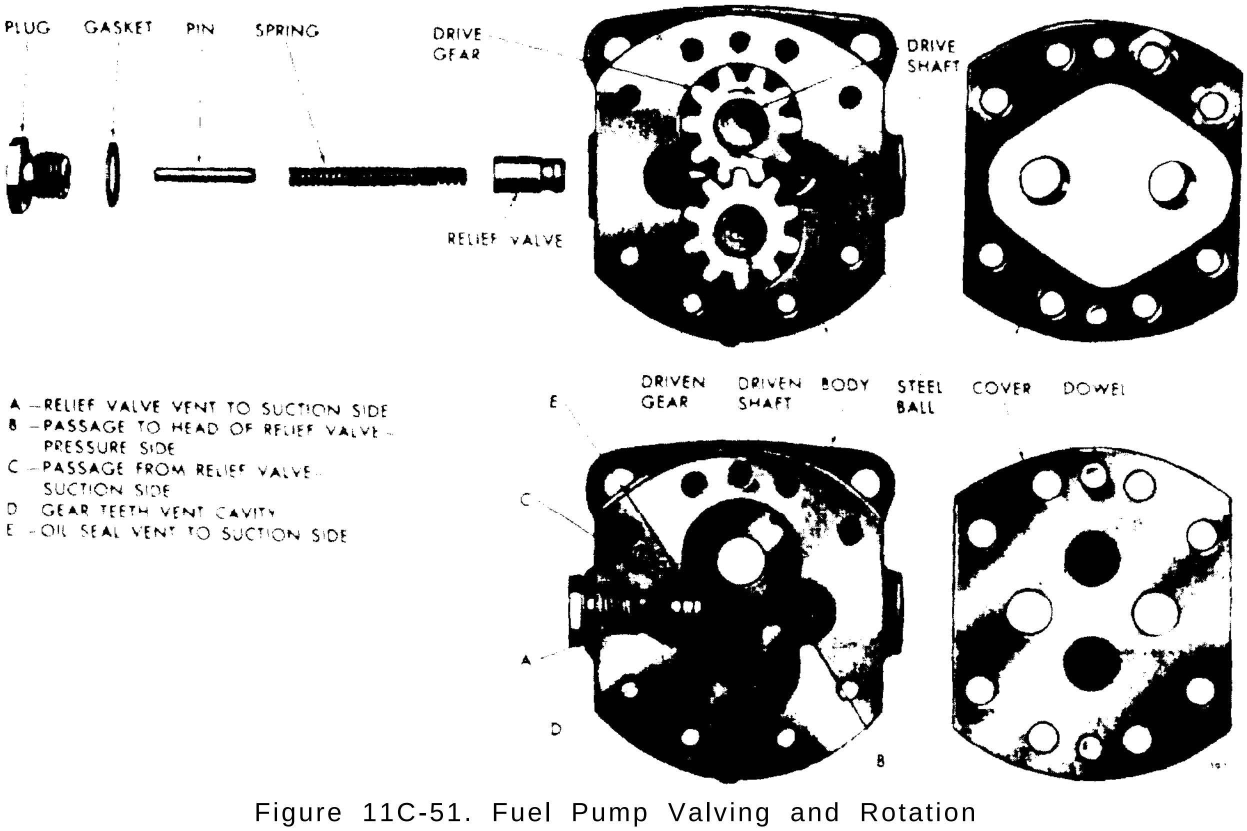


Figure 11C-51. Fuel Pump Valving and Rotation

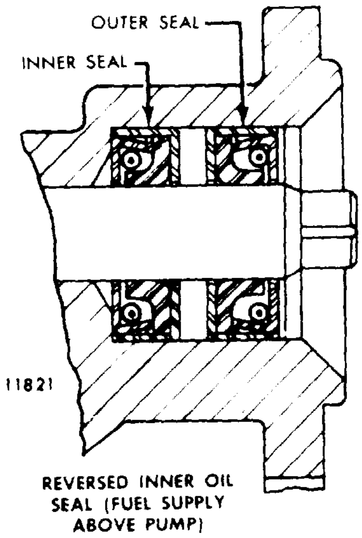


Figure 11C-52. Fuel Pump Oil Seal

4. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508-10 as shown in Figure 11C-53, refer to Figure 11C-49 on page 11C-27 end Figure 11C-55 on page 11C-31 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.

5. Remove the relief valve plug and copper gasket,

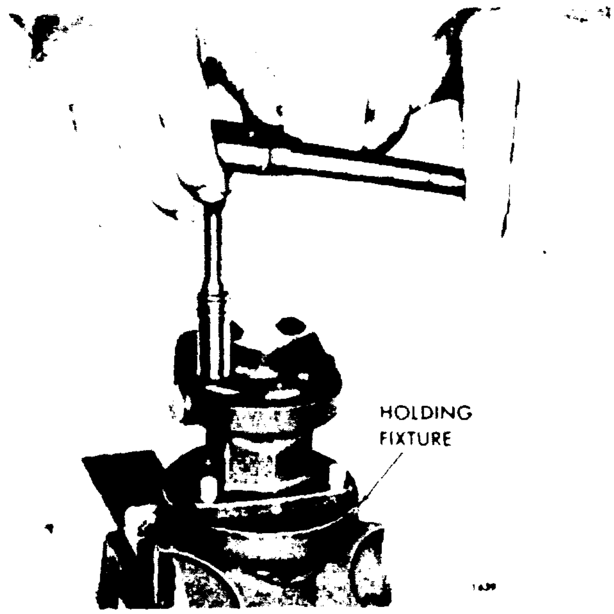


Figure 11C-53. Removing Pump Cover

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 (Figure 11C-54 on page 11C-31). 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.

Inspection

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.

Figure 11C-54. Removing Oil Seals

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.

Assemble Fuel Pump

Refer to Figure 11C-49 on page 11C-27, Figure 11C-51 on page 11C-29 and Figure 11C-55 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.

B. With the pump body supported on wood blocks (Figure 11C-56 on page 11C-32), 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

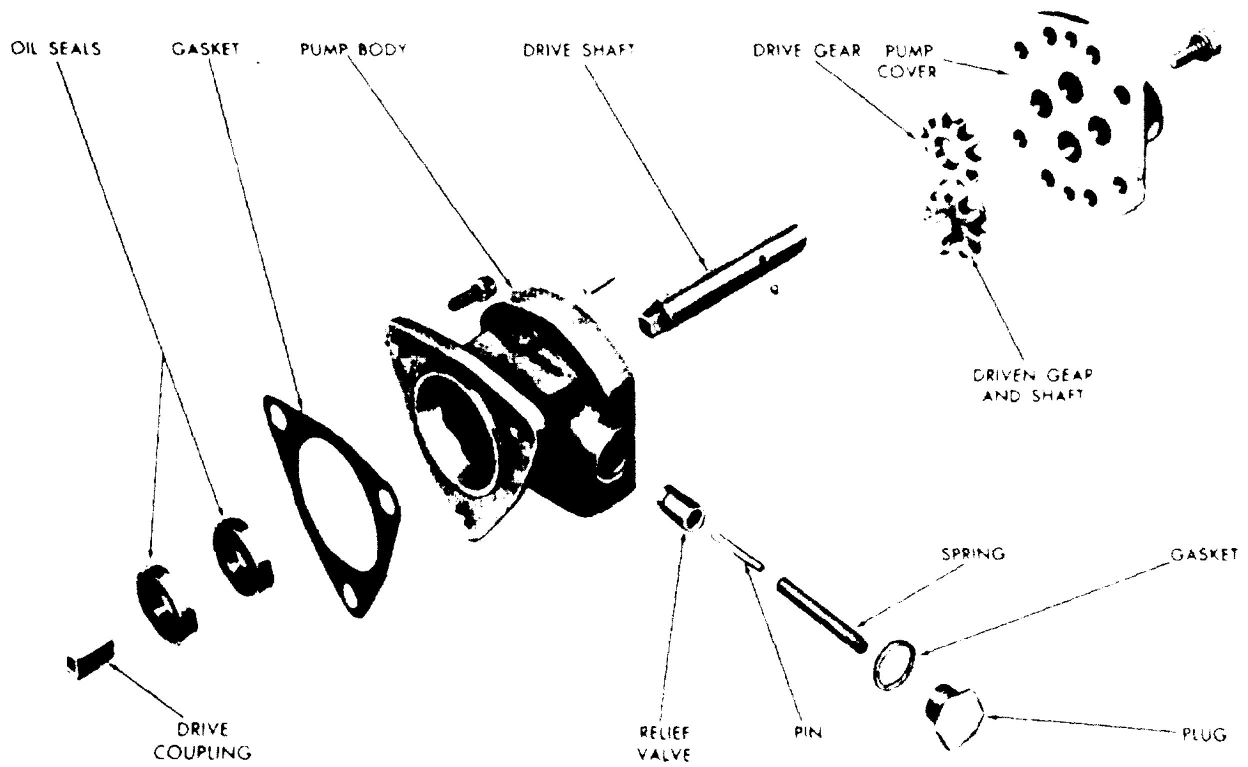


Figure 11C-55. Fuel Pump Parts

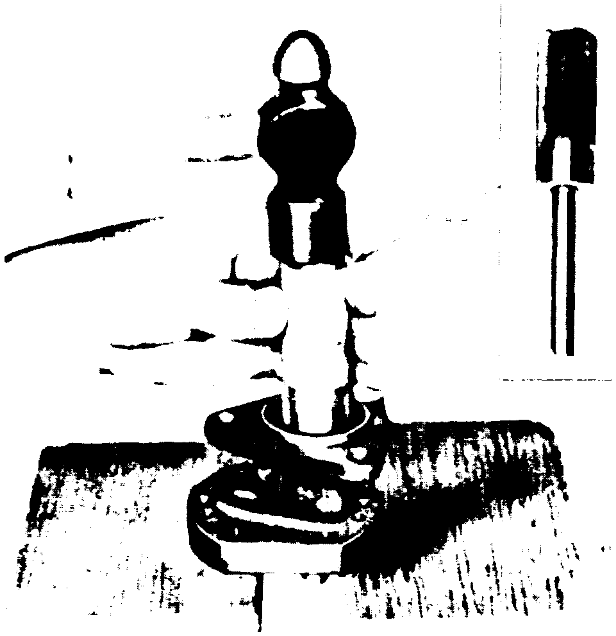


Figure 11C-56. Installing Inner Oil Seal

seal facing the adaptor. Then inset the pilot of the installer handle into the pump body and drive the seal in (Figure 11C-57 on page 11C-32) 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 lb-ft (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

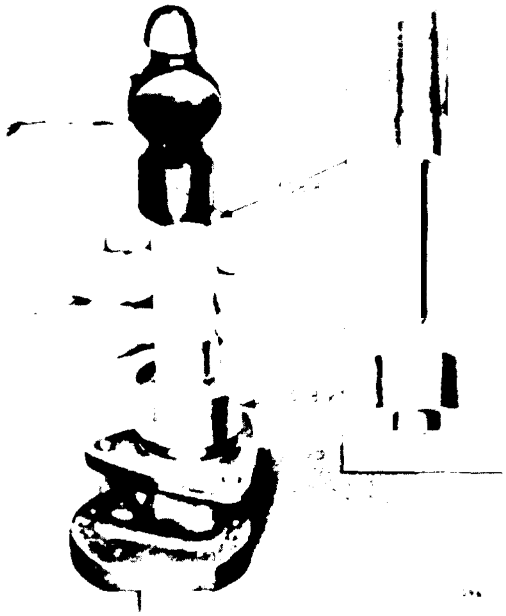


Figure 11C-57. Installing Outer Oil Seal

bail 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 Figure 11C-58 on page 11C-33.

5. Place the driven shaft and gear assembly in the pump body.

NOTE

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.

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.

Figure 11C-58. Install Drive Shaft and Gear

NOTE

The coating of sealant must be extremely thin since the pump clearance 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.

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.

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 Figure 11C-50 on page 11C-29 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 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 blower, being certain that the drive coupling 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.

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 using tool J 5956. This will prevent the possibility of pump seizure upon initial starting.

FUEL MANIFOLD

Description

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 cylinder head (see Figure 11C-59 on page 11C-34). Since there are inlet ans 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 assembled to the integral fuel manifold cylinder head, using special steel sealing washers, and tightened to 40-45 lb-ft (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.

MECHANICAL GOVERNORS

Description

Horsepower requirements on an engine may vary due to fluctuating loads; therefor, 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. This machine is equipped with a variable speed mechanical governor.

Engines subjected to varying load conditions that require an automatic fuel compensation to maintain a near constant engine speed, which may be changed manually by the operator, are equipped with a 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.

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. If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined under "Fuel Injector" on page 11C-1.

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

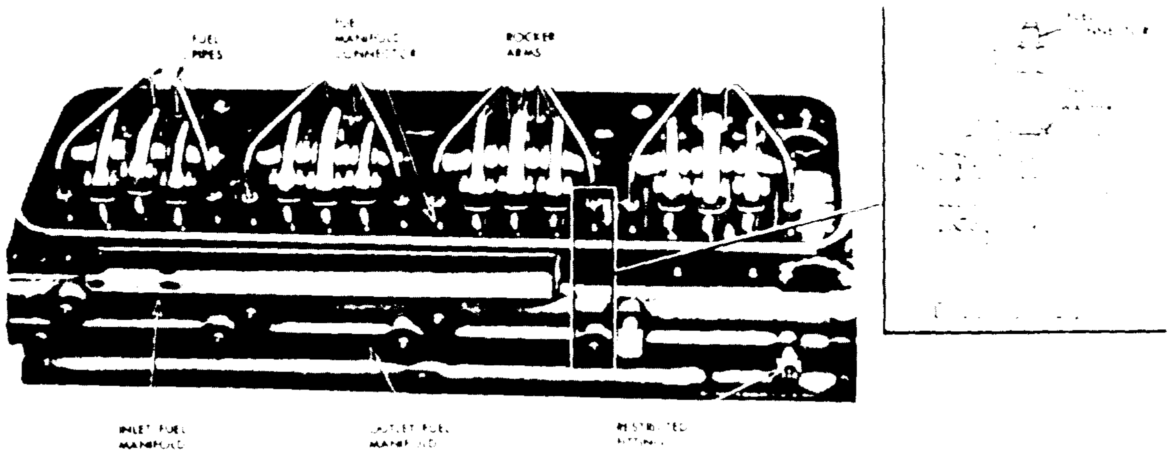


Figure 11C-59. Cylinder Head with Integral Fuel Manifolds hold-down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolts to 20-25 lb-ft (27-34 Nm) torque.

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 under “Fuel Injector” on page 11C-1.

3. An injector rack may bind as the result of an improperly position 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 Subsection 11H.

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 tighten, the injector racks must be repositioned as outlined in Subsection 11H.

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.

VARIABLE SPEED MECHANICAL GOVERNOR

Description

The variable speed mechanical governor (Figure 11C-60 on page 11C-36) performs three functions:

1. Controls the engine idle speed.

2. Limits the maximum no-load speed.

3. Hold the engine at any constant speed, between idle and maximum, as desired by the operator.

The single weight governor is mounted on the front the blower (Figure 11C-61 on page 11C-36) and is driven by the upper blower rotor.

The governor consists of four subassemblies:

1. Control Housing Cover.

2. Control Housing.

3. Weight and Housing.

4. Variable Speed Spring Housing and Shaft.

Operation

Two manual controls are provided on the variable speed governor: a stop lever (Figure 11C-60 on page 11C-36) 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 balance 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

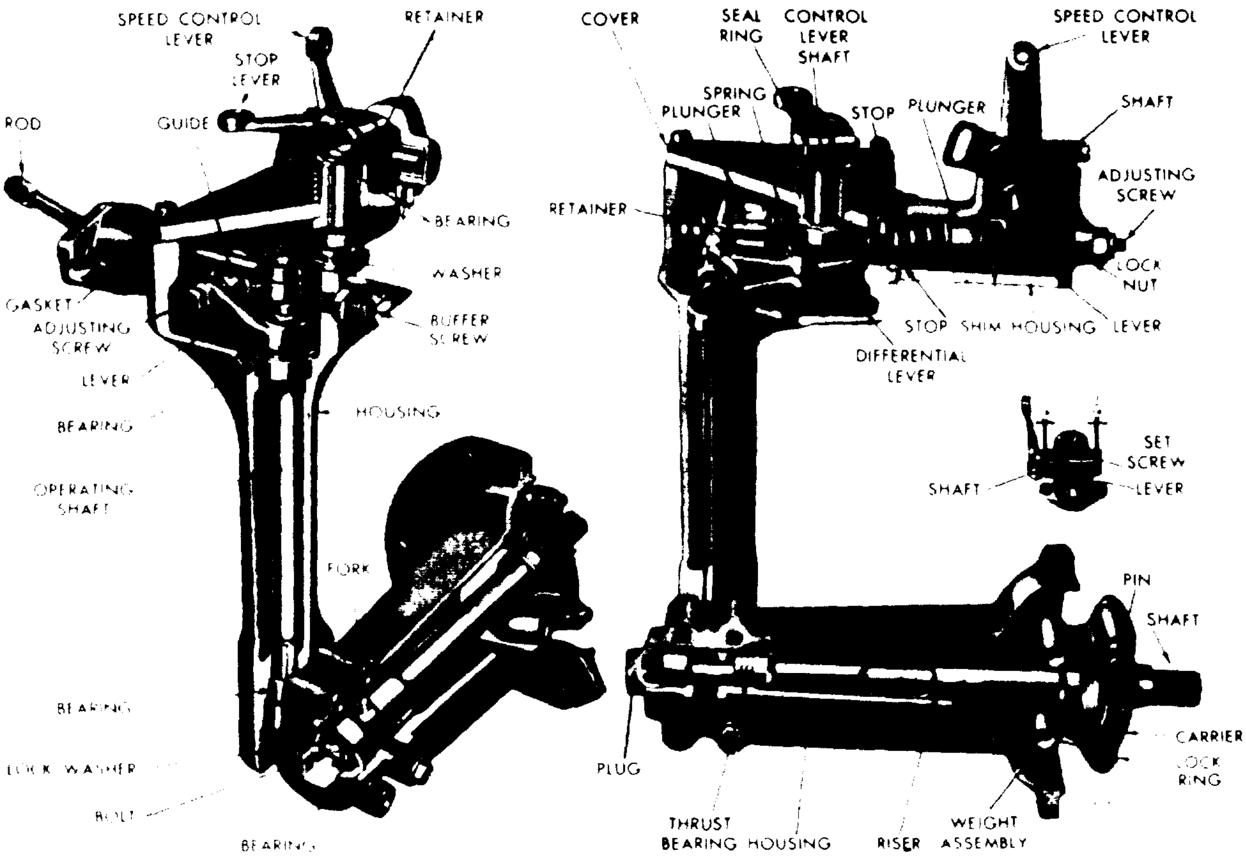


Figure 11C-60. Variable Speed Mechanical Governor

check 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.

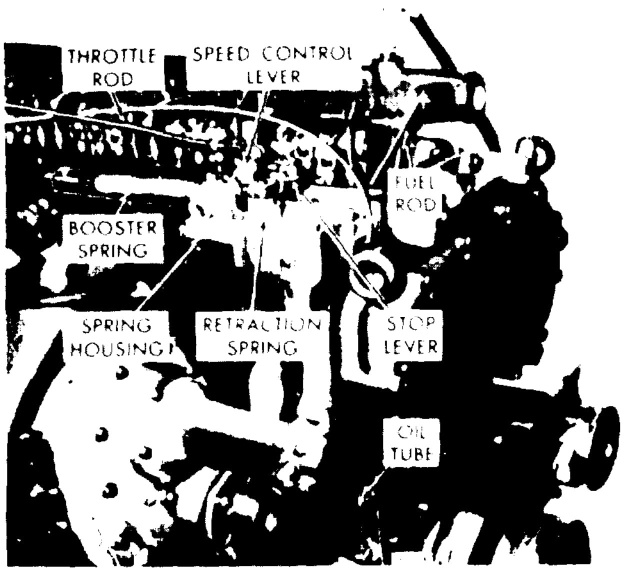


Figure 11C-61. Variable Speed Governor Mounting

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 Subsection 11H for idle speed adjustment.

Adjustment of the maximum no-load speed is accomplished by varying the tension on the variable speed spring by the installation or removal of stops and shims, as required Refer to Subsection 11H for maximum no-load speed adjustment.

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. The oil tube is attached between the oil gallery in the cylinder block and the governor weight housing.

Remove Governor

Governor operation should be checked as outlined under "Check Governor Operation" on page 11C-34 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.

1. Refer to Figure 11C-61 on page 11C-36 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 Figure 11C-60 on page 11C-36 and Figure 11C-61 on page 11C-36 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, if used.

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.

Disassemble Governor

With the cover removed from the control housing, disassemble the governor as follows:

1. Disassemble the governor cover (Figure 11C-62).

A. Loosen the clamping bolt and remove the stop lever from the shaft. Remove the lever torsion retraction spring.

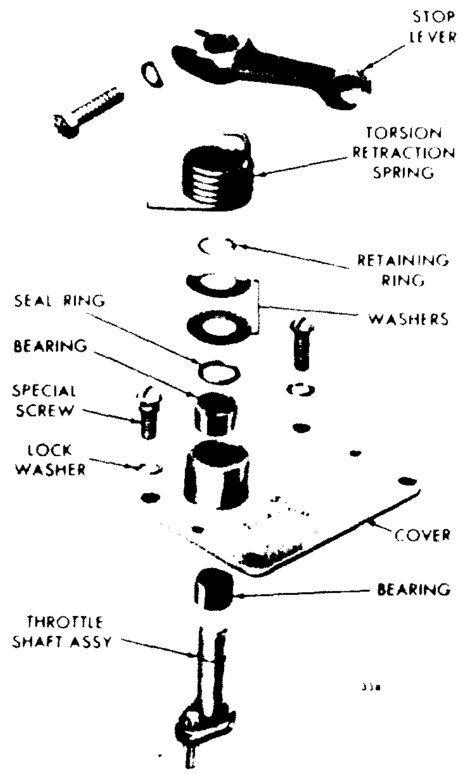


Figure 11C-62. Governor Cover Details

B. Remove the control shaft lock ring and seal retainer. Withdraw the control shaft from the cover.

C. Remove the seal ring from the governor cover.

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 needle bearings or bushings for wear or damage.

E. If needle bearing or bushing removal is necessary, place the inner face of the cover over the opening in the bed of an arbor press (see Figure 11C-63 on page 11C-38). Place remover J 21967-01 on top of the bearing or bushing and press both bearings or bushings out of the cover.

2. Disassemble the governor control housing.

A. Place the control housing in the soft jaws of a vise (see Figure 11C-64 or page 11C-38)

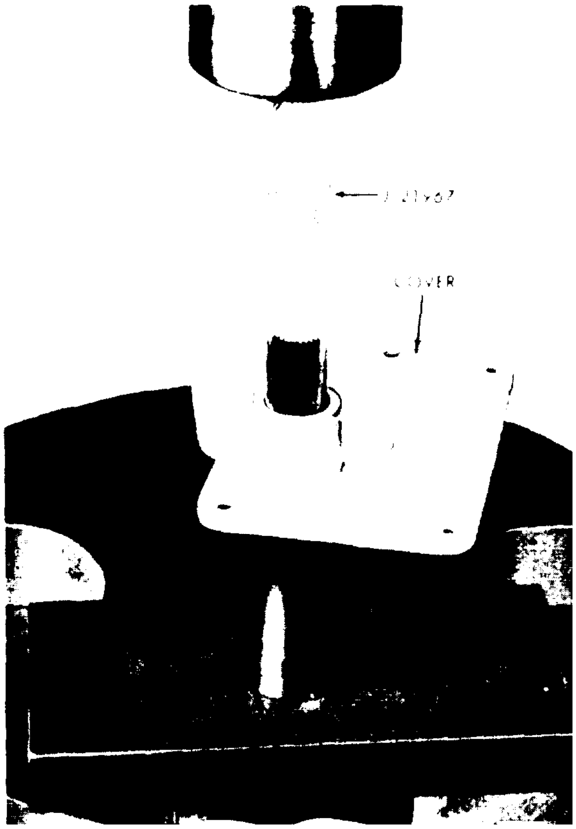


Figure 11C-63. Removing Bearings from Cover Using J 23967-01

B. Remove two bolts and lock washers 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 Figure 11C-65 on page 11 C-39 and remove the variable speed spring plunger guide. Remove the bearing retaining screw, flat washer and lock washer.

E. Remove the expansion plug out of the lower end of the control housing.

F. Loosen the operating fork set screw, if used.

G. 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 (see Figure 11C-66 on page 11C-39). Withdraw the operating shaft, operat-

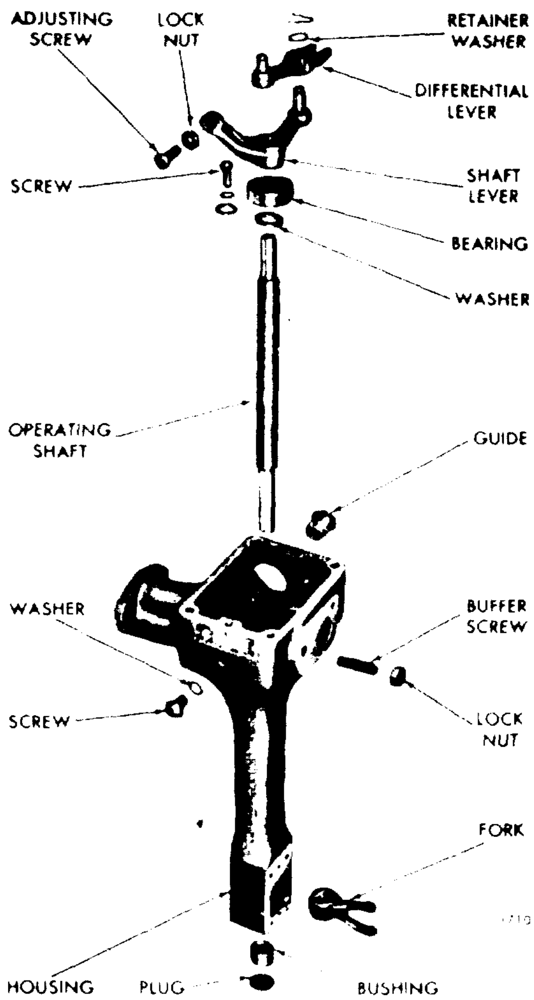


Figure 11C-64. Governor Control Housing Details

ing lever and bearing as an assembly from the control housing (see Figure 11C-64).

H. Support the operating shaft and lever on the bed of the press as shown in Figure 11C-67 on page 11C-39. 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 in the soft jaws of a vise (Figure 11C-68 on page 11C-40). Remove the end plug and gasket.

B. Straighten the tang of the lock washer and remove the bearing retaining bolt.

Figure 11C-65. Removing Variable Speed Spring Plunger Guide

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 Figure 11C-69 on page 11C-40, then press the shaft from the bearing.

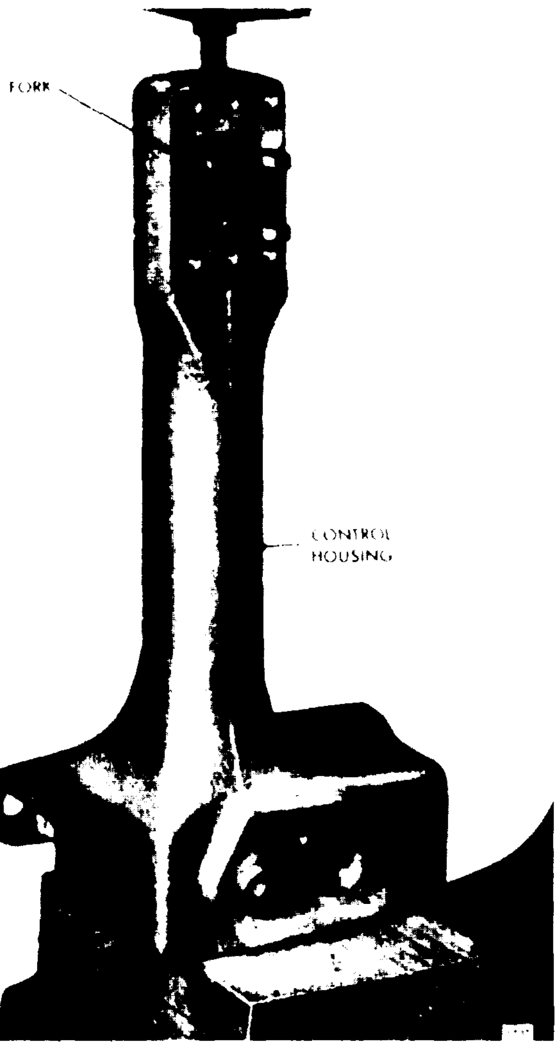


Figure 11C-66. Removing Operating Shaft from Fork

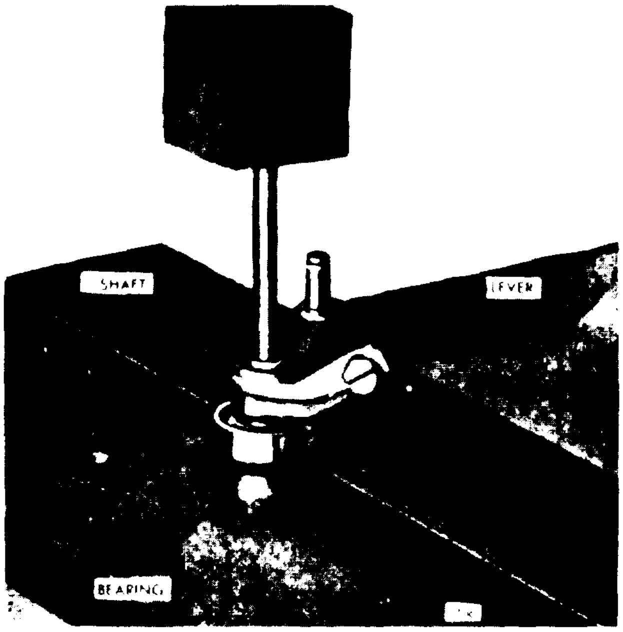


Figure 11C-67. Removing Operating Shaft from Lever

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 J4880 and remove one lock ring from each weight pin. Withdraw the pins, flat washers and governor weights.

G. If required, the weight carrier (Figure 11C-68 on page 11C-40) may be pressed from the governor weight shaft and a new carrier installed.

4. Disassemble the governor variable speed spring housing.

A. Refer to Figure 11C-60 on page 11C-36 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 from the speed control lever shaft. Remove the Woodruff key (Figure 11C-72 on page 11C-43) from the shaft.

C. Remove the plain washer and sea! from the shaft.

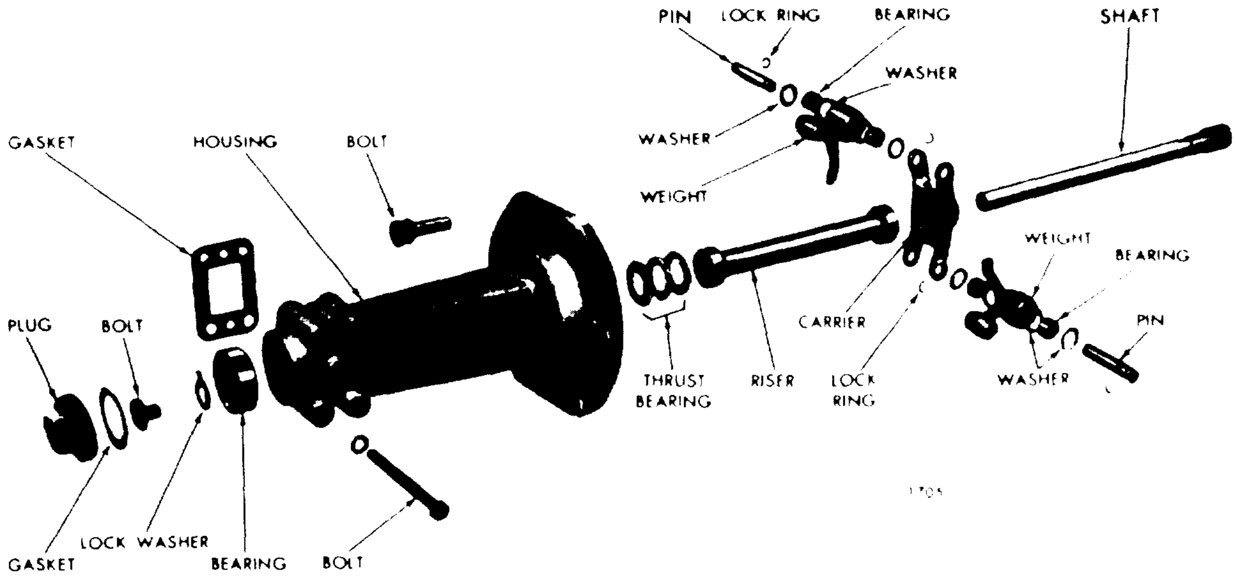


Figure 11C-68 Governor Weight Housing Details

D. Remove one screw and lock washer 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 bearing from the housing. Remove the bearing from the shaft and the spring -lever from the housing.

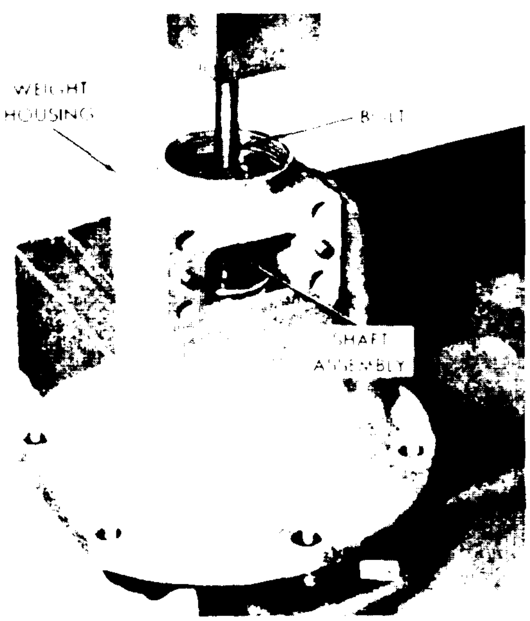


Figure 11C-69. Removing Governor Weight and Shaft

F. If required, the second bearing may be pressed from the housing.

Inspection

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, fiat spots or corrosion. If any of these conditions exist, a new thrust bearing assembly must be installed.

Inspect the needle bearing or 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 exists, 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.

Check the finished surface of the governor weights for flat spots. If flat spots are noted, new weight should be installed.

Assemble Governor Cover

1. If new 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 (Figure 11C-70) 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.

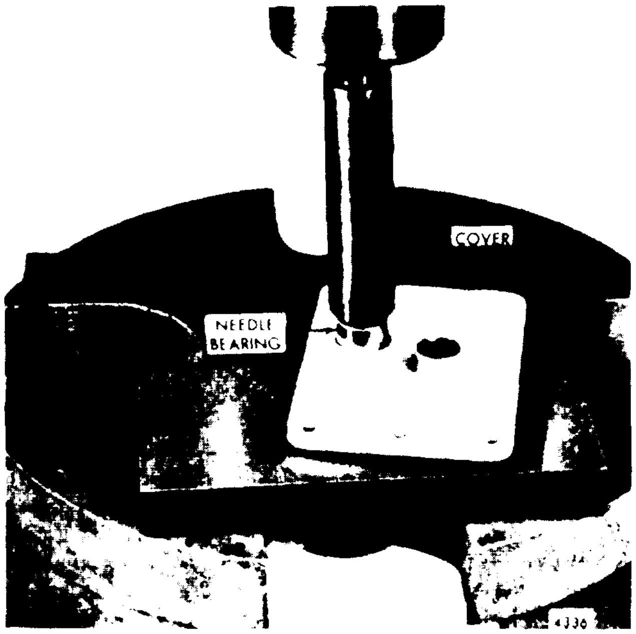


Figure 11C-70. Installing Needle Bearing in Cover

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 (see Figure 11C-61 on page 11C-36). Then place the stop lever on the shaft and tighten the clamping bolt.

Assemble Governor Control Housing

1. Place the bearing washer over the short, finished end of the operating shaft (see Figure 11C-64 on page 11C-38). 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.

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 Figure 11C-60 on page 11C-36.

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. Tighten the fork set screw (if used).

7. Place the differential lever over the pivot pin of the operating lever. Install the plain washer and spring retainer.

8. Place the lock washer and the flat washer over the bearing retaining screw. Refer to Figure 11C-60 on page 11C-36 and thread the screw in the control housing tight to secure the bearing.

9. Refer to Figure 11C-65 on page 11C-39 and insert the variable speed spring plunger guide in the control housing.

10. 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.

Assemble Governor Weight Housing

1. Install the lock ring in the groove of the weight pin (see Figure 11C-68 on page 11C-40). 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 in the same manner.

6. Slide the riser over the shaft and against the finished surfaces of the governor weights as shown in Figure 11C-60 on page 11C-36.

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.

9. Support the splined end of the shaft on the bed of an arbor press. Start the shaft end bearing in the housing and over 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 (Figure 11C-68 on page 11C-40) 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 360° circumference of the end plug and thread the plug into the tapped end of the governor weight housing. Tighten the plug to 45 lb-ft (61 Nm) torque with either the flat or the point of the head on a horizontal line.

Assemble Variable Speed Spring Housing

1. Refer to Figure 11C-71 on page 11C-43 and Figure 11C-72 on page 11C-43. 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.

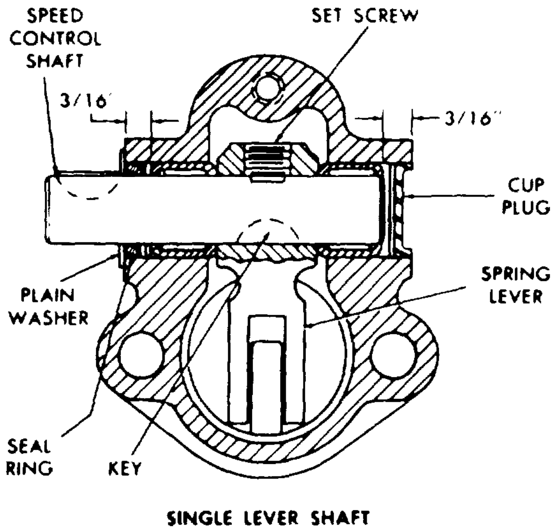


Figure 11C-71. Cross Section of Governor Variable Speed Spring Housings

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.

2. 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 Figure 11C-73 on page 11C-44, 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.

3. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

4. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

5. Insert the correct end of the single lever type, speed control lever shaft (Figure 11C-71) 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.

6. Thread the set screw into the spring lever, make sure the point of the screw is seated in the flat on the shaft.

7. 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.

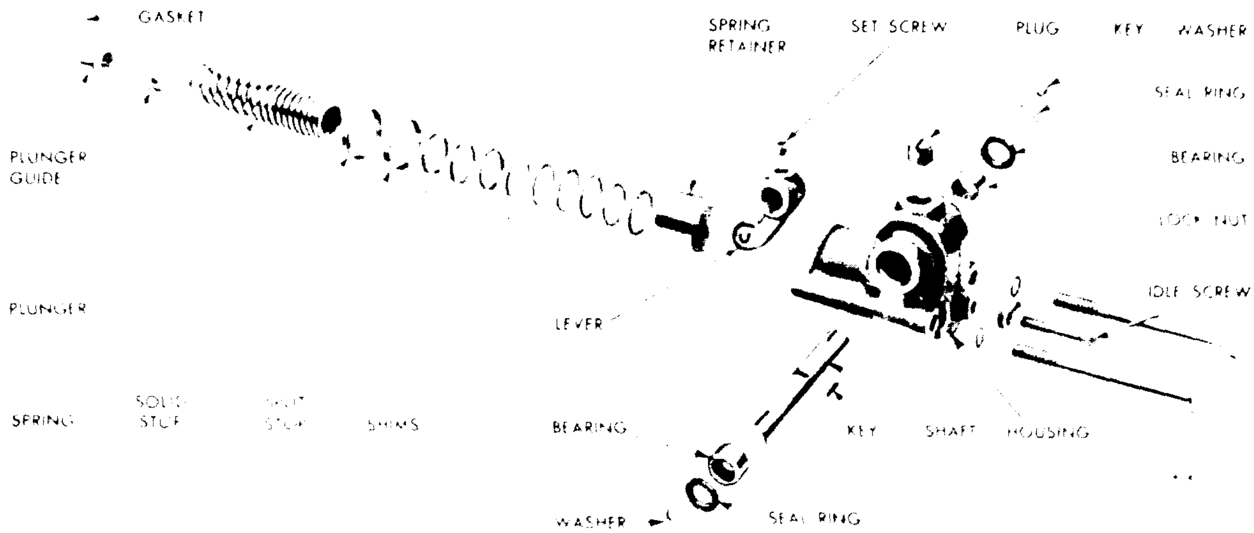


Figure 11C-72. Variable Speed Spring Housing Details

8. Remove the bearing pilot rod J9196-2 from installer body J 9196-1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press as shown in Figure 11C-73, then press the bearing in the housing until the shoulder on the installer contacts the housing.

9. If a single lever shaft was installed in the spring housing, 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 (see Figure 11C-71 on page 11C-43).

10. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to 5-7 lb-ft (7-10 Nm) torque.

11. 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.

12. On a single lever shaft, 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.

13. 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 lock washer.

14. If removed, thread the lock nut on the idle speed adjusting screw. Then, thread the idle speed adjusting screw into the spring housing cover approximately 1".

Assemble Variable Speed Spring Housing in Control Housing

1. Refer to Figure 11C-72 on page 11C-43 and insert the small end of the spring plunger in the plunger guide. Insert the solid stop in the governor control housing.

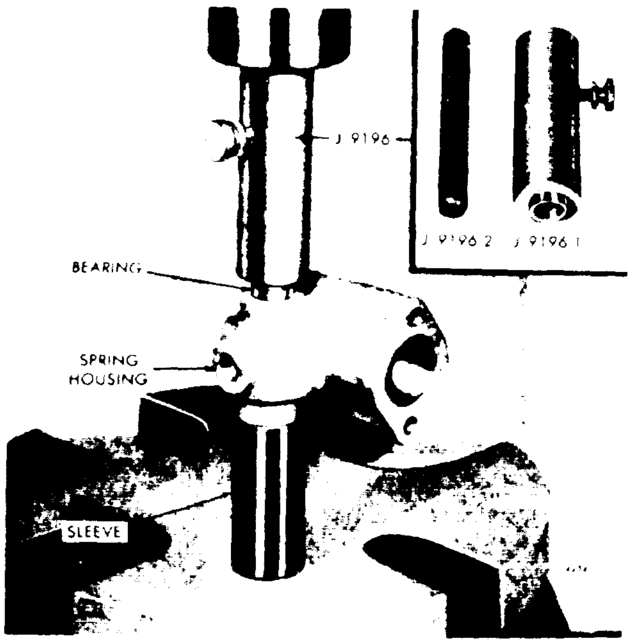


Figure 11C-73. Installing Speed Control Shaft Bearings

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 0.344" inside diameter. Either spring retainer may be used with shims which have a 0.750" I.D.. However, do not use the 0.344" I.D. shims with a spring retainer which has only one air bleed hole.

3. Insert the variable speed spring in the spring plunger with the tightly wound end of the spring against the shims.

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.

Install Governor

1. Affix a new governor-to-blower gasket to the governor weight housing. Refer to Figure 11C-61 on page 11C-36 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 (Figure 11C-68 on page 11C-40) 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 Figure 11C-61 on page 11C-36 and position the lower end of the control housing over the dowel pins of the weight housing.

CAUTION

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, 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 toward 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 (see Figure 11C-61 on page 11C-36). Tighten the bolts.

7. Tighten the governor-to-blower bolts with tool J 4242.

8. Place cover in position and install the four weight housing-to-control housing bolts with lock washers and tighten the bolts.

9. Connect the oil tube to the restricted fitting on the weight housing, or cover if used.

10. Refer to Figure 11C-60 on page 11C-36 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 Figure 11C-60 on page 11C-36.

13. Secure the cover to the governor housing with three regular screws, one special screw and lock washers.

14. Hook the torsion retraction spring to the special cover screw and stop lever (see Figure 11C-61 on page 11C-36).

15. Perform an engine tune-up as outlined in Subsection 11H.

SHOP NOTES - TROUBLESHOOTING

Shop Notes

INJECTOR CALIBRATOR READINGS. Several factors affect the injector calibrator output readings. The four 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 (see Figure 11C-74 on page 11C-46).

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.

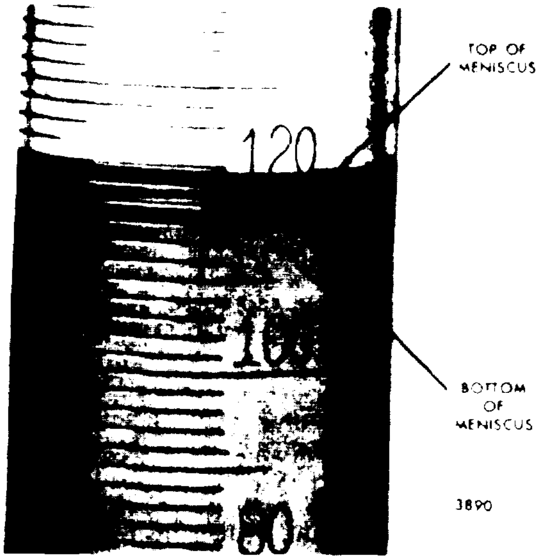


Figure 11C-74. Checking Fuel Output

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. 1 regular diesel fuel oil (or any other fluid) 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.

CHECK INJECTOR TESTER J 23010. The injector tester should be checked monthly to be sure that it is operating proper- 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 (16,536-17,255 kPa). Close the valve on the fuel supply line. After a slight initial drop, the pressure should remain steady. This indicates that the injector test is operating properly. Open the fuel valve and remove the test block.

If there is a leak in the test 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. Otherwise, the pump check valve must be removed, lapped and cleaned or replaced (J 9787). 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, 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.

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 block together as shown in Figure 11C-75. 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 grey. 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.

When not in use, protect the lapping blocks against damage and dust by storing them in a close fitting wooden container.

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 master, the calibrator can be considered accurate.

injector testing can be carried out now without any adjustment of figures. However, when testing new injectors for

Figure 11C-75. Refreshing Lapping

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.

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 and appears in the “advanced” or “retarted” position position, disassemble the injector and correct the rack-to-gear timing (see Figure 11C-76 on page 11C-48).

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 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.

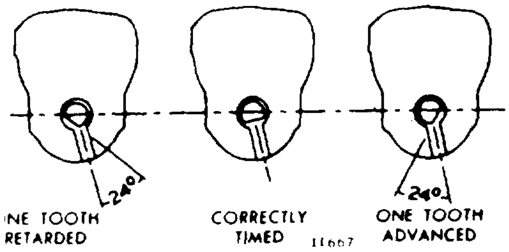


Figure 11C-76. Injector Rack-To-Gear Timing

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 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.

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 Figure 11C-77. 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 machine.

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.

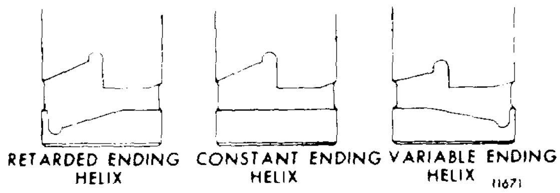


Figure 11C-77. Types of Injector Plungers

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 1.645" minimum as shown in Figure 11C-78 on page 11C-49. 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.

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.

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

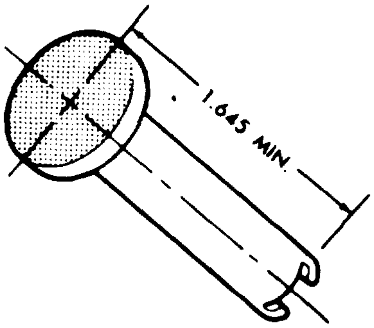


Figure 11C-78. Injector Follower

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 could 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 leaks 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.

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.

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.

Use one of the following methods to check for leaks:

1. Use when the engine has been operating 20-30 minutes

After operating the engine, shut it off and remove the rocker covers. Inspect the lube oil puddles that normally form where the fuel connector joins 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 suspected part (connector, washer, injector or jumper line). Test and reinspect.

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 above.

Block off the fuel return line and disconnect the fuel pump supply line at the secondary filter. Install a pressure gauge in the filter adaptor, then apply 60-80 psi (413-522 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 (276-553 kPa) for 20 to 30 minutes, a careful puddle inspection should reveal any suspected connectors. Inspect and repair or replace connector as necessary. Test and reinspect.

3. Use while engine is operating at 400-600 RPM.

Apply an outside fuel source capable of 60-80 psi (413-522 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, all injectors will leak to some extent when pressurized. The leakage occurs because there is no place else for the pressurize 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 described in 2 above. Injectors should be removed from the engine and tested for pressure holding capability.

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.

TROUBLESHOOTING

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 it 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 with 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 thoroughout 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.

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. (see Figure 11C-79 on page 11C-51).

2. Start and run the engine at 1200 RPM and measure the fuel flow. Refer to the

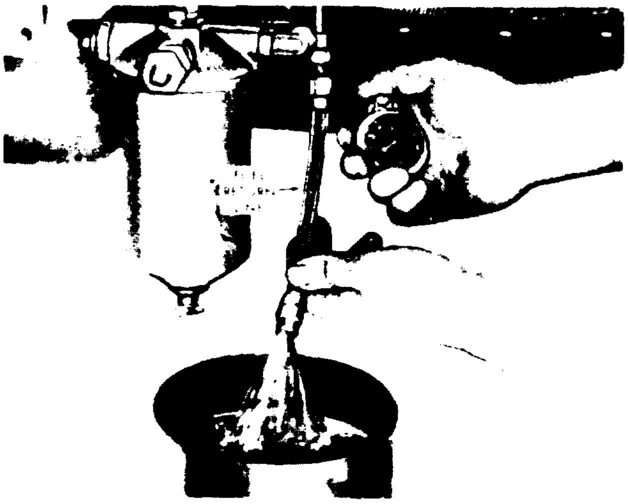


Figure 11C-79. Measuring Fuel Flow

end of Section 11A 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 the next step.

B. Replace the element in the fuel filter. If the flow is still unsatisfactory, perform the next step.

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.

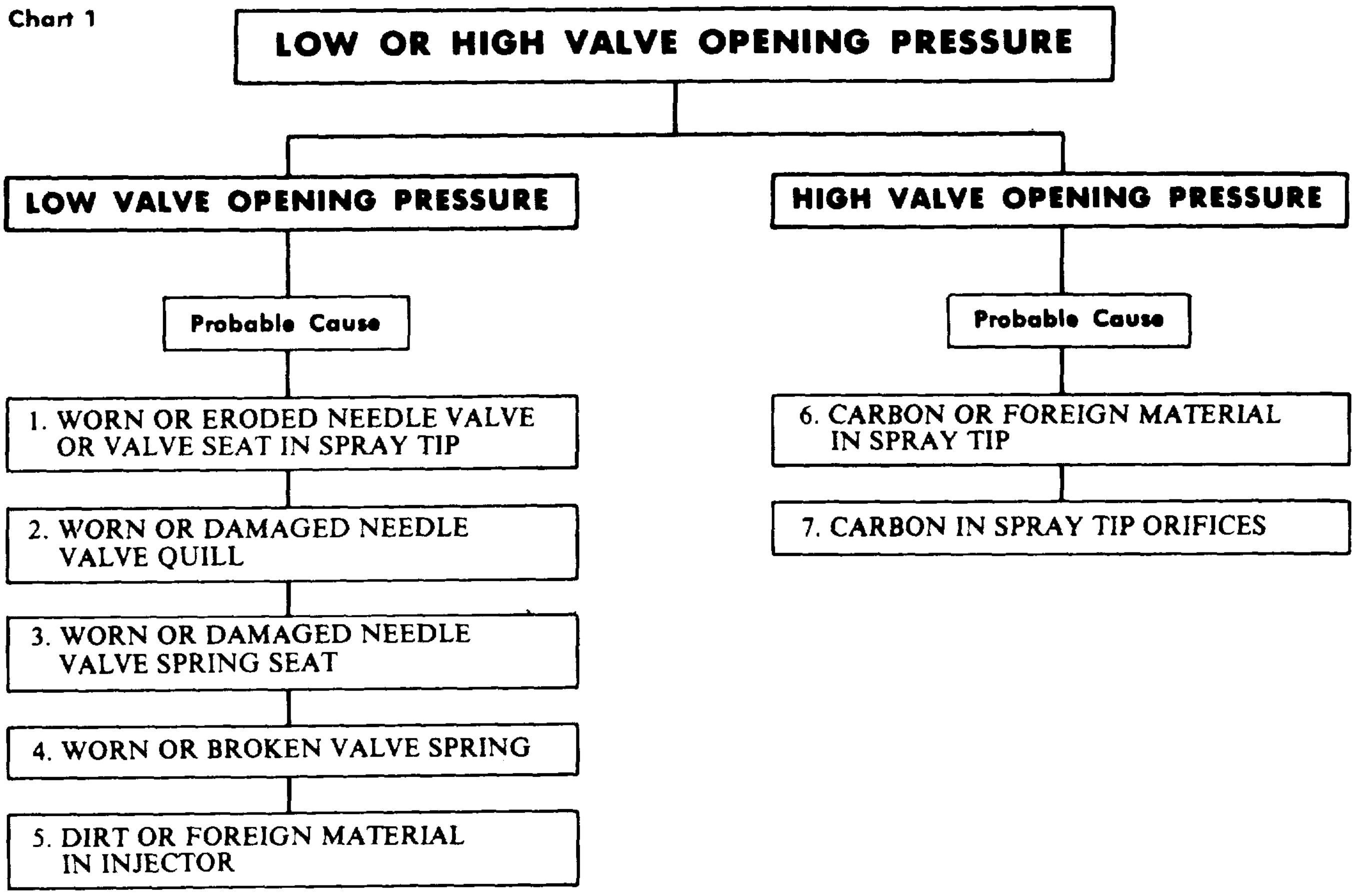
If the engine still does not perform satisfactorily, one or more tuel injectors may be at fault and may be checked as follows:

1. Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screw driver. 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.

Chart 1



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.

Chart 2

INSUFFICIENT INJECTOR HOLDING TIME

Probable Cause

1. POOR BUSHING TO BODY FIT
2. INJECTOR NUT NOT TIGHTENED TO SPECIFIED TORQUE
3. EXCESSIVE PLUNGER TO BUSHING CLEARANCE
4. CRACKED SPRAY TIP
5. WORN OR ERODED NEEDLE VALVE
6. WORN OR ERODED NEEDLE VALVE SEAT IN SPRAY TIP
7. WORN OR BROKEN NEEDLE VALVE QUILL
8. WORN OR BROKEN VALVE SPRING
9. WORN OR DAMAGED VALVE SPRING SEAT
10. DEFECTIVE SEAL RINGS
11. BODY PLUG LEAKS
12. FILTER GASKETS LEAK
13. POOR SEALING SURFACES ON FUEL FITTINGS
14. DIRT OR FOREIGN MATERIAL IN INJECTOR

SUGGESTED REMEDY

1. Lap the injector body.

2. Tighten the injector nut to 75-85 lb-ft (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 lb-ft (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

INCORRECT INJECTOR OUTPUT

Probable Cause

1. SPRAY TIP OR ORIFICES PARTIALLY PLUGGED
2. SPRAY TIP ORIFICES ENLARGED
3. CARBON BUILD-UP IN SPRAY TIP
4. WORN PLUNGER AND BUSHING
5. WORN OR DAMAGED NEEDLE VALVE QUILL
6. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
7. WORN OR BROKEN VALVE SPRING
8. CRACKED CHECK VALVE CAGE, SPRING CAGE OR SPRAY TIP
9. CRACKED BUSHING
10. IMPROPERLY LAPPED SURFACES
11. FOREIGN MATERIAL BETWEEN VALVE AND SEAT
12. RACK AND GEAR NOT IN TIME
13. SPRAY TIP - PLUNGER AND BUSHING COMBINATION PROVIDES INCORRECT OUTPUT

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 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.

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	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	928-342

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	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	1	No. 6 thru 1 1/2	60,000
None	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	7	1/4 thru 1 1/2	133,000
Bolts and Screws	8	1/4 thru 1 1/2	150,000
Bolts and Screws	None	No. 6 thru 1 1/2	55,000

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
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

*Lubricate before assembly.
†75-85 lb-ft (102-115 Nm) torque on the two bolts attaching load limit or power control screw bracket (if used) to the rocker arm shaft brackets.

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR	
Auxiliary injector tester	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 calibrator	J 22410
Injector nut seal ring installer	J 29197
Injector service set (includes *tools)	J 1241-07
Injector service set (includes §tools)	J 23435-02
*Deburring tool	J 7174
§*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
*Injector tip cleaner	J 1243-01
§*Pin vise	J 4298-1
§*Rack hole brush	J 8150
§*Spray tip carbon remover	J 24838
*Spray tip seat remover	J 4986-01
§*Spraytip wire (.005")	J 21459-01
§*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 23010
Injector tester modification package (J23010 only)	J 23010-194
Injector tip concentricity gage	J 29584
Injector vise and rack freeness tester	J 22396
Injector vise jaws (offset body)	J 8912
Lapping Block set	J 22090
Polishing compound	J 23038
Polishing stick set	J 22964
Spray tip flow gage	J 25600
Spray tip gage	J 9462-02
Spring tester	J 22738-02
Wire brush (brass)	J 7944
INJECTOR TUBE	
Cylinder head holding plates	J 3087-01
Injector protrusion gage	J 25521
Injector tube service tool set	J 22525
Injector tube service tool set (for power equipment)	J 22515
Injector tube swaging tool	J 28611-A

†Available in 5, 15, 30 and 55 gallons.

TOOL NAME	TOOL NO.
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
Elastic stop nut adjustment tool	J 28598-A
Governor cover bearing installer	J 21068
Governor cover baring remover/installer	J 21967-01
High-speed spring retainer nut wrench	J 1652-01
Variable speed spring housing bearing installer set	J 9196

TABLE OF CONTENTS

SUBSECTION 11D

AIR INTAKE SYSTEM

GENERAL

This subsection contains repair information on the blower and turbocharger.

DESCRIPTION

In the scavenging process employed in this engine, 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 Figure 11D-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 starts 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.

Turbopowering of the engine is accomplished by introducing a turbocharger in series with the blower of the air system as illustrated in Figure 11D-2 on page 11D-2. The expanding exhaust gases

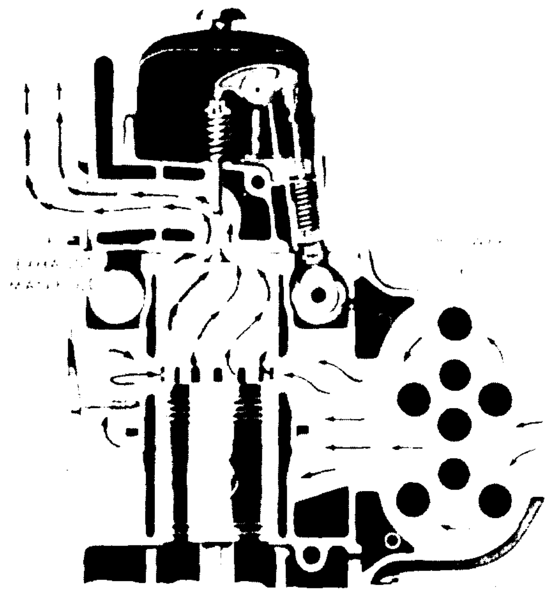


Figure 11D-1. Air Flow Through Blower and Engine

turn a single stage turbine wheel which drives an impeller thus supplying air under pressure to the blower. Even though the blower speed is reduced considerably through an additional pair of gears in the blower gear train, the air box pressure is nearly doubled by the increased flow of air and the result is freer breathing, quieter operation and more complete combustion and scavenging.

BLOWER

Description

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

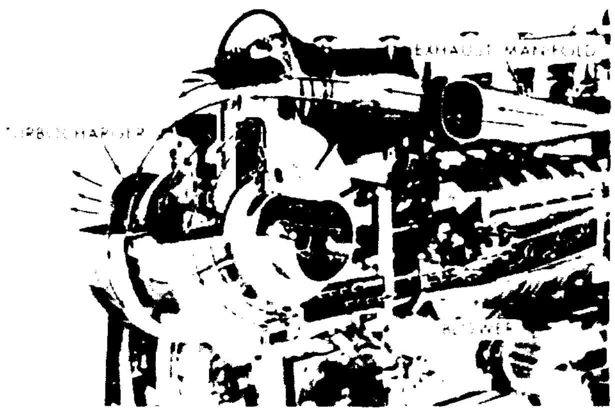


Figure 11D-2. Air Flow Through Turbocharger and Blower

lobe rotors revolves 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 (see Figure 11D-3 on page 11D-3).

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.

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, Figure 11D-3 on page 11D-3).

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), and prevent the transfer of torque fluctuations to the blower.

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 read 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 lobe and the trailing edge of the tower rotor lobes.

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 0.004", the gears must be replaced.

Lubrication

Oil drains from the valve operating mechanism on the cylinder head into the balance shaft pocket in the cylinder block; then, when it reaches a certain level, the oil flows from the pocket into the 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 read 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 driven gear.

Surplus oil overflows the dams in the end plates and returns through two drilled holes in the cylinder block in the engine crankcase.

Inspection of Blower

The blower may be inspected for any of the following conditions without being

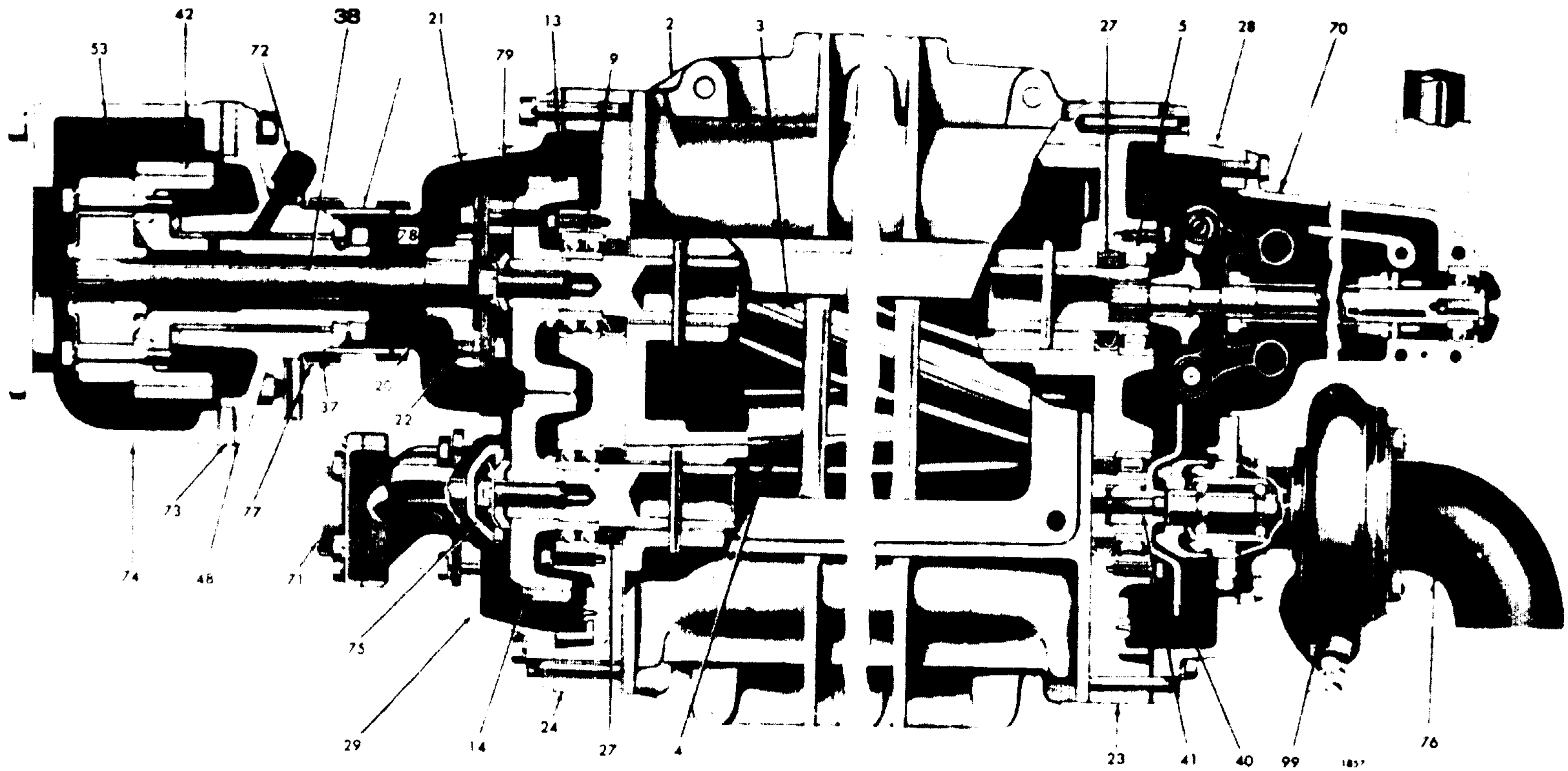


Figure 11D-3. Blower Assembly

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

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.

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 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.

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 bearing 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.

Inspect the blower inlet screen periodically, 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.

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 Figure 11D-4 on page 11D-5 and proceed as follows:

1. Drain the cooling system.

2. Remove the governor control housing assembly as outlined under "Remove Governor" in Subsection 11C.

3. Disconnect the fuel lines at the fuel pump.

4. Loosen the water pump connections at the pump cover and the cylinder block.

5. Loosen the turbocharger hose clamps and slide the hose and clamps back on the air inlet housing.

6. Remove the air inlet housing, gasket, striker plate and air inlet screen from the blower.

7. Remove the blower driver shaft as outlined in Subsection 11B.

8. Loosen the blower drive shaft cover seal clamp at the blower drive gear hub support.

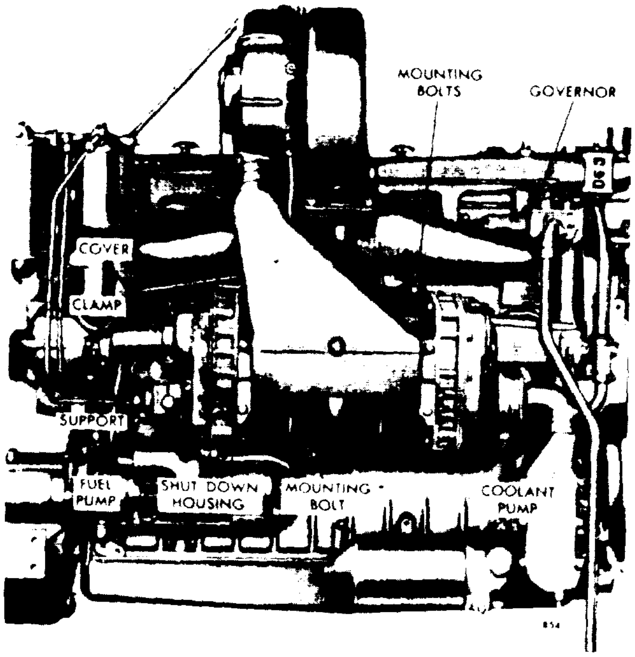


Figure 11D-4. Blower Mounting

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.

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. 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 water pump to the blower front end plate cover, then remove the water pump and asket. If necessary, tap the pump with a plastic hammer to loosen it.

4. Remove the six bolts and seal washer assemblies securing the governor weight housing to the blower front end plate cover, then remove the weight housing and gasket.

Disassemble Blower

Refer to Figure 11D-3 on page 11D-3 and Figure 11D-11 on page 11D-8 and disassemble the blower as follows:

1. Remove the ten bolts and lock washers 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 Figure 11D-5.

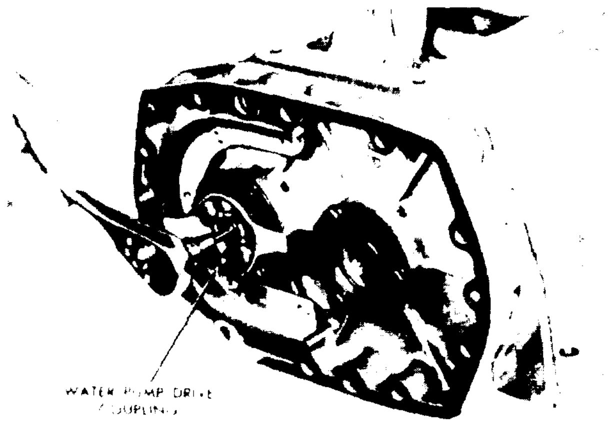


Figure 11D-5. Removing Water Pump Drive

3. Thread adaptor J 6471-4 (1/2"-20 threads) or adaptor J 6471-10 (9/16"-18) into the water pump drive coupling, then attach slide hammer and shaft J 2619-5 to the adaptor and pull the drive coupling from the blower rotor shaft.

4. Remove bolts (21), lock washers and plain washers securing blower rotor drive hub (20) and driven hub plate (115) to blower rotor timing gear (13) or drive gear (140). Then remove the drive hub plates and spacer (116) from the gear. If necessary, remove three bolts (22), lock washers and plain washers securing the drive plates to the drive hub.

5. Remove the blower rotor timing gears as follows:

A. Remove bolt, lock washer and retainer securing the timing gear, to the right hand helix rotor shaft. Then remove the bolt, lock washer 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 time.

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 (see Figure 11D-6).

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.

Figure 11D-6. Removing Blower Rotor Gears

6. Remove the bolts and lock washers securing rotor shaft bearing retainer (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 two fillister head screws (26) securing rear end plate (24) to the blower housing. Loosen the two fillister head screws securing front end plate (23) to the housing approximately three turns.

B. Back out the center screw of the pullers 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" x 1-1/4" 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 Figure 11D-7.

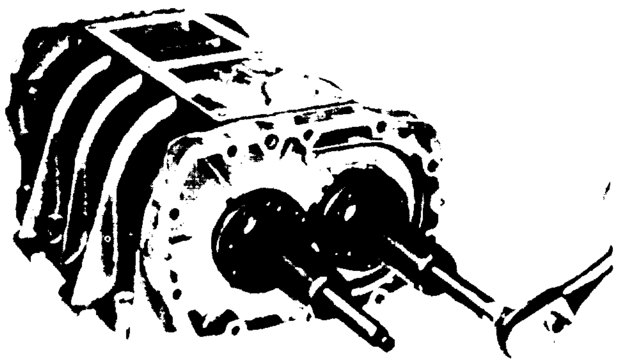


Figure 11D-7. Removing Blower End Plate

8. Remove the blower front end plate in the same manner as described above.

9. Withdraw the blower rotors from the housing.

10. Remove the bearings and ring type oil seals, carriers and collars from the blower rotor shaft and end plates as follows:

A. Clamp one lobe of the rotor in a bench vise equipped with soft jaws (see Figure 11D-8 on page 11D-7). Tighten the vise just enough to hold the rotor stationary.

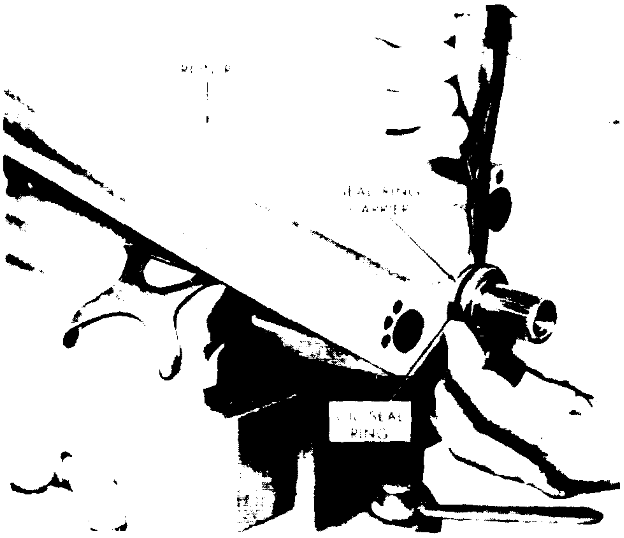


Figure 11D-8. Removing Oil Seal Ring from Carrier

B. Remove the oil seal ring from the seal ring carrier on each blower rotor with a pair of snap ring pliers J 4880 as shown in Figure 11D-8.

C. Refer to Figure 11D-9 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.

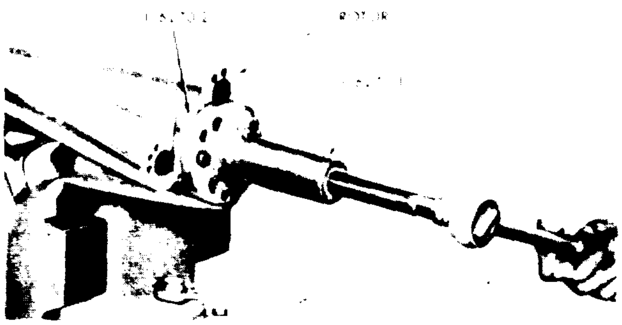


Figure 11D-9. Removing Oil Seal Ring Carrier

D. Back out the center screw of puller J 6270-1 far enough to permit the puller flange to lay flat against 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. Then secure the puller to the adaptor with two bolts.

F. Turn the puller screw clockwise and pull the oil seal carrier from the rotor shaft (see Figure 11D-9).

G. Remove the remaining oil seal ring carriers from the rotor shafts in the same manner.

H. Refer to Figure 11D-10 and support the outer face of the blower end plate on wood blocks on the bed of an arbor press.

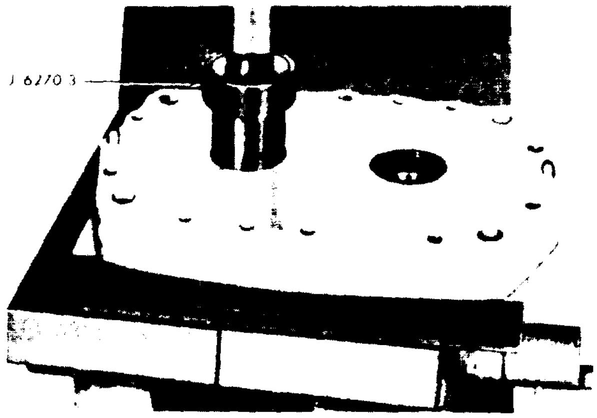


Figure 11D-10. Removing Seal Ring and Bearing from End Plate

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. 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.

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 bearing with light engine oil. Then while hold 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 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 seals 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 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.

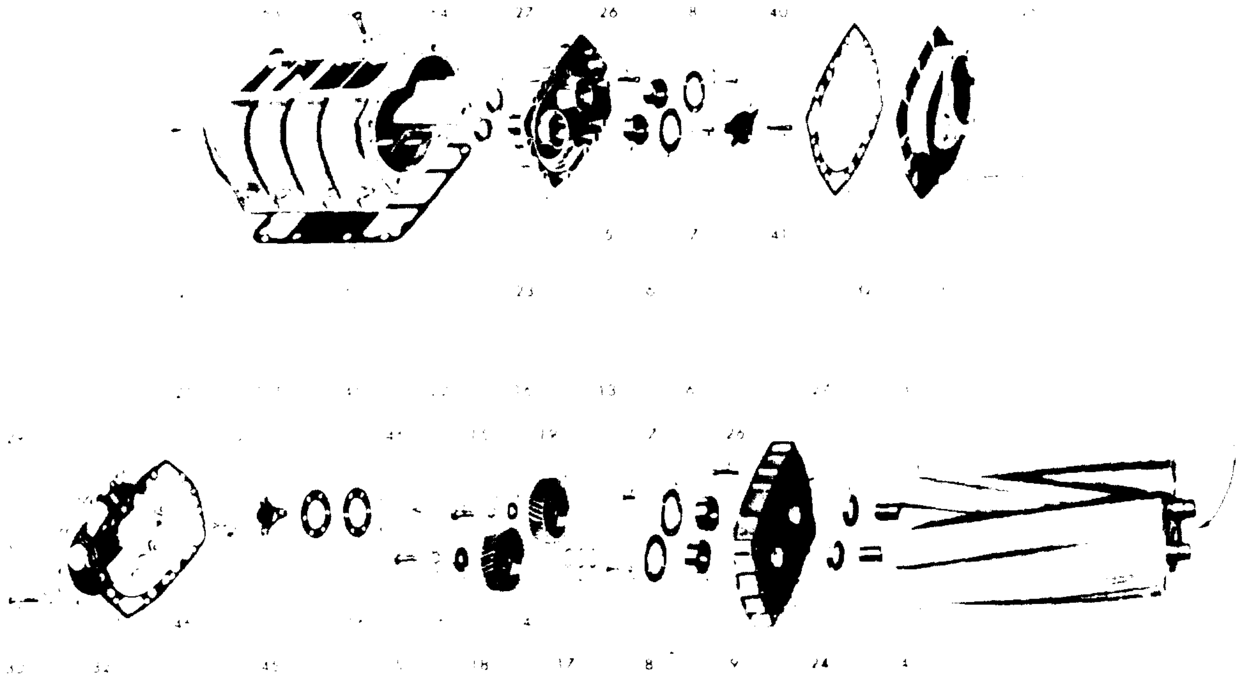
Examine the rotor shaft serrations for wear, burrs, or peening. Also, inspect the bearings and oil seal contact surfaces for wear and scoring.

inspect the inside surface of the blower housing for burrs and scoring. The inside surface must be smooth for efficient operation of the blower. 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 lower 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 0.004", or damaged



2. Housing--Blower
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. Lock Washer
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. Lock Washer--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. Lock Washer
32. Gasket--End Plate Cover
40. Coupling Assy.--Water Pump Drive
41. Bolt--Allen Head
45. Plain Washer
46. Lock Washer
63. Bolt--Blower Mounting
64. Plain Washer--Blower Mounting
65. Gasket--Blower Housing
115. Plate--Blower Rotor Drive Hub
116. Spacer--Plate to Gear

Figure 11D-11. Blower Details

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 cam for wear.

Replace all worn or excessively damaged blower parts.

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 blower rotor and gear form a left hand helix. Therefore, a rotor with a right hand helix lobe must be used with a gear having a right hand helix teeth and vice versa (see Figure 11D-12).

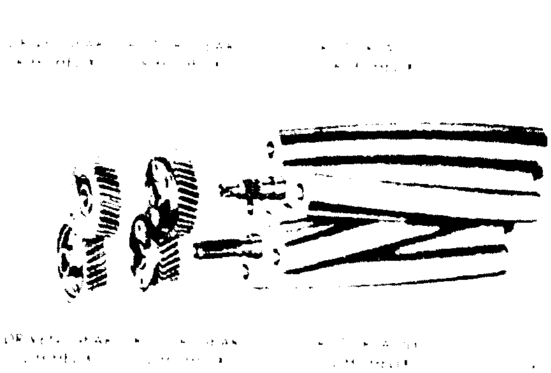


Figure 11D-12. Upper and Lower Rotors and Gears

With this precaution in mind, proceed with blower assembly.

1. 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 Figure 11D-14 on page 11D-10.

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.

CAUTION

To avoid breaking the oil seal rings, do not spread them more than necessary to place them over the end of the carrier.

E. Support one of the blower end plates, inner face up, on wood blocks on the bed of an arbor press as shown in Figure 11D-13.

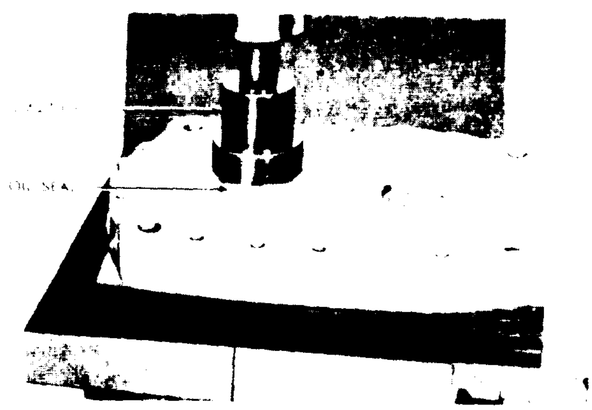


Figure 11D-13. Installing Seal Ring Collar

F. 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.

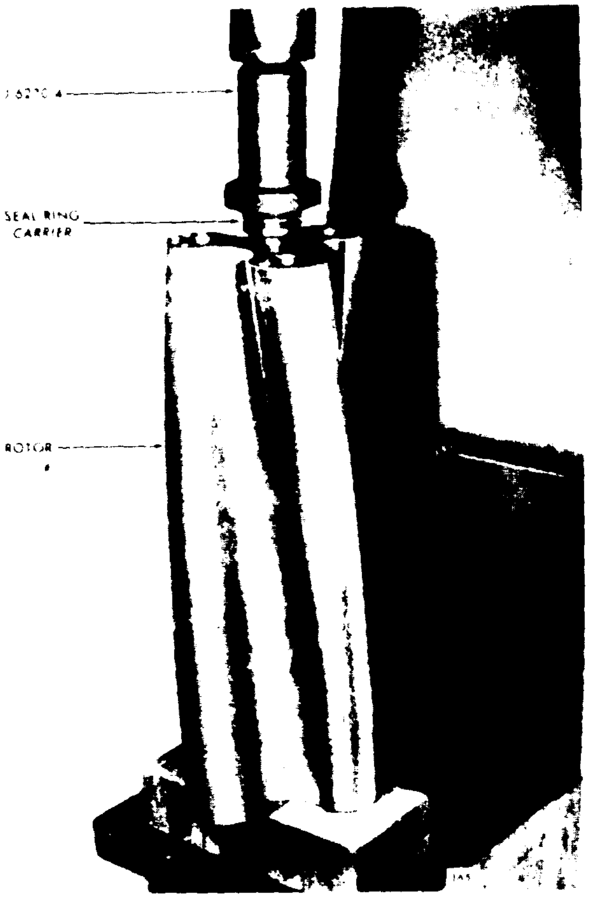


Figure 11D-14. Installing Oil Seal Ring Carrier on Blower Rotor

G. 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 Figure 11D-13 on page 11D-9. 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 0.005" below the finished face of the end plate. This is within the 0.002" to 0.008" specified.

H. Install the remaining oil seal ring collar in the end plates in the same manner.

Assemble Rotors and End Plates

Note that no gaskets are used between the end plates and the housing. Therfore, the mating surfaces must be perfectly flat and smooth.

1. 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.

2. Install the blower rotors in the blower rear end plate as outlined below:

NOTE

The front and rear blower end plates are interchangeable.

A. Check the dowel pins. The dowel pins must project 0.380" from the flat inner face, and 0.270" 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 (see Figure 11D-15 on page 11D-11).

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 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 (see Figure 11D-15 on page 11D-11). Continue to lower the rotor and very

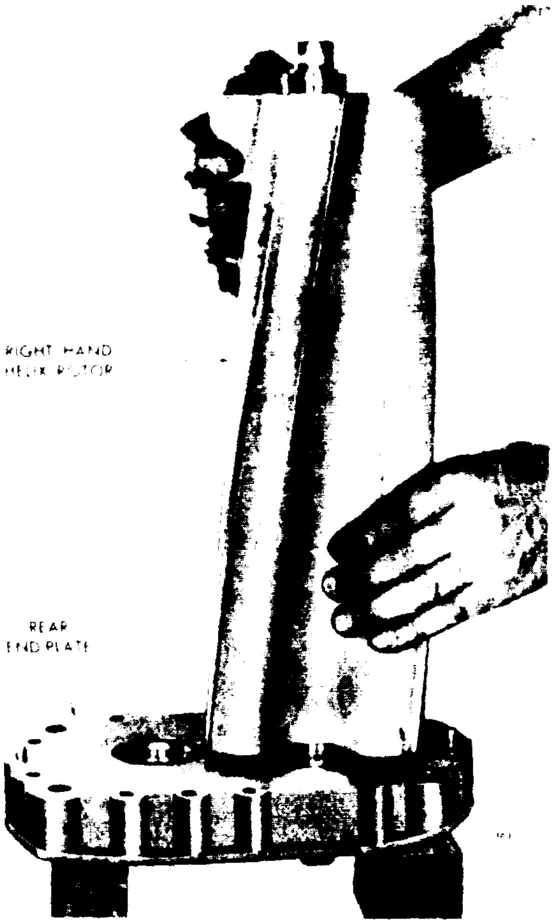


Figure 11D-15. Installing Blower Rotor in Rear End Plate

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. Repeat 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.

3. 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.

4. Install the blower front end plate on the rotors and housing as follows:

A. Check the dowel pins. The dowel pins must project 0.380" from the flat inner face, and 0.270" 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.

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 Figure 11D-16 on page 11D-12.

E. Lower the end plate straight over the rotor shaft until the dowel pins in the end plate contact the blower housing. 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 lb-ft (7-14 Nm) torque. Do not use lock washers on these screws.

Installer 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 bearings on the rotor shafts and in the front end plate as follows:

A. Lubricate one of the roller bearings with engine oil. Start the bearing,

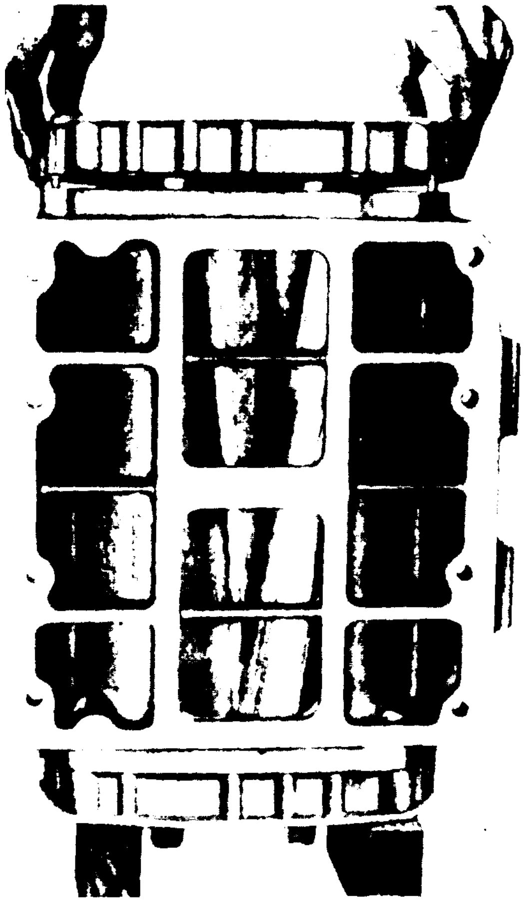


Figure 11D-16. Installing Front End Plate

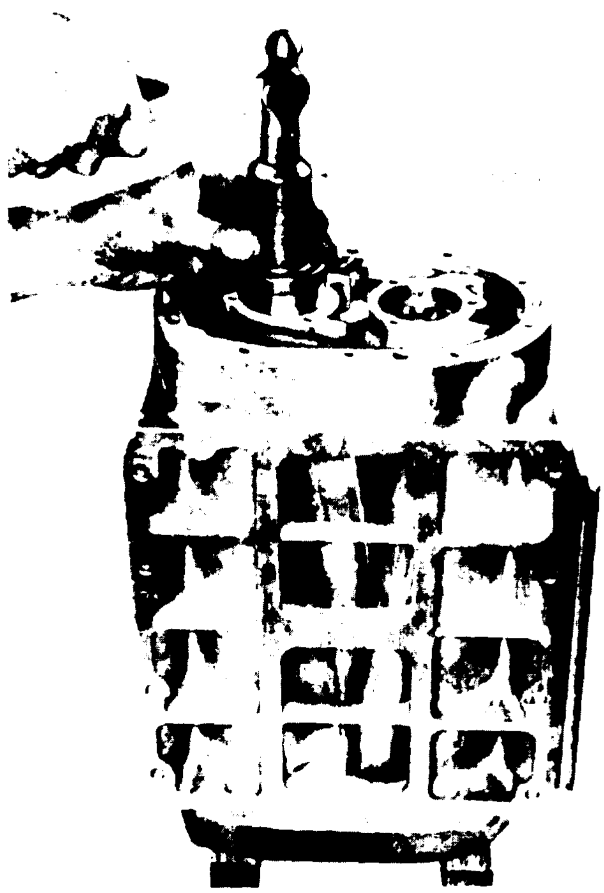


Figure 11D-17. Installing Bearings in End Plate

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 Figure 11D-17.

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 lock washers. Tighten the bolts to 7-9 lb-ft (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 lb-ft (24 Nm) torque.

3. Affix a new gasket (32) to blower front end plate cover (38).

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 lock washers. Tighten the bolts to 13-17 lb-ft (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 (see Figure 11D-18 on page 11D-13).

B. Insert the two fillister head screws through the rear end plate and thread them into the housing. Tighten the screws to 5-10 lb-ft (7-14 Nm) torque. Do not use lock washers 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 the shaft and into the rear end plate as shown in Figure 11D-18 on page 11D-13.

E. Install the second ball bearing on the remaining rotor shaft in the same manner.

F. Place the bearing retainers on top of the bearing and end plate. Then install the retainer bolts and lock washers. Tighten the bolts to 7-9 lb-ft (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 Figure 11D-23 on page 11D-16. Refer to Figure 11D-21 on page 11D-15 for minimum blower clearances.

7. Install the blower rotor timing gears as follows:

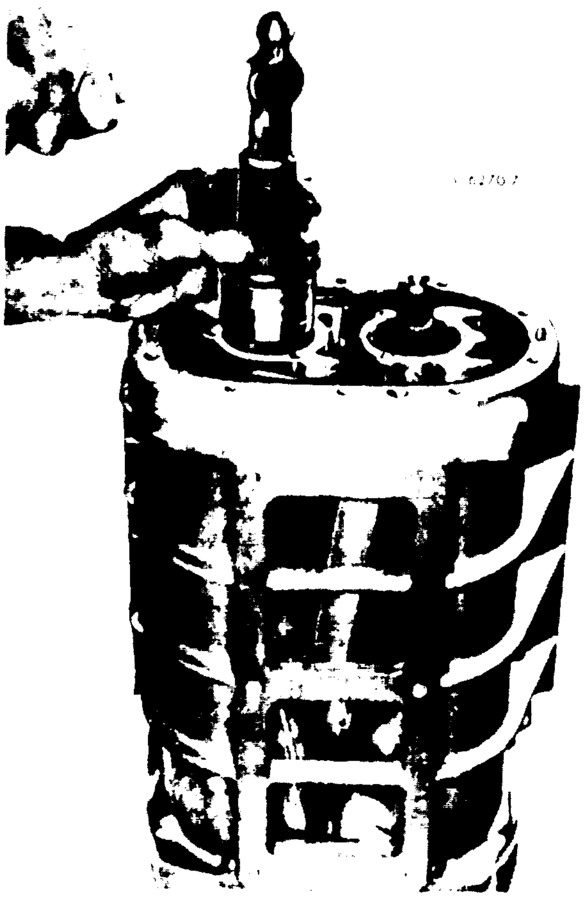


Figure 11D-18. Installing Ball Bearings on Rotor Shaft

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 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 and facing the top of the blower housing (see Figure 11D-22 on page 11D-16).

C. Install the same number and thickness of shims on the rotor shafts that were removed at the time of disassembly.

NOTE

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 (see Figure 11D-22 on page 11D-16).

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 (see Figure 11D-19).

Figure 11D-19. Installing Rotor Gears on Rotor Shaft

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 Figure 11D-19 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 lock washer (16) and 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 slot 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 lb-ft (75-88 Nm) torque.

K. Place a lock washer (16) and 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 lock washer over into the slot in the disc. Tighten the gear retaining bolt to 55-65 lb-ft (75-88 Nm) torque.

L. Bend one of the tangs of each lock washer over against the head of the gear retaining bolt. Remove the cloth from the blower rotors.

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 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 Figure 11D-20 on page 11D-15. When measuring clearances of more than 0.005", laminated feeler gauges that are made up of 0.002", 0.003" or 0./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 rotors as follows:

1. Time the rotors to have 0.002" to 0.006" clearance between the TRAILING

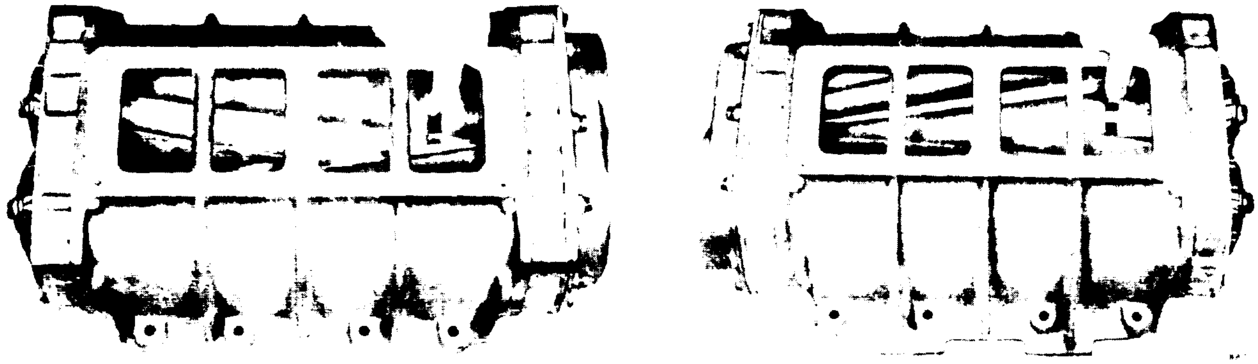
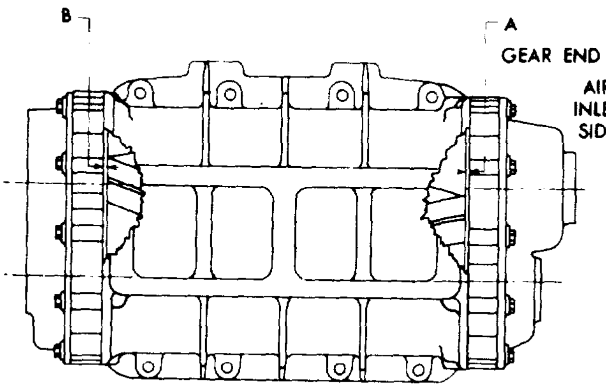
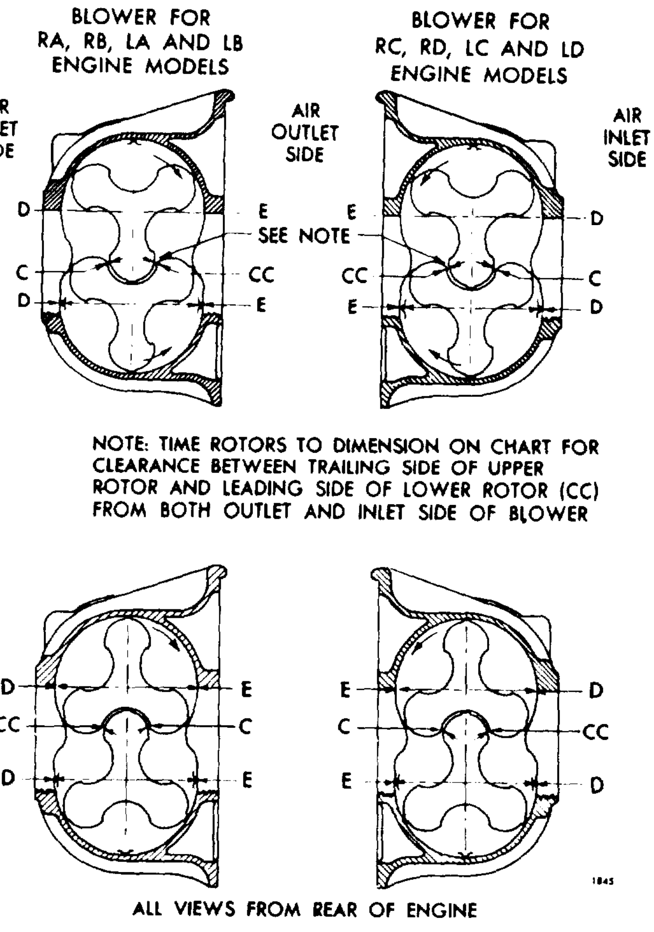


Figure 11D-20. Measuring "CC" and "C" Clearances Between Blower Lobes

edge of the UPPER rotor and LEADING edge of the LOWER rotor (“CC” clearance) measured from both the inlet and outlet sides. If possible, keep this clearance to the minimum (0.002"). Then check the clearance between the LEADING edge of the UPPER and the TRAILING edge of the LOWER rotors ("C" clearance) for the minimum clearances shown in Figure 11D-21. 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 Figure 11D-22 on page 11D-16 to produce the desired result. When more or less shims are required, both gears must be removed from the rotors. Placing a 0.003" shim in





		A	B	C	CC	D	E
4-71	MIN.	.007	.009	.012	.002	.015	.004
	MAX.				.006		

TIME ROTORS TO DIMENSIONS ABOVE

Figure 11D-21. Chart of Minimum Clearances back of a rotor will revolve the rotor 0.001".

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 clearance between the rotor lobes.

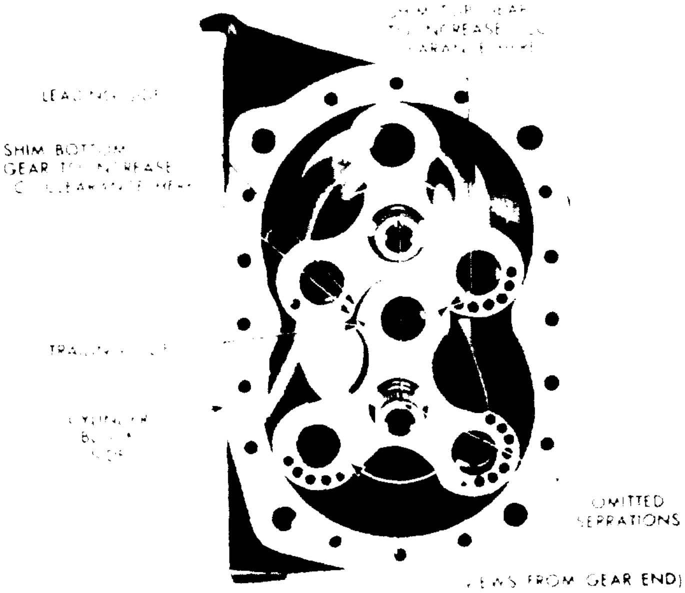


Figure 11D-22. Shim Locations for Correct Lobe Clearances

4. Determine the minimum clearances at point "A" and "B" shown in Figure 11D-21 on page 11D-15 Insert the feeler gauges, as shown in Figure 11D-23, between the end plates and the ends of the rotors. This operation must be performed at the ends of each lobe, making twelve measurements in all. See Figure 11D-21 on page 11D-15 for the minimum clearances.

5. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side- twelve measurement in all. See Figure 11D-21 on page 11D-15 for the minimum clearances.

After the blower rotors are timed, complete the assembly of the blower as follows:

1. Refer to Figure 11D-11 on page 11D-8 and attach blower rotor drive hub (20) and drive hub plates (115) to the blower gears as follows:

Figure 11D-23. Measuring End Clearance

A. If removed, attach rotor drive hub plates (115) to drive hub (20) with three bolts (22), lock washers and plain washers. Tighten the bolts to 25-30 lb-ft (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), lock washers, plain washers and three spacers (116) and bearing retainers (117) between the plates and the face of the gear. Tighten the bolts to 25-30 lb-ft (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 0.020" total indicator reading.

2. Affix a new gasket (32) to blower rear end plate (29).

3. Position the end plate cover over the end plate dowel pins. Then push the cover against the end plate. Install the ten bolts and lock washers. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

Attach Accessories to Blower

Refer to Figure 11D-3 on page 11D-3 and attach the fuel pump, water pump, blower drive shaft cover and governor weight housing as follows:

1. Attach the fuel pump to the blower as outlined under “Attach Fuel Pump to Blower" in Subsection 11C.

2. Attach the water pump to the blower as outlined under "Install Water Pump" in Subsection 11F.

3. Attach the governor weight housing to the blower as outlined under "Install Governor" in Subsection 11C.

4. Attach blower drive shaft cover (33) to blower rear end plate cover (29) with cover seal (37) and seal clamp (114) as shown in Figure 11D-3 on page 11D-3.

Attach Blower to Engine

Refer to Figure 11D-4 on page 11D-5 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 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 lb-ft (75-81 Nm) torque.

6. Slide blower drive shaft cover seal (37) into position against the blower drive gear hub support and tighten the seal clamp.

7. Install blower drive shaft (38) by pushing the plain end, without squared hole, or 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 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 over to the oil cooler housing.

10. Place the blower air shutdown housing, together with the strike plate gasket, strike plate (if used) 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 lock washers. Tighten the bolts to 16-20 lb-ft (22-27 Nm) torque.

11. Install the governor control housing assembly as outlined under "Install Governor" in Subsection 11C.

12. Connect the fuel lines to the fuel pump.

13. Slide the turbocharger hose into position on the air inlet housing and turbocharger (Figure 11D-4 on page 11D-5) and secure it in place with hose clamps.

14. 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.

TURBOCHARGER

Description

The turbocharger (Figure 11D-24 on page 11D-18 and Figure 11D-25 on page 11D-18) is designed to increase the overall 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, a turbine housing and a 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.

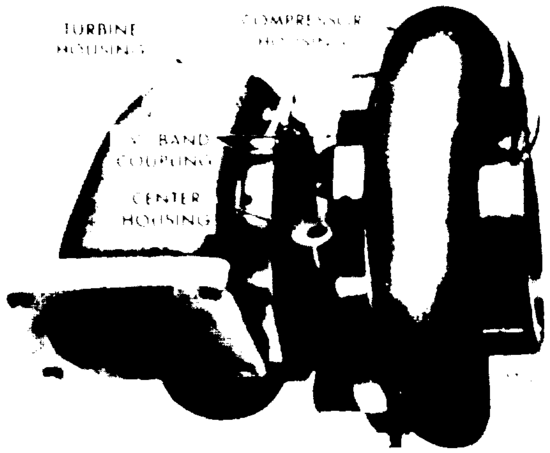


Figure 11D-24. Turbocharger Assembly

The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer, 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, thrust washer, thrust collar and thrust spacer.

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 compressor end of the center housing backplate assembly with a "V" band coupling.

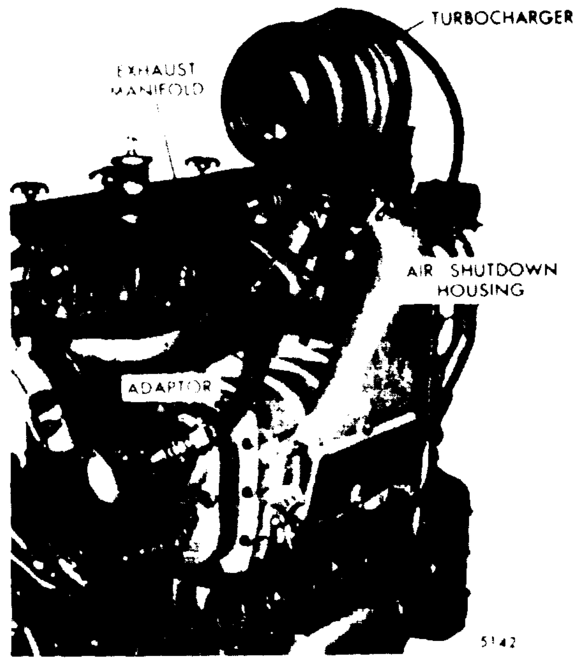


Figure 11D-25. Turbocharger Mounting

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 (see Figure 11D-26 on page 11D-19). 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.

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an ex-

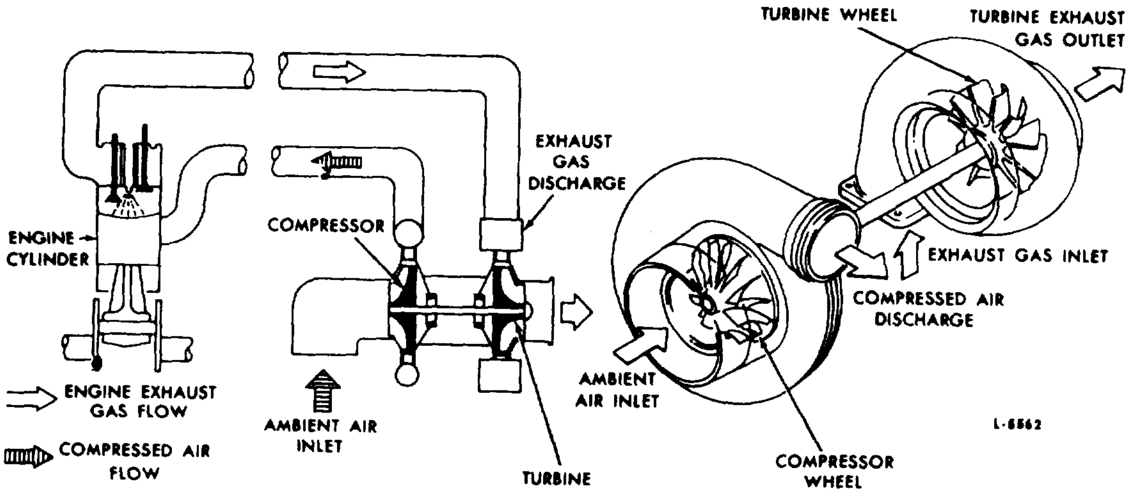


Figure 11D-26. Schematic Air Flow Diagram

ternal 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, thrust ring, thrust bearing and backplate or thrust plate (see Figure 11D-28 on page 11D-20). 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.

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be prelubricated as outlined under "Install Turbocharger" on page 11D-28.

NOTE

> Failure to perform the prelubrication procedure may result in premature bearing failure due to oil lag" or lack of lubrication.

Periodic Inspection

NOTE

> A turbocharger compressor inlet shield J 26554 (Figure 11D-27) is available for use anytime the engine is operated with the air inlet piping removed. The shield helps to prevent foreign objects from entering the turbocharger and prevents a serviceman from touching the moving impeller. The use of this shield does not preclude any other safety practices contained in this manual.

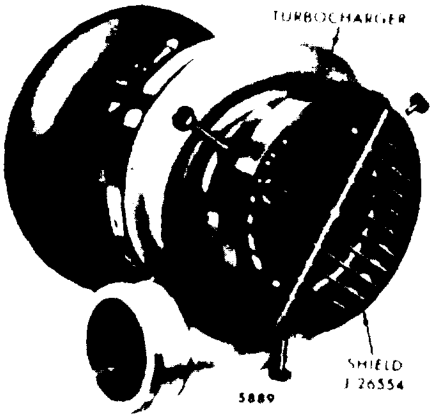


Figure 11D-27. Inlet Shield

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 (see Subsection 11A).

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 shutdown. Check for leaks at the manifold connections, the turbine inlet and exhaust manifold gasket.

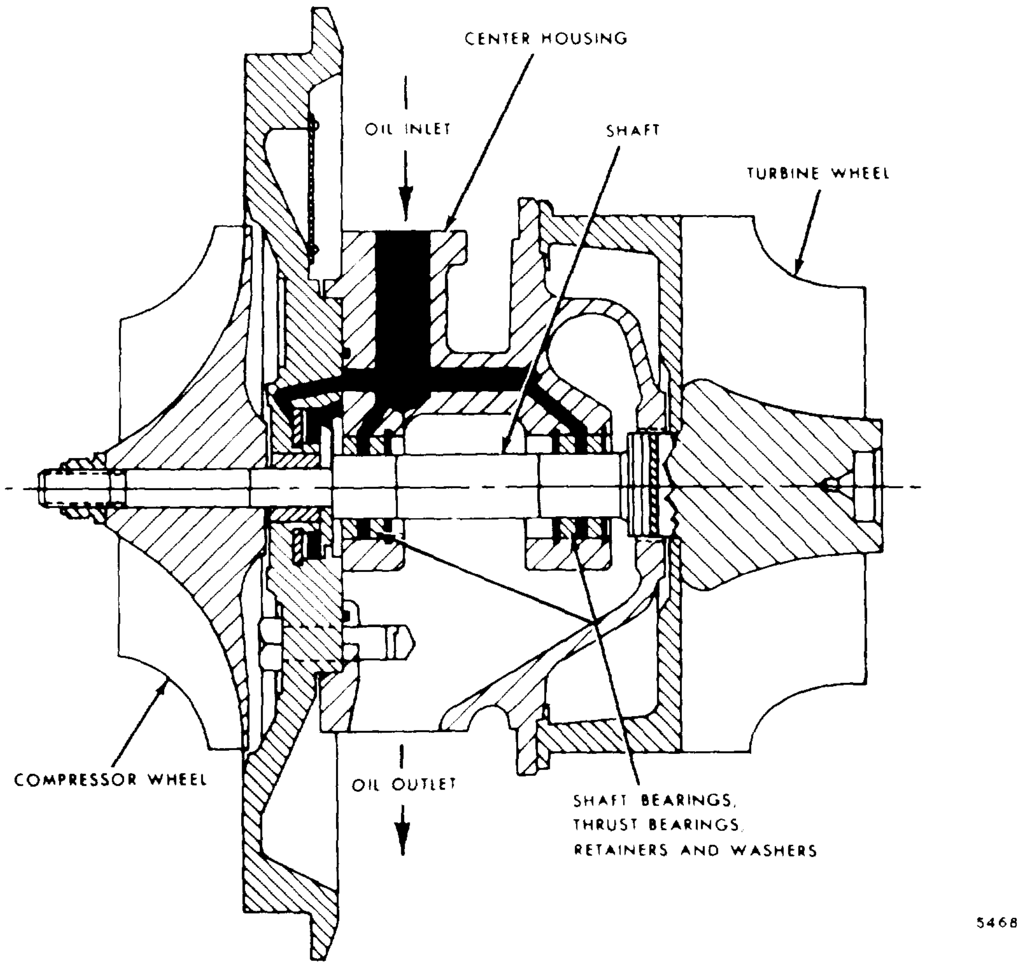


Figure 11D-28. Turbocharger Oil Flow Diagram

NOTE

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.

Remove the 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, Specifications & Service Tools” on page 11D-31. Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

NOTE

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 unbalance condition would exist and subsequent failure of the bearings would result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt or 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 Figure 11D-29 on page 11D-21. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or

TROUBLE SHOOTING CHARTS

CHART 1

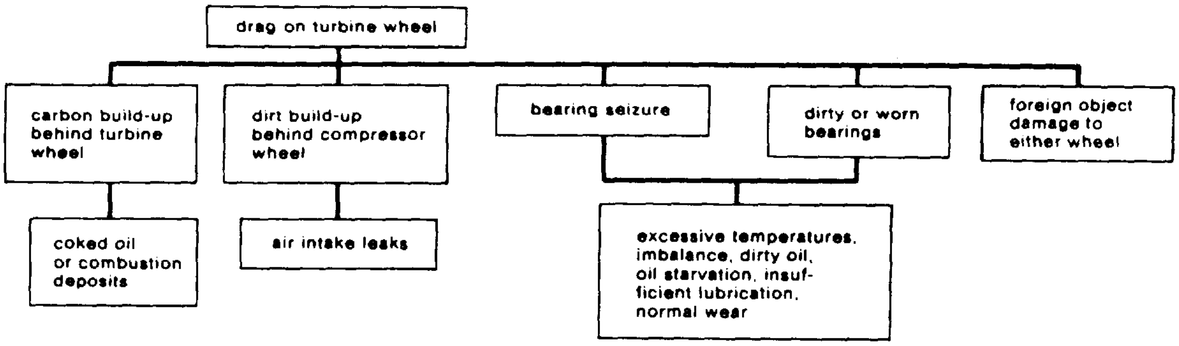


CHART 2

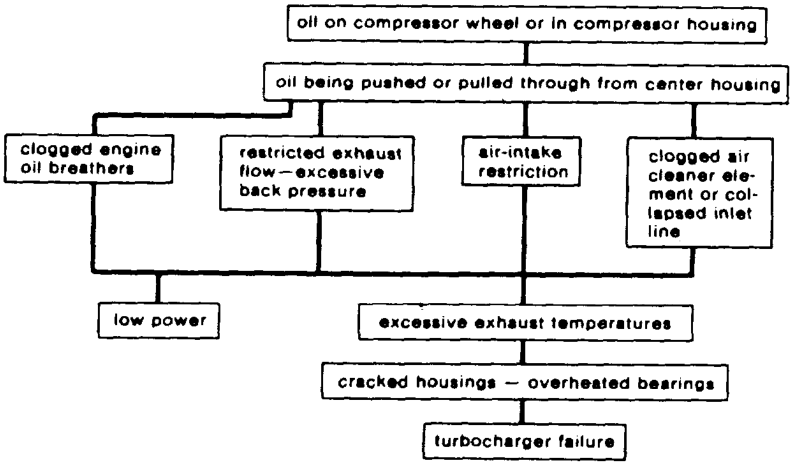


CHART 3

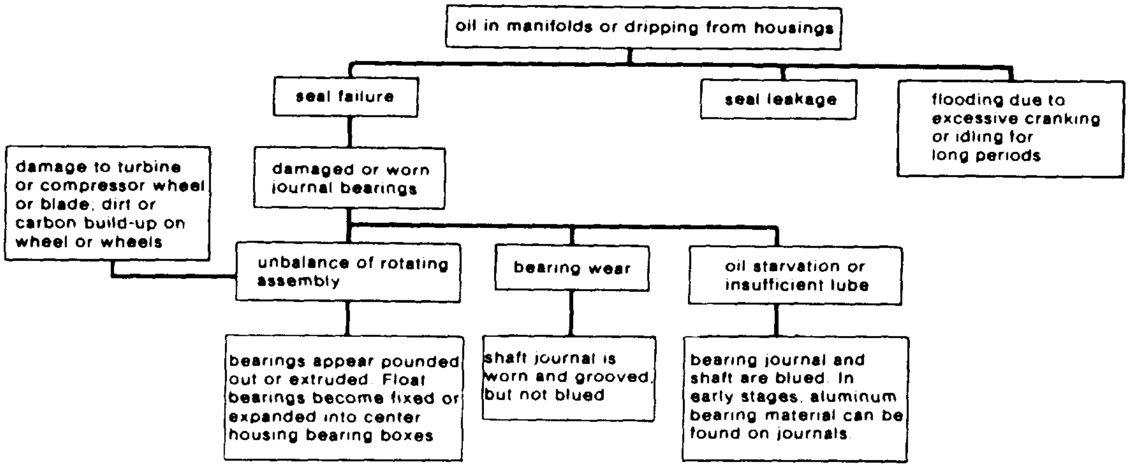


Figure 11D-29. Inspection Checks for Turbocharger bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

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.

NOTE

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 Figure 11D-29 on page 11D-21.

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.

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.). 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 all 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 Subsection 11A.

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 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 a leak near an oil source as an engine breather, etc.

5. Remove the compressor housing from the turbocharger.

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 the 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.

Remove Turbocharger

1. Disconnect the exhaust manifold adaptor attached to the turbine housing.

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 turbocharger 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.

Disassemble Turbocharger

Clean the exterior of the turbocharger with 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 reassembly in the same relative position.

1. Refer to Figure 11D-30 on page 11D-24 and loosen "V" band coupling (1) securing compressor housing (2) to backplate assembly (14) and remove the compressor housing and "V" band.

NOTE

Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. Loosen "V" band coupling (28) securing turbine housing (6) to 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 turbine wheel (9) of the center housing assembly in a suitable holding fixture (see Figure 11D-31 on page 11D-25). Remove wheel nut (7) from the shaft.

NOTE

If a holding fixture is not available, clamp a suitable socket or box 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.

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. Press compressor wheel (8) from wheel shaft assembly (9).

5. Withdraw wheel shaft assembly (9) from the center housing. Wheel shroud (10), which is not retained, will fall free when the wheel shaft is removed.

6. Remove and discard turbine piston ring (11) from the wheel shaft.

7. Bend down the lock tabs and remove the four bolts (12) and lock plates (13) securing backplate assembly (14) to center housing (27) and remove backplate assembly.

1. Coupling--"V" Band	8. Wheel--Compressor	14. Backplate Assembly	21. Washer--Bearing
2. Housing--Compressor	9. Shaft--Turbine Wheel Assembly	15. Ring--Seal	22. Ring--Snap
3. Bolt	10. Shroud--Turbine Wheel	16. Spacer--Thrust	23. Ring--Snap
4. Lockplate	11. Ring--Piston	17. Ring--Piston	24. Bearing
5. Clamp--Turbine Housing	12. Screw	18. Collar--Thrust	25. Washer--Bearing
6. Housing--Turbine	13. Lockplate	19. Washer--Inboard Thrust	26. Ring--Snap
7. Nut--Self-Locking		20. Bearing	27. Housing--Center

Figure 11D-30. Turbocharger Details

NOTE

Tap the backplate lightly to remove it from the center housing recess.

8. Remove and discard seal ring (15) from the groove in the center housing.

9. Remove thrust spacer (16) and piston ring(s) (17) from the backplate assembly. discard the piston ring(s).

10. Remove thrust collar (18), inboard thrust washer (19), bearing (20), bearing washer (21) and snap ring (22) from the center housing. Discard the thrust washer, bearing, washer and snap ring.

11. Remove snap ring (23), bearing (24), bearing washer (25) and snap ring (26) from the opposite end of the center housing. Discard the snap rings, bearing and washers.

Cleaning

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. Keep away from open flames. Do not use a wire brush or steel blade scraper to clean 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 center housing thrust plate with dry compressed air.

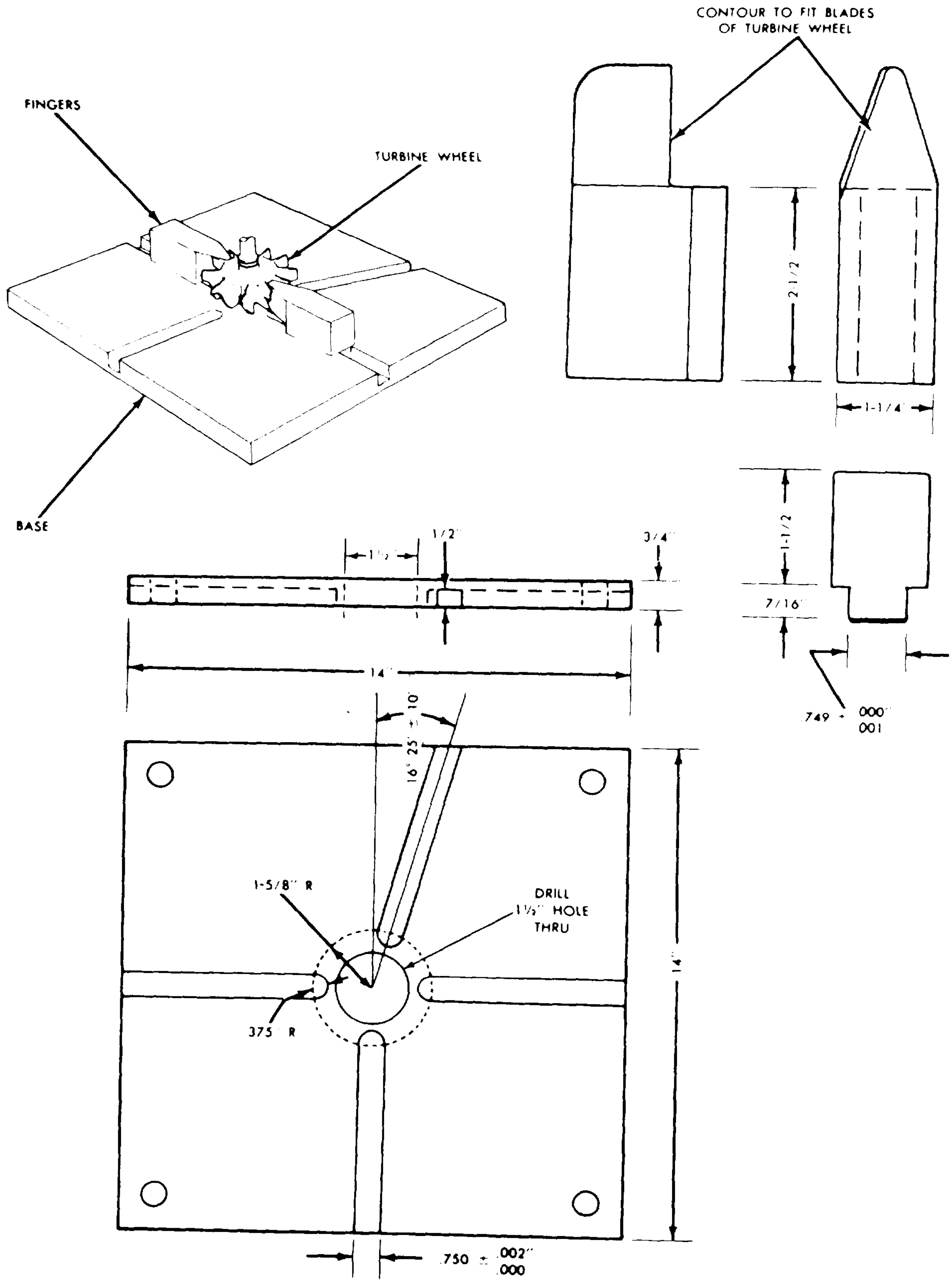


Figure 11D-31. Turbocharger Holding Fixture

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.

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 for signs of rubbing or wear. For shaft bearing journal dimensions and wear limits, refer to "Specifications" on page 11D-32.

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 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.

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 piston ring(s), thrust washers, bearing, bearing washers and snap rings be replaced at time of disassembly.

Inspect the exhaust outlet elbow seal ring for signs of wear or breakage.

Assemble 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 Figure 11D-30 on page 11D-24 for parts orientation and proceed as follows:

1. Lubricate 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 center housing (27).

3. Install a new snap ring (22), bearing washer (21) and bearing in the compressor end of the center housing.

NOTE

Install the inboard thrust bearing (three oil grooves) with the smooth side against the center housing.

4. Install a new piston ring(s) (17) on thrust spacer (16) and gently insert the spacer into backplate assembly (14).

CAUTION

Do not force the piston rings into place.

5. Make sure the compressor bearing is in place, then position the new inboard thrust bearing (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 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 and the backplate assembly and attach the backplate to the center housing with four bolts (12) and new lockplate (13). Tighten the bolts to 80-100 lb-in (9-11 Nm) torque and bend the lockplate tangs up against the side of the bolt heads.

NOTE

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 piston ring (11) on the turbine 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 wheel shroud (10) against the center housing and insert wheel shaft assembly (9) through the wheel shroud and into the center housing.

NOTE

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 upright in a suitable holding fixture as shown in Figure 11D-31 on page 11D-25.

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 engine oil and install the retaining nut. Tighten the nut to 125-150 lb-in (14-17 Nm) torque to seat the compressor wheel against the thrust spacer.

14. Loosen the nut and inspect the nut face and front face of the compressor wheel to be sure they are smooth and clean.

15. Retighten the nut to 35-55 lb-in (4-6 Nm) torque.

16. Continue to tighten the retaining nut until the shaft increases in length 0.009"-0.010".

NOTE

Tighten the nut in such a manner as not to impose bending loads on the shafts.

If equipment is not available to measure the shaft stretch, tighten the wheel retaining nut to 35-55 lb-in (4-6 Nm) torque. Then continue to tighten the nut through an angle of 120-130°.

17. Check the bearing axial end play:

A. Clamp the center housing in a bench vise equipped with soft jaws as shown in Figure 11D-32.

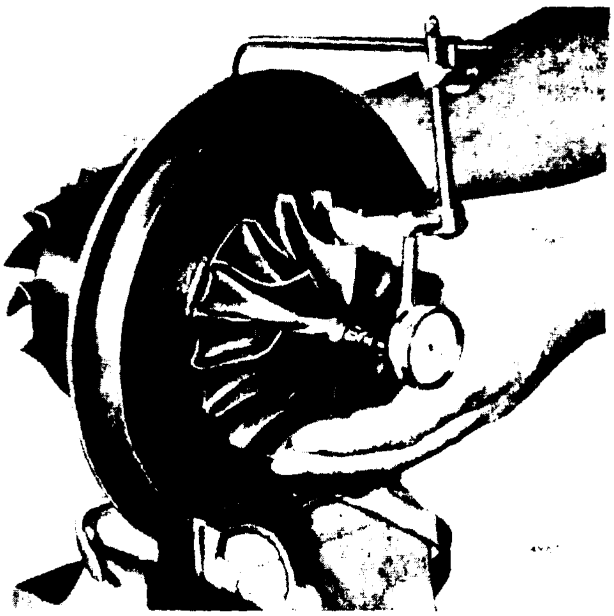


Figure 11D-32. Checking Bearing Axial End Play

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 (see Figure 11D-33 on page 11D-28).

Figure 11D-33. Checking Shaft Radial Movement

C. Move the shaft axially back and forth by hand. Total indicator reading (thrust float) should be between 0.003" and 0.010". If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

18. Position turbine housing (6) as marked at disassembly against the center housing and secure it in place.

19. Secure the turbine housing with “V” band coupling (28). Tighten the toggle nut as follows:

A. Lubricate the toggle bolt threads with a high temperature anti-seize compound such as Jet Lube (Mil Spec A-907D), or equivalent.

B. Tighten the nut on the "V" band toggle bolt to approximately 160 lb-in (18 Nm) torque.

NOTE

Do not pull a misaligned turbine housing into alignment with the "V" band coupling. The parts must be aligned and seated first.

C. Loosen the "V" band coupling nut to approximately 50 lb-in (6 Nm) torque, then retorque the nut to 152-168 lb-in (17-19 Nm) torque.

20. Position compressor housing (2) as marked at disassembly against the backplate and secure it in place with "V" band coupling (1). Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 110-130 lb-in (12-15 Nm) torque.

21. Check the shaft radial movement:

A. Position the magnetic base J 7872-2 with the swivel adaptor J 7872-3 on the flat surface of the turbine housing inlet flange as shown in Figure 11D-33.

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 adaptor.

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.

NOTE

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 and, applying equal pressure at each end, move the rotating shaft first forward and then away from the dial indicator, creating a transverse movement in the shaft (see Figure 11D-33). The dial indicator displacement should be between 0.003" and 0.007". If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

22. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

23. Stamp the letter "R" in the lower left hand corner of the name plate to identify that the turbocharger has been reworked.

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. Install inlet shield J 26554 in place (see Figure 11D-27 on page 11D-19).

3. Place the turbocharger assembly into position on the mounting bracket. Use a new gasket between the exhaust manifold adaptor and the turbine housing flange.

4. Secure the turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the bracket.

CAUTION

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. Tighten the turbocharger to exhaust manifold adaptor bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.

7. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.

8. Attach the oil inlet line to the cylinder block.

9. 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 line at the bearing housing (see Figure 11D-28 on page 11D-20).

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 gauge registers pressure (10 psig or 69 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 turbocharged 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.

10. Check all ducts and gaskets for leaks.

11. 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

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.

12. Remove inlet shield J 26554 from the turbocharger.

TROUBLE SHOOTING

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, dis-assemble and inspect turbocharger 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.

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 with 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 judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for parts more frequently replaced in engine overhaul work. For addition information, refer to the text.

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
Blower			
Backlash (timing gears)	.0005 "	.0025 "	.0040 "
Oil seal or seal collar (below end plate surface)	.0020 "	.0080 "	
Dowel pin (projection beyond inside face of end plates)	.3800 "		
Turbocharger			
End play -- rotating shaft	.0030 "	.0100 "	
Radial movement -- rotating shaft	.0030 "	.0070 "	
Turbine wheel shaft journal bearings:			
Inside diameter	.6268 "	.6272 "	
Outside diameter..................	.9782 "	.9787 "	
Journal diameter -- turbine wheel shaft	.6250 "	.6254 "	
Bearing bore -- center housing:			
Inside diameter	.9827 "	.9832 "	.9842 "
Back 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 "
Thrust washer, inboard:			
Thickness	.0900 "	.0920 "	
Compressor wheel bore:			
Inside diameter (TV61)	.3121 "	.3124 "	.3134 "

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	260M BOLTS TORQUE Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	280M OR BETTER 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	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	1	No. 6 thru 1 1/2	60,000
None	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	7	1/4 thru 1 1/2	133,000
Bolts and Screws	8	1/4 thru 1 1/2	150,000
Bolts and Screws	None	No. 6 thru 1 1/2	55,000

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE lb-ft	TORQUE Nm
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
Blower lower front bearing retaining bolt (Allen head)	5/16-24	18	24
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

SERVICE TOOLS

TOOL NAME	TOOL NO.
Blower	
Blower clearance feeler set	J 1698-02
Blower rotor shaft remover and installer set	J 4254
Blower service tool set	J 6270-F
Slide hammer set	J 6471-02
Snap ring pliers (external type)	J 4880
Turbocharger	
Compressor wheel nut wrench	J 21223-02
Compressor wheel remover	J 9496
Dial indicator adaptor	J 21224
Dial indicator set (magnetic base)	J 7872
Turbocharger tool set	J 29149
Turbocharger inlet shield	J 26554-A

TABLE OF CONTENTS

SUBSECTION 11E

LUBRICATION SYSTEM

GENERAL

This section covers repair information on the oil pump, oil pressure regulator, oil filters, oil cooler, dipstick, oil pan, and ventilation system.

DESCRIPTION

General

Figure 11E-1 on page 11E-2 schematically illustrates the flow of oil through the 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.

A by-pass type filter with replaceable element is used, A portion of the oil is continually by-passed through the filter and the filtered oil is returned to the engine oil pan.

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.

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 Figure 11E-1 on page 11E-2, 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 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

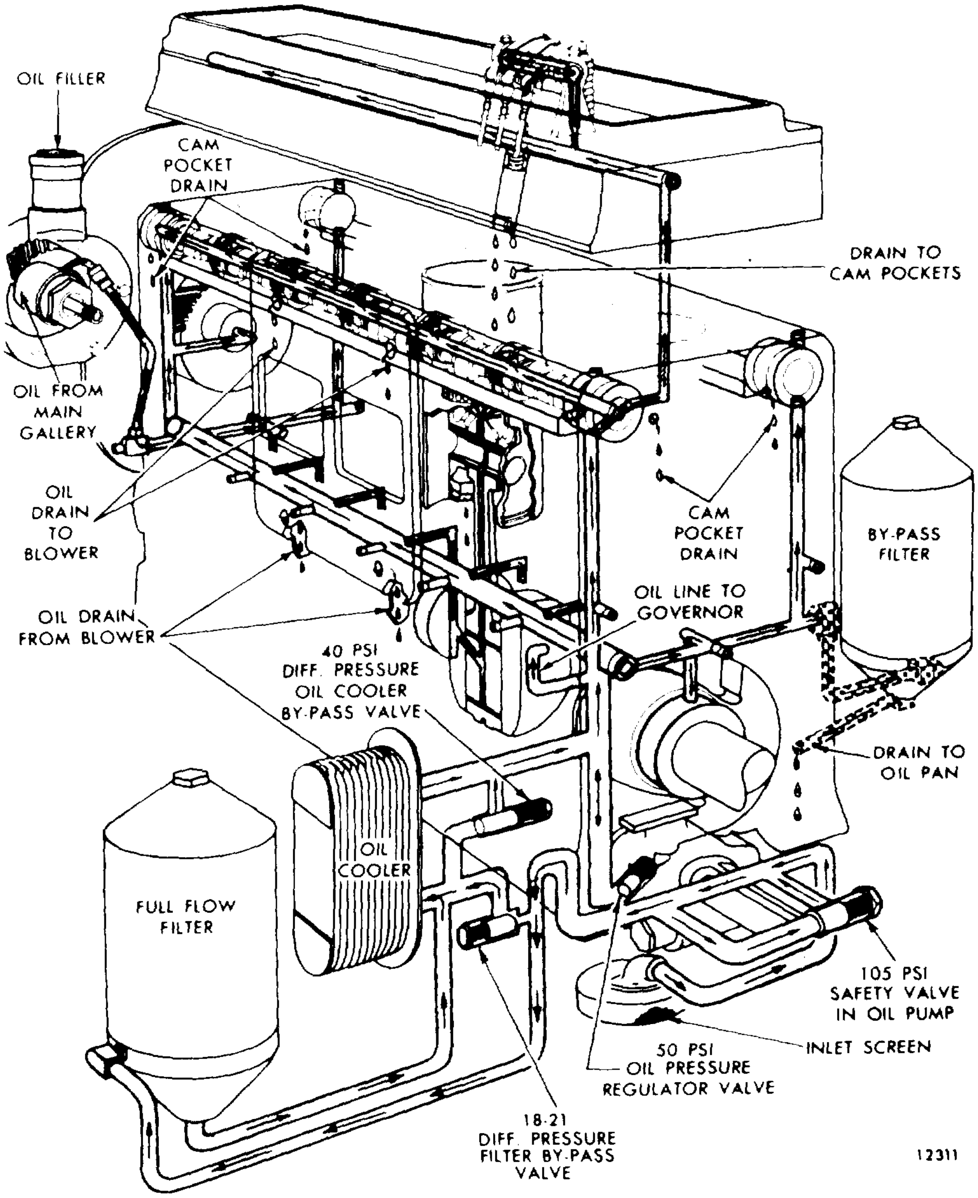


Figure 11E-1. Schematic Diagram of Lubrication System

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 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 the 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 Figure 11E-1 and Figure 11E-2 on page 11E-3, 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.

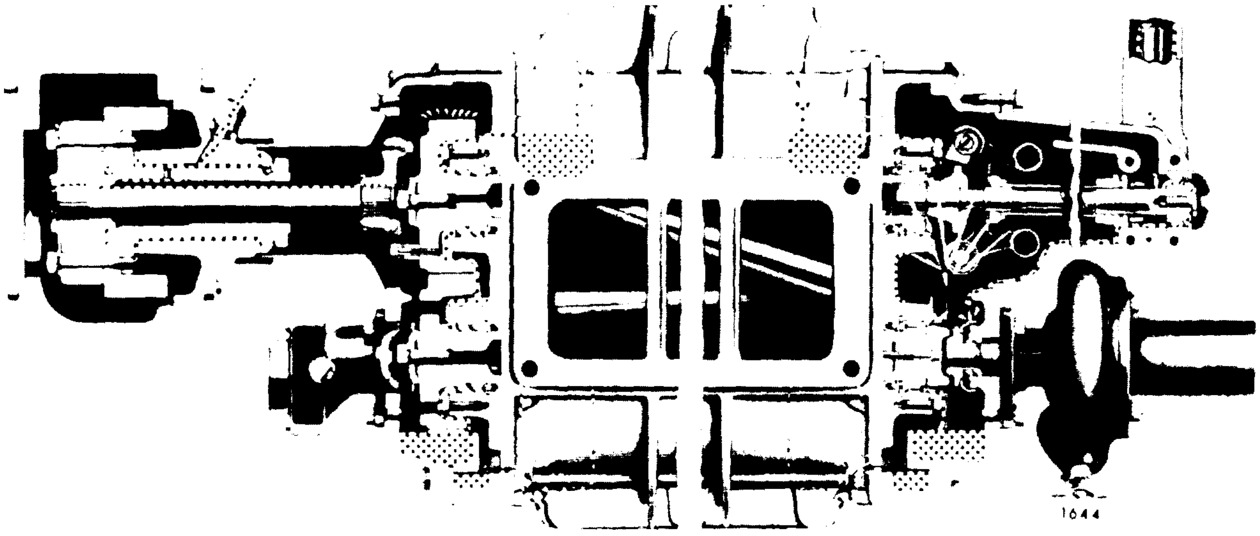


Figure 11E-2. Blower Lubrication

A slinger at the forward end of the 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.

Lubrication System Maintenance

Use the proper viscosity grade and type of heavy duty oil as outlined in the Lubrication Section III. 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.

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 Subsection 11F for the recommended cleaning procedure.

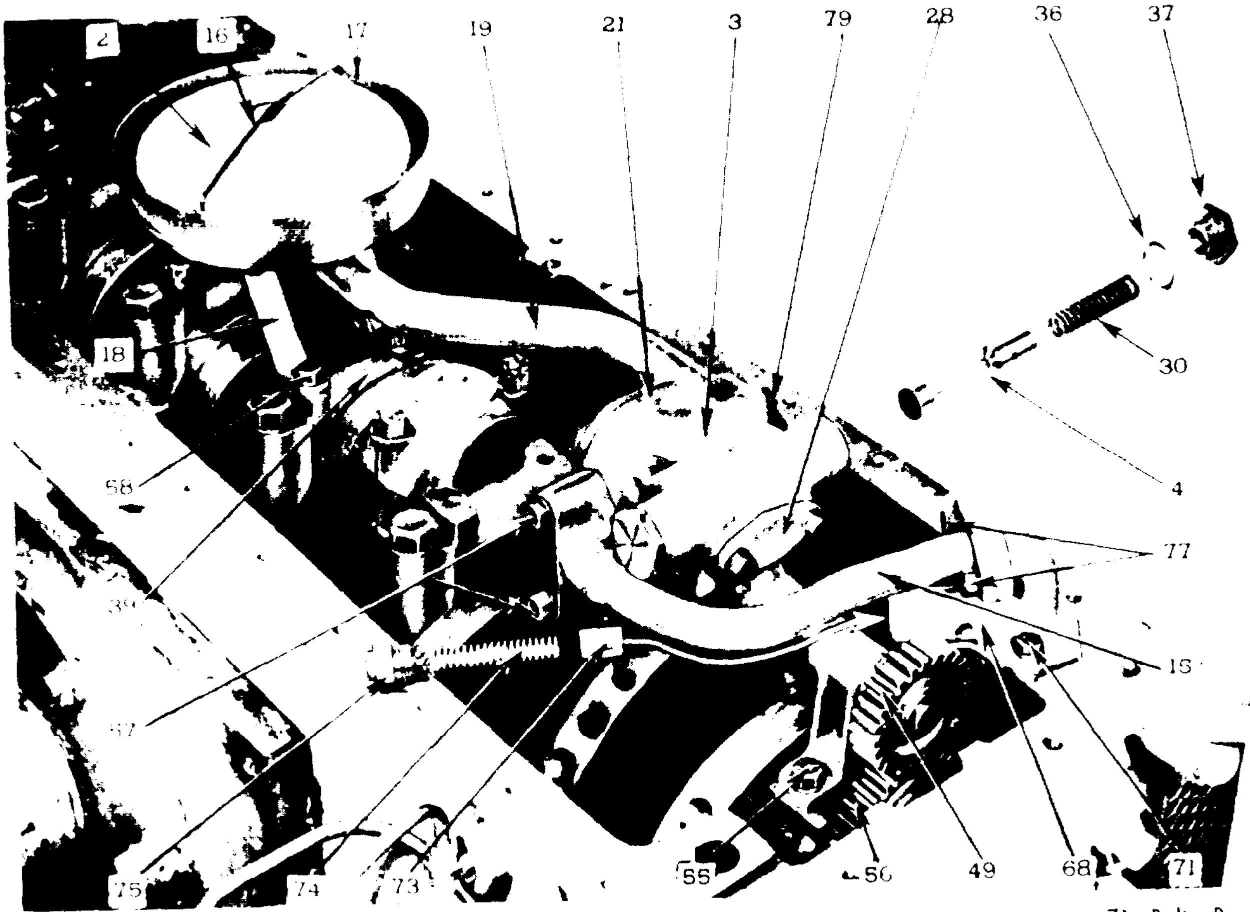
OIL PUMP

Description

The gear type oil pump shown in Figure 11E-3 on page 11E-4 and Figure 11E-4 on page 11E-5 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 (Figure 11E-3 on page 11E-4). 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



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--Screen
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

Figure 11E-3. Oil Pump Mounting

lines exceeds 105 pounds per square inch.

An inlet pipe (19), attached to the inlet opening in the pump body, leads to 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.

Remove Oil Pump

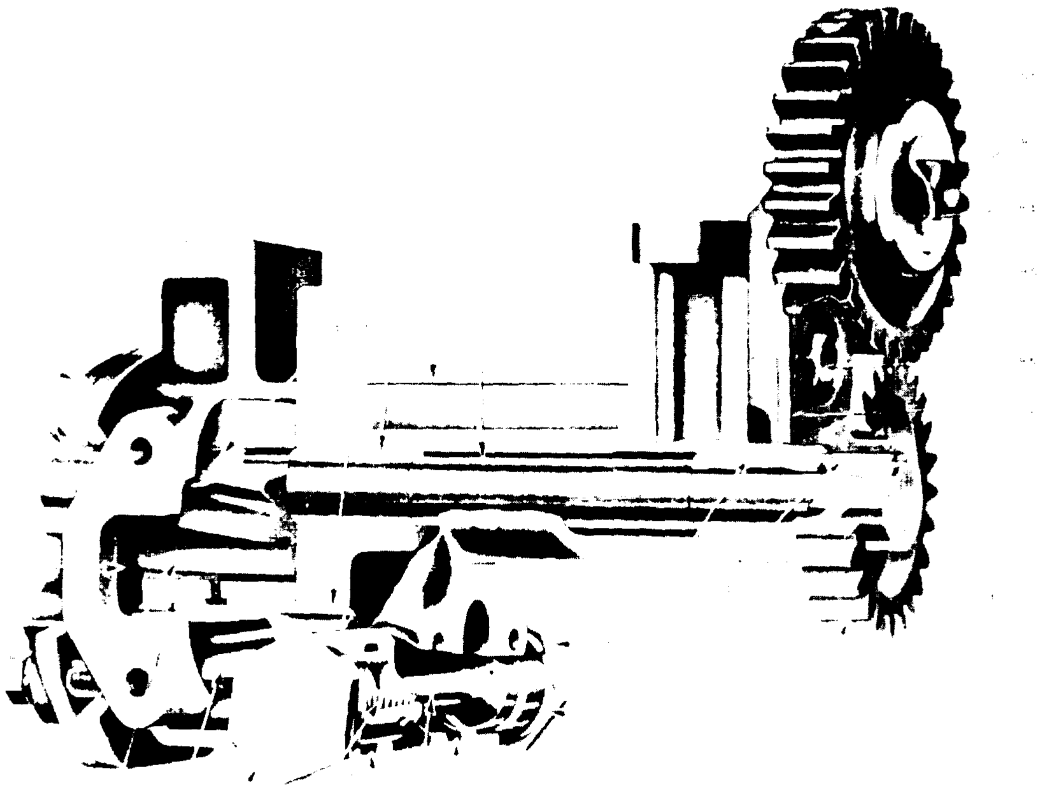
1. Remove the drain plug from the oil pan and drain the oil.

2. Remove the oil pan bolts and remove the oil pan.

3. Remove the bolts and lock washers securing the oil pump, regulator body and oil outlet tube and oil inlet tube support from the main bearing caps, and cylinder block (Figure 11E-3).

NOTE

> Remove and save the shims, if used between the oil pump mounting feet and the bearing caps.



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. Lock Washer
85. Thrust Washer--Idler Gear-to-Support Bolt
86. Bolt--Support-to-Pump

Figure 11E-4. Oil Pump Assembly

Disassemble Oil Pump

Observe carefully the position of all parts including the oil inlet and outlet pipes during disassembly to facilitate reassembly of the pump.

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 four bolts and lock washers securing the cover to the oil pump body (3).

4. Remove the valve plugs (37) and copper gaskets (36) from each side of the pump body, and jar the relief valve parts from the body (Figure 11E-3 on page 11E-4).

5. Remove the pump driven gear (22) from the driven gear shaft (24).

6. Straighten the lip of the lock washer (84) and unscrew the bolt (83) thus freeing the idler gear (56).

7. 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 Figure 11E-5.

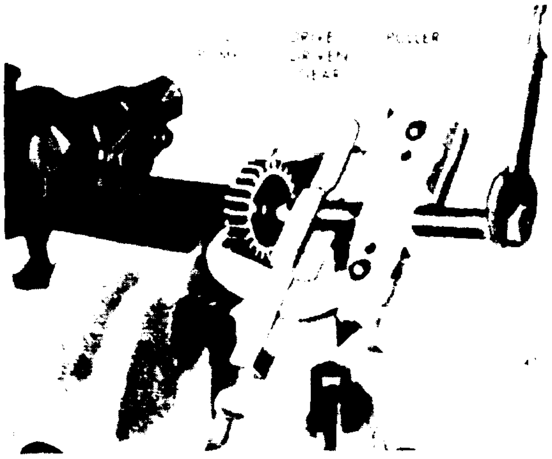


Figure 11E-5. Removing Oil Pump Drive-Driven Gear from Shaft

8. Remove the Woodruff key (14) from the drive shaft and withdraw the shaft and driven gear (22) from the pump body.

9. Unscrew bolt (86) and remove idler gear support (82) from the pump body.

10. If the drive gear (23) is to be replaced, position the gear and shaft assembly on bed of an arbor press with long end of shaft extending down through slot in bed plate and with the face of the gear resting on the plate as shown in Figure 11E-6. Place a short 1/2" round steel rod on the end of the shaft, and press the shaft from the gear.

Inspect Oil Pump Parts

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 0.499" diameter driven gear

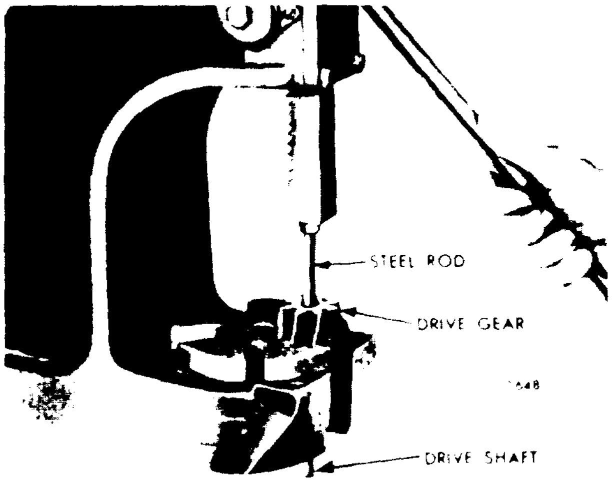


Figure 11E-6. Removing Oil Pump Drive Gear from Shaft

shaft must be reamed to 0.500" ±0.0005" and bushings used with the 0.623" diameter shaft must be reamed to 0.625" ±0.0005".

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 Figure 11E-7 on page 11E-7. Also, the gear bore and the bushing bore in both the pump body and cover or scavenging pump body must be concentric within 0.001". The shaft-to-pump body-bushing clearance with new parts is 0.0008" to 0.0025". The shaft-to-pump cover bushing clearance with new parts is 0.0010" to 0.0027".

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 with in turn, may lead to serious damage through out the engine.

Inspect the pressure relief valve and its seat in the pump body. If necessary, install new parts.

Assemble Oil Pump

Refer to Figure 11E-4 on page 11E-5 and assemble the oil pump as follows:

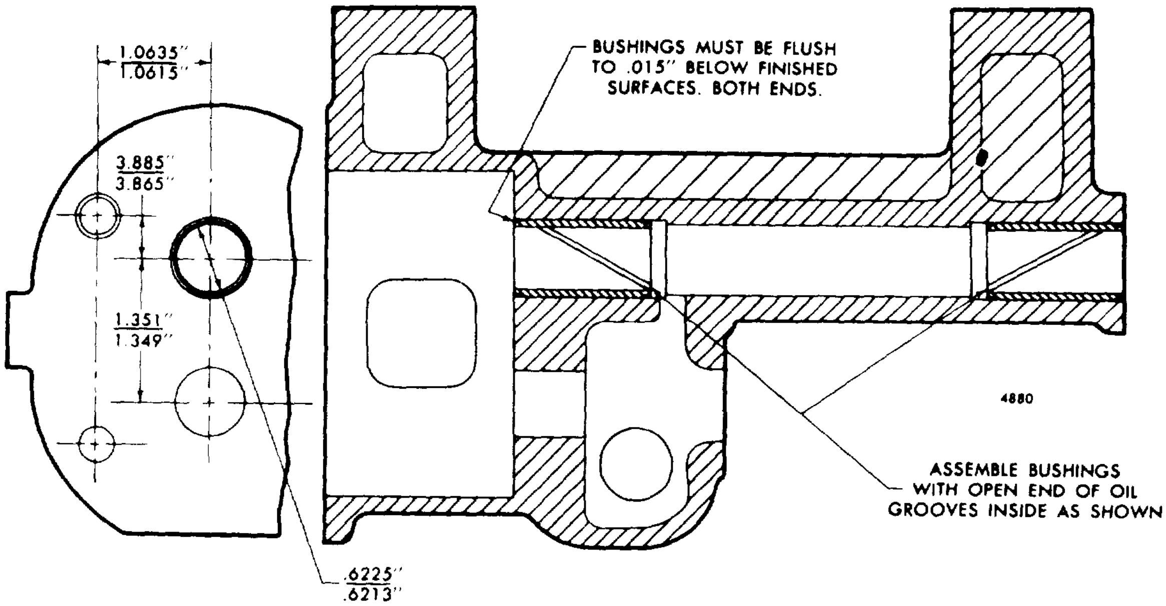


Figure 11E-7. Diameter and Location of Bushing in Oil Pump

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 Figure 11E-7, press the shaft into the gear.

The gear must be 6-15/16" from the keyway end of the drive shaft (Figure 11E-8).

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 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. Secure the pump cover (21) to the oil pump body with four bolts (54) and lock washers.

6. Support the drive gear end of the drive shaft (13) on the bed of an arbor press and insert 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 0.005" 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 0.005".

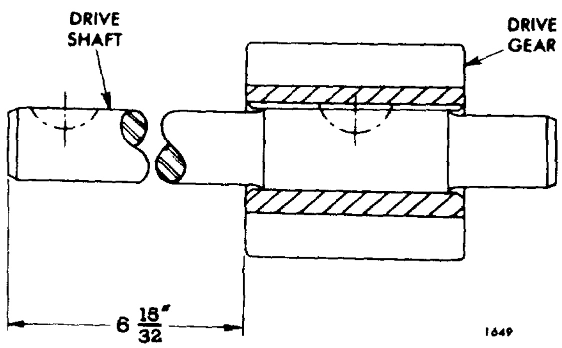


Figure 11E-8. Oil Pump Drive Shaft and Gear Assembly

7. 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.

8. Place the lock washer (84) on the bolt (83) and the special washer (85) next to the lock washer and start the bolt into the idler gear support. Then rotate the special washer and lock washer so that the slot in each washer engages the locating pin (87).

9. Tighten the idler gear bolt so the bolt head is over the end of the locating pin

(87). Then bend the lock washer against one flat of the bolt head.

10. 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 Figure 11E-3 on page 11E-4, while compressing the spring, start the second relief valve plug (37), with gasket (36), into the body. Tighten the plugs.

11. If the cover (28) and gasket (29) were removed from the pump body, reinstall and secure then 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.

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 (Subsection 11A).

2. Remove the oil slinger.

3. If required use puller J 3051 (Figure 11E-9) 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.

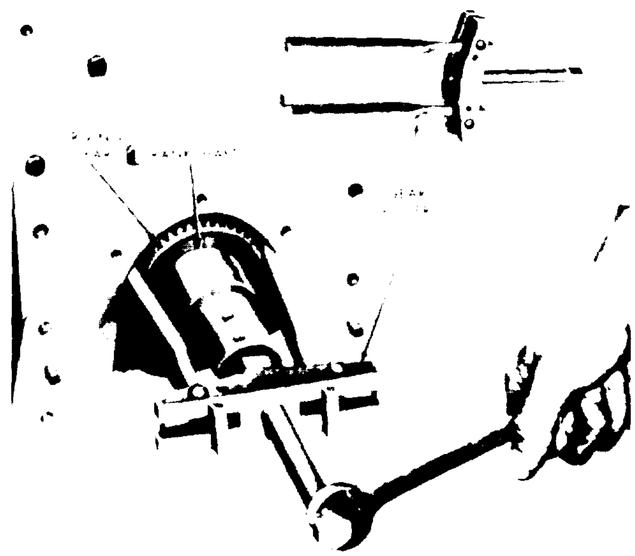


Figure 11E-9. Removing Oil Pump Driving Gear from Crankshaft

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 Figure 11E-10, and drive the gear tight against the shoulder on the crankshaft.

Figure 11E-10. Installing Oil Pump Driving Gear on Crankshaft

4. Install the oil slinger with the dished side away from the gear.

5. Install the crankshaft front cover as outlined in Subsection 11A.

Install Oil Pump

Refer to Figure 11E-3 on page 11E-4 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 lock washers through the mounting feet of the pump and into the bearing caps (39). Align the pump so that the teeth of crankshaft gear and idler gear are parallel; then tighten the bolts to 35-39 lb-ft and check clearance between the gear teeth with a feeler gage. Proper clearance between the crankshaft gear and idler gear is 0.005" minimum, 0.012" maximum (Figure 11E-11).

CAUTION

Always check the clearance between the crankshaft gear and the oil pump idler gear with the engine in the upright or running position.

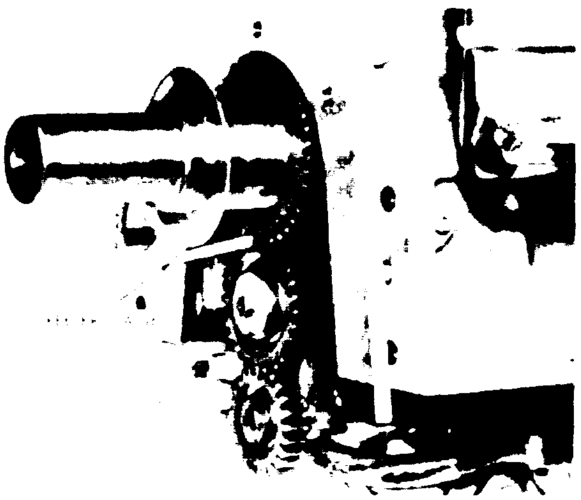


Figure 11E-11. Measuring Clearance Between Teeth of Oil Pump Gears

If the 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 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 0.005" shim will change the gear tooth clearance by 0.0035".

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 lock washers 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, lock washers, and nuts (65). Tighten the bracket bolts (58) to the bearing caps.

7. Place the screen (2) in 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 crankcases to the proper level with oil recommended in Section III.

LUBRICATING OIL PRESSURE REGULATOR

Description

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 (Figure 11E-12). A die cast lubricating oil pressure regulator assembly is used (Figure 11E-13).

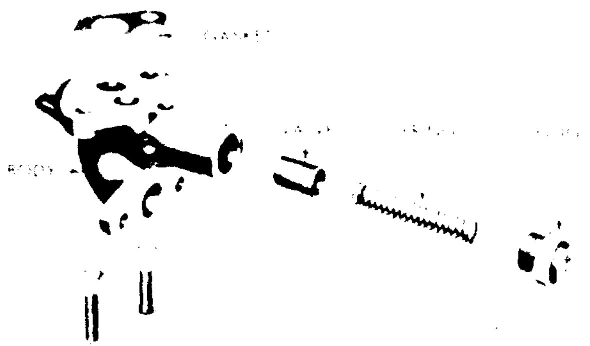


Figure 11E-12. Lubricating Oil Pressure Regulator Parts

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.

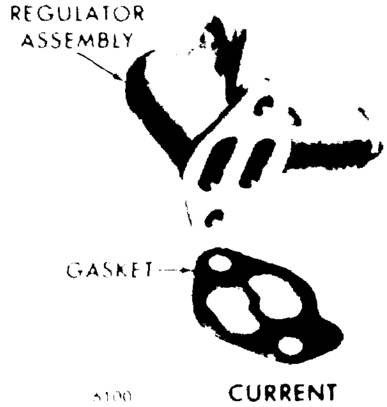


Figure 11E-13. Lubricating Oil Pressure Regulator

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.

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.

Remove Oil Pressure Regulator

1. Remove the two oil pump outlet pipe to regulator attaching bolts and lock washers.

2. Remove the two regulator body-to-cylinder block bolts and lock washers.

3. Tap the lower end of the regulator body lightly to loosen the body from the gasket and cylinder block. Remove the gasket.

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.

Inspection

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 must be replaced.

Replace a fractured or pitted spring.

Assemble Oil Pressure Regulator

Refer to Figure 11E-12 on page 11E-10 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.

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.

NOTE

> When attaching a new regulator be sure the new gasket is installed so that the tab on the gasket faces the oil pump and crankshaft drive gears (lower front cover side).

3. Place a new gasket between the regulator and the pump outlet pipe and connect these parts together with two bolts.

OIL COOLER

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.

The lubricating oil cooler is located on the side of the engine just below the water pump (Figure 11E-14).

Figure 11E-14. Lubricating Oil Cooler Mounting-Radiator Cooled Engine

To assure engine lubrication if the oil cooler becomes clogged, a by-pass valve located at the oil inlet to the cooler by-passes 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 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.

Remove Lubricating Oil Cooler

1. Drain the cooling system by opening the drain valve at the bottom of the oil cooler housing (Figure 11E-14 on page 11E-11).

2. Remove the bolts and lock washers 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 "Clean Oil Cooler Core."

9. Pressure check the oil cooler core as outlined under "Pressure Check Oil Cooler Core."

Clean Oil Cooler Core

1. Clean Oil Side of Core - Circulate a solution of trichloroethylene through the core passages with a force pump to remove carbon and sludge.

CAUTION

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 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 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.

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 core (Figure 11E-15).

Figure 11E-15. Oil Cooler Core Prepared for Pressure Check

2. Attach an air hose and apply 75-150 psi (517-1 034 kPa) air pressure. Then, submerge the oil cooler core and plate assembly in a tank of heated water (180°F or 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.

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

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 Subsection 11F).

Install Lubricating Oil Cooler

Refer to Figure 11E-16 on page 11E-14 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, lock washers and copper washer.

NOTE

The copper washer must be installed on the second bolt from the bottom of the oil cooler adaptor to prevent leakage of oil from the adaptor.

2. Affix new gaskets and to each side of the core and position the core 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 particles that may not have been removed to be loosened and circulated through the engine.

3. Set the housing with the cooler core against the adaptor and secure with bolts and lock washers, at the same time locating the seal and clamp. Tighten the clamp (Figure 11E-14 on page 11E-11).

4. Affix a new gasket to the oil cooler water inlet connector and secure with bolts and lock washers.

LUBRICATING OIL COOLER BY-PASS VALVE

Description

To assure proper lubrication if the oil cooler core becomes clogged, a valve, located between the oil inlet and the core, by-passes the oil around the cooler directly to the oil gallery in the cylinder block.

The by-pass valve, spring, plug, and gasket are housed in the oil cooler adaptor (Figure 11E-14 on page 11E-11).

The by-pass valve should be removed, cleaned and reassembled whenever the cooler core is cleaned or replace. However, if occasion requires, the by-pass valve can be removed without removing the oil cooler.

Remove By-pass Valve

The by-pass valve may be--removed by removing the plug and lifting the gasket, valve and spring from the adaptor.

Inspection

Clean the by-pass valve components with fuel oil and dry them with compressed air.

Inspect the valve parts for wear and replace the parts if necessary.

Install By-Pass Valve

1. Apply clean engine oil to the outside surface of the by-pass valve and place

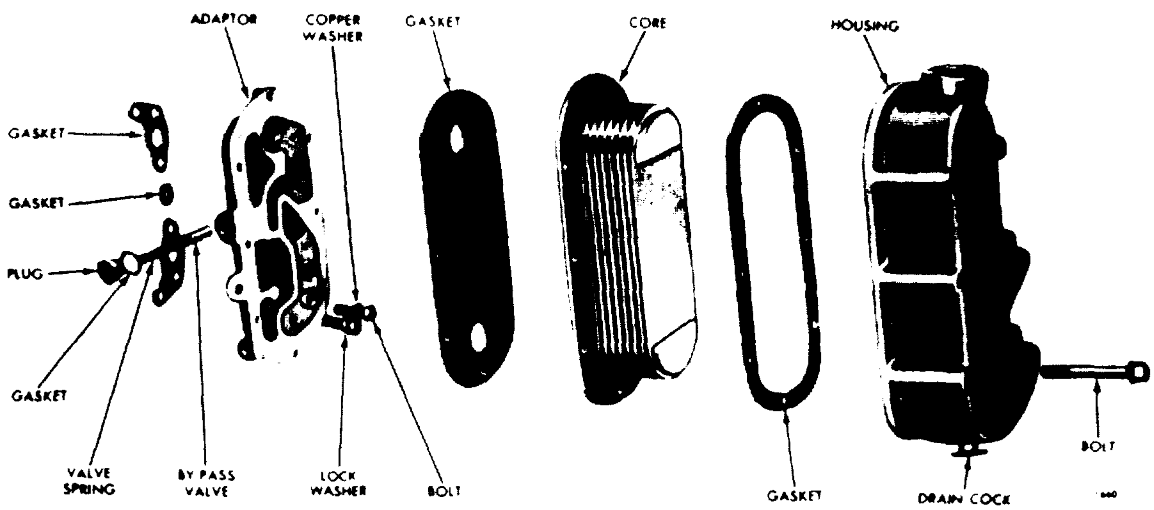


Figure 11E-16. Lubricating Oil Cooler Parts

the valve in the housing or adaptor, closed end first.

2. Slide the valve spring into the valve and screw the plug, with the gasket, into the housing or adaptor.

OIL LEVEL DIPSTICK

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. The engine includes a 3/4" long rubber oil seal which prevents the escape of vapors carrying oil from the dipstick tube.

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.

OIL PAN

The engine is equipped with a deep sump oil pan (Figure 11E-17 on page 11E-15, which has a one piece gasket.

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 the stamped oil pan for dents or breaks in the metal which may necessitate repair or replacement. Check for

Figure 11E-17. Deep Sump-Type Oil Pan

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 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 lb-ft (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 oil pan gasket. If a leak should develop at the oil pan, check if the lock washer is compressed. If not, the bolt may be tightened. However, if the lock washer 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 lb-ft (34-27 Nm)

7. Fill the oil pan with new oil 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.

VENTILATING SYSTEM

Description

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 component through cavities in the lifter brackets and vent castings.

Ventilating air in the valve compartment is drawn off through a breather attached to the valve rocker cover.

Minute particles of lubricating oil, carried along with the moving vapors, are trapped in an oil separator within the breather and eventually returned to the crankcase. The vapors are exhausted to the atmosphere through the breather pipe.

Service

Consult the Operator's Manual for further maintenance.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	26OM BOLTS TORQUE (lb-ft)	Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	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	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	1	No. 6 thru 1 1/2	60,000
None	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	7	1/4 thru 1 1/2	133,000
Bolts and Screws	8	1/4 thru 1 1/2	150,000
Bolts and Screws	None	No. 6 thru 1 1/2	55,000

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
Oil pan bolts	5/16-18	10-20	14-27
Oil pump-to-bearing cap bolt	3/8 -24		
Oil pump drive idler gear nut	112 .20	60-70	81-95
Oil pan drain plug (nylon washer)	18mm	25-35	34-47
Oil pump relief valve plug	7/8 -18	15-25	20-34
By-pass valve plug	1 1/4-16	95-105	129-143

STUD TORQUE SPECIFICATIONS

APPLICATION	TORQUE lb-ft)	TORQUE (Nm)
Oil filter center stud	50-60	68-81

SERVICE TOOLS

TOOL NAME	TOOL NO.
Oil pump driving gear installer	J 22285
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

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SUBSECTION 11F

COOLING SYSTEM

GENERAL

The cooling system includes the radiator, fan, water pump and thermostat.

RADIATOR AND COOLING FAN

The engine coolant is circulated through the radiator (Figure 11F-1 on page 11F-2) where the heat is absorbed in the air stream developed by a suction fan which is belt driven from the crankshaft. The water pump draws the coolant through the oil cooler and discharges it into the lower parts 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 by-passed from the water manifold directly to the pump, thus providing water circulation within the engine during the warm-up period.

COOLING SYSTEM OF TURBOCHARGER UNITS

The cooling system has been altered to provide adequate cooling for both the turbocharger and the engine.

The turbocharger is cooled by the addition of a line leading from the water gallery within the cylinder block, near the rear of the blower, to the cooling water inlet, located near the bottom of the turbocharger. The coolant flows through a water jacket, within the turbocharger, which is adjacent to the turbine end, retarding the flow of heat at this point. The coolant discharges at the cooling water outlet, located near the top of the turbocharger and returns to the engine.

ENGINE COOLING SYSTEM MAINTENANCE

General

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 the operating temperature ranges and at their proper operating clearances.

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 components 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.

Cooling System Capacity

The capacity of the basic cooling system (cylinder block, head, thermostat hous-

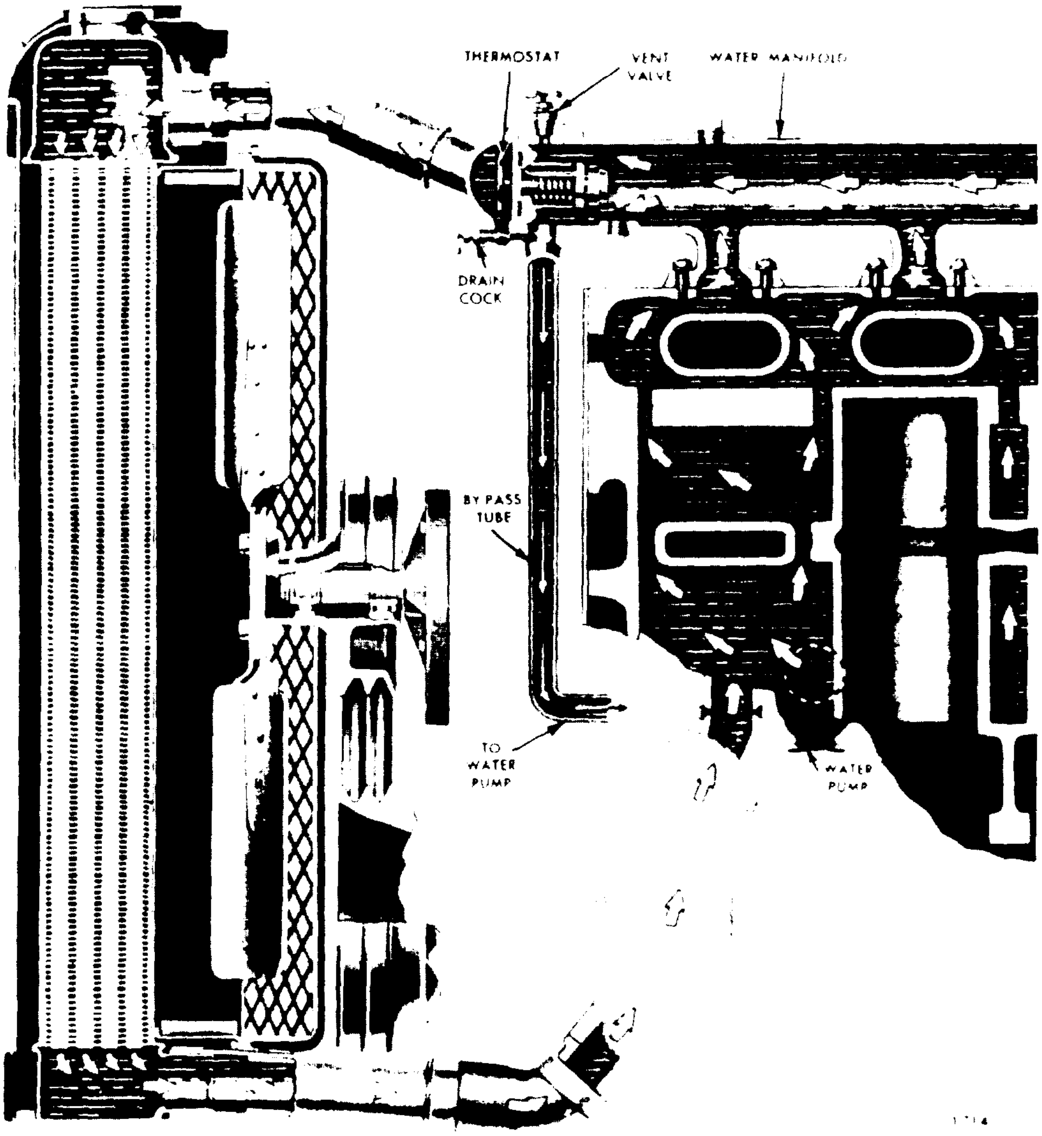

Figure 11F-1. Cooling System With Radiator And Fan

ings and oil cooler housing) is (5.5 Gallons/20.8 L).

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 system is given in the operator's manual.

Drain Cooling System

Drain the coolant by opening the drain cocks in the water outlet elbow, oil cooler housing, the fresh water pump, and the radiator. 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.

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.

Flush Cooling System

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.

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.

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 clog ing the radiator tubes or being force 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 to 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 passages 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.

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 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.

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 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 addicted parts thoroughly.

NOTE

Make certain that the cause of the internal coolant leak has been corrected before returning the engine to service.

WATER PUMP

Description

The centrifugal-type water pump (Figure 11F-2 on page 11F-6) 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.

The water pump uses a ceramic insert and spring loaded seal assembly. The spring-loaded water pump seal assembly bears against the insert. The ceramic insert prevents coolant from passing along the shaft to the sealed ball bearing.

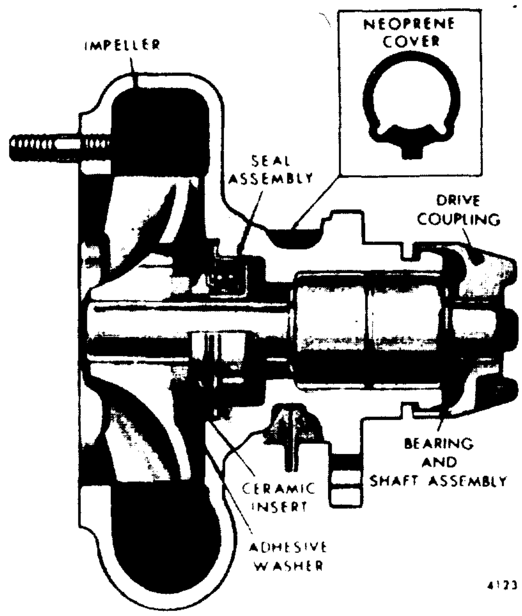

Figure 11F-2. Water Pump With Ceramic Insert in Impeller

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 (Figure 11F-3) and is driven by the lower blower rotor shaft. The drive coupling, pressed on the end of pump shaft, has an integral oil thrower that shrouds the flange end of the pump body and deflects the oil away from the bearing.

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.

Remove Water Pump

Refer to Figure 11F-4 on page 11F-7 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 lock washers that attach the pump outlet flange to the cylinder block. Remove the flange and packing ring.

4. Remove the three bolt seal assemblies that attach the pump to he blower assembly.

5. Withdraw the pump and remove the gasket.

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 (Figure 11F-5 on page 11F-7). 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.

3. Remove the impeller and seal assembly from the pump body.

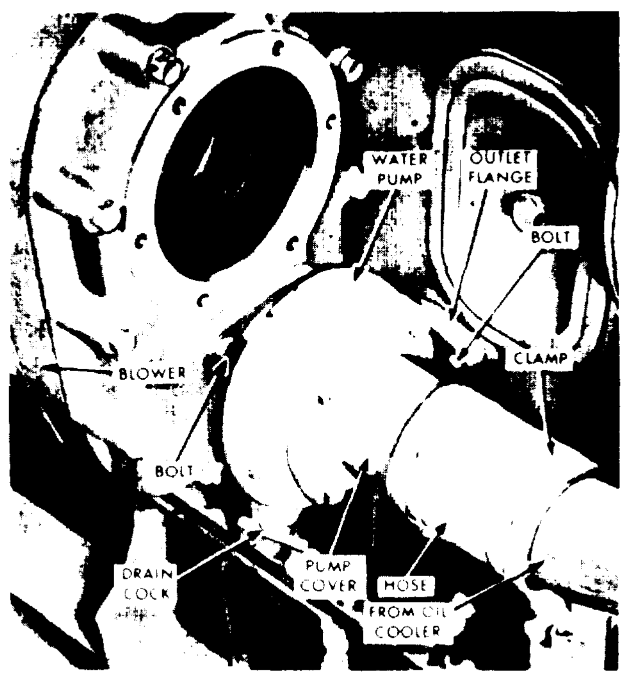

Figure 11F-3. Water Pump Mounting

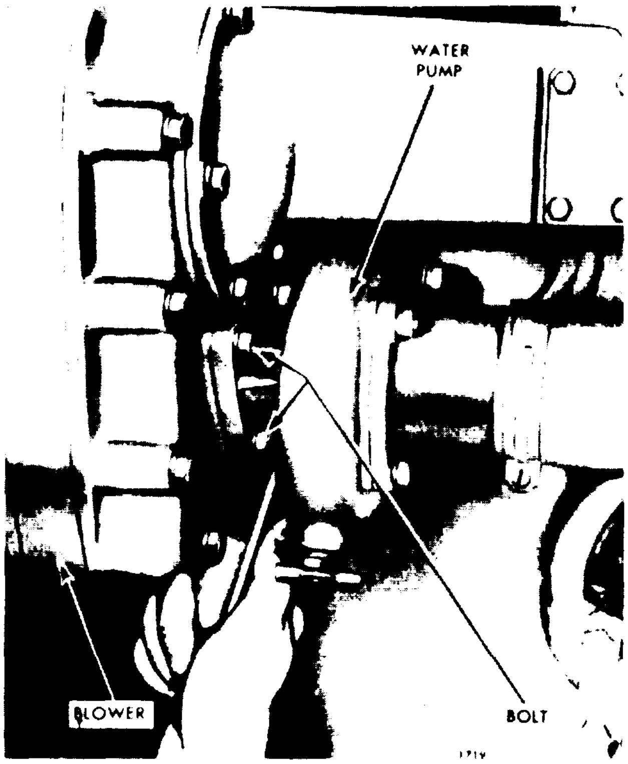

Figure 11F-4. Loosening Inner Pump-to-Blower Bolt with Tool J 4242

NOTE

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.

4. If necessary, remove the pump drive coupling from the shaft with tool J 1930 as shown in Figure 11F-6.

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.

Revolve the pump shaft bearing slowly by hand. Replace the shaft and the seal assembly.

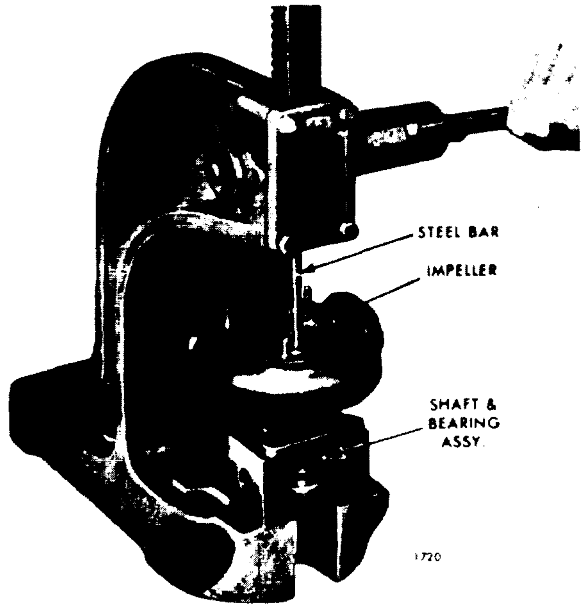

Figure 11F-5. Pressing Pump Shaft from Impeller

Inspect the ceramic insert for cracks, scratches and bond to the impeller. If the insert is damaged, replace it as follows:

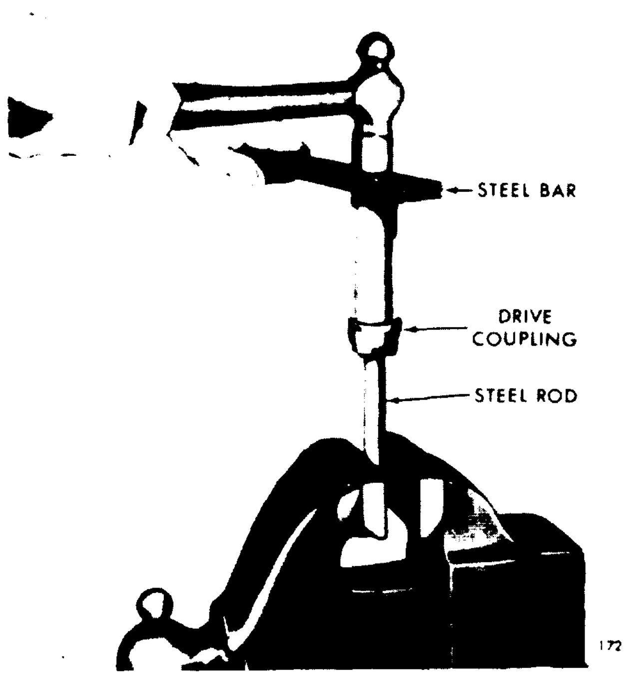

Figure 11F-6. Removing Pump Drive Coupling with Tool J 1930

1. Bake the insert and impeller assembly at 500°F (260°C) for one hour. The insert can be removed easily while the adhesive is hot.

2. 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.

3. 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 lb-ft (8-11 Nm) torque.

Assemble Water Pump

Refer to Figure 11F-2 on page 11F-6 and assemble the pump as follows:

1. 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.

2. 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" bolt and nut and two smooth .125" thick washers. Tighten the bolt to 10 lb-ft (14 Nm) torque.

NOTE

Do not mar the polished surface of the ceramic insert.

3. Place the impeller assembly in a level position, with the ceramic insert up, in an oven preheated to 350°F (177°C) and 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.

4. 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.

5. Support the bearing end of the shaft on the bed of an arbor press. Then press the impeller on the shaft using tool J 22437, Figure 11F-7. Do not press against the outer race of the bearing. The distance between the end of the shaft and the face of the impeller hub is 0.031"-0.033", with the bearing held against the shoulder in the pump body (see Figure 11F-8 on page 11F-9).

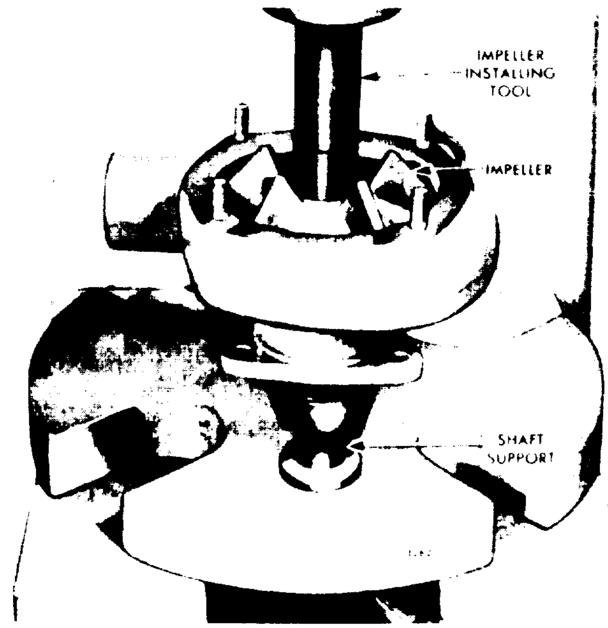

Figure 11F-7. Installing Pump Impeller

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.

7. This pump includes a neoprene cover 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.

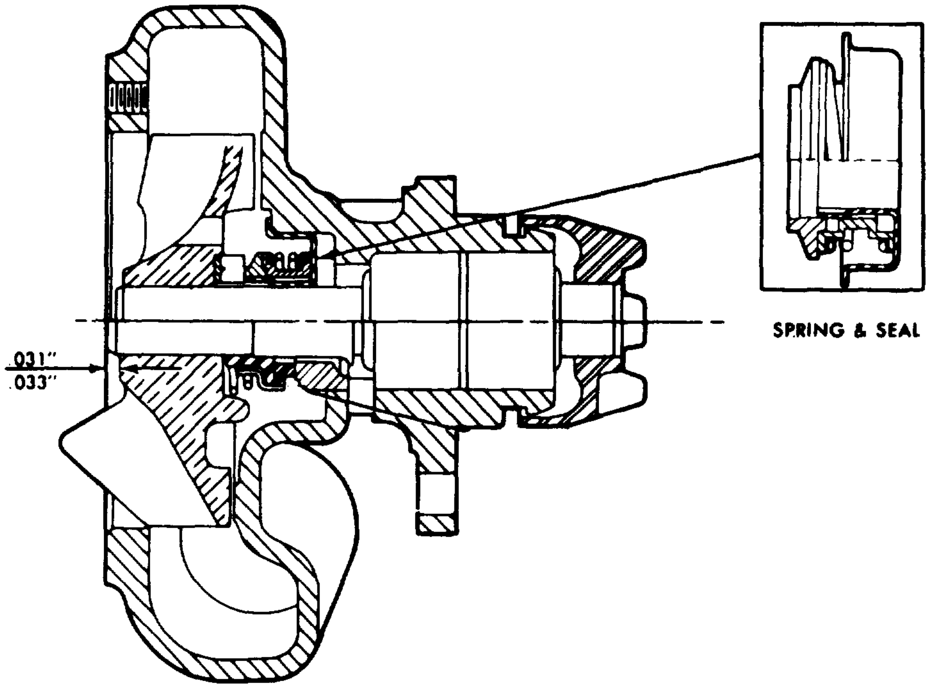

Figure 11F-8. Impeller Clearance

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 lock washers and nuts.

9. If previously removed, install the drain cock in the pump body.

Install Water Pump

Refer to Figure 11F-3 on page 11F-6 and install the water pump on the engine as follows:

1. 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.

2. 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.

3. Slide the pump outlet packing ring and packing flange against the cylinder block and secure the flange with two bolts and lock washers.

4. Slide the water pump inlet hose in place and secure it with the hose clamps.

5. Close the pump drain cock and fill the engine cooling system.

WATER MANIFOLD

Description

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 lock washers at each of the six water openings, as shown in Figure 11F-9 on page 11F-10. A separate gasket is used at each attaching flange between the manifold and the cylinder head.

A gradually increasing area in the cast manifold from the rear end terminates in mounting flange to which the thermostat housing is attached by means of bolts and lock washers.

Remove Water Manifold

The water manifold may be removed as follows:

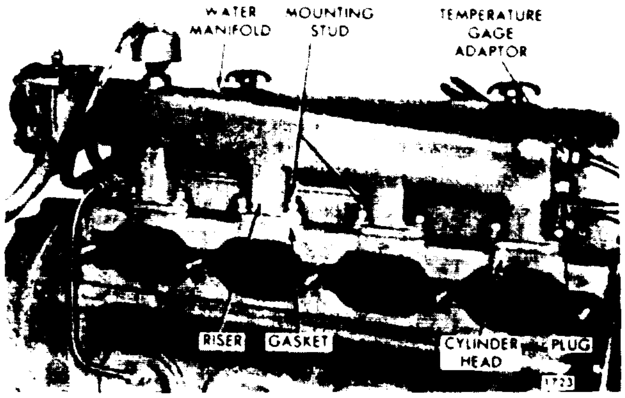

Figure 11F-9. Water Manifold Mounting

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 gage adaptor from the rear end of the water manifold.

4. Remove the water manifold stud nuts and lock washers and lift the manifold straight up off the studs. Remove the manifold to cylinder head gaskets.

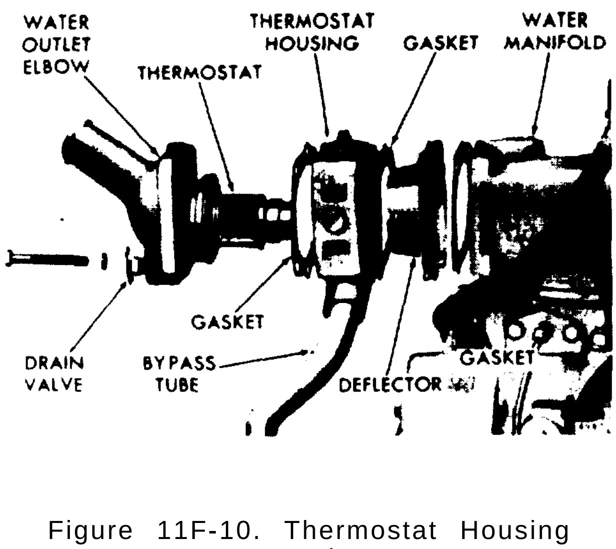

Figure 11F-10. Thermostat Housing Mounting

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 lb-ft (34-41 Nm) torque.

2. Install the temperature gage adaptor in the end of the manifold.

3. Attach the thermostat housing and outlet elbow to the water manifold with bolts and lock washers.

4. Fill cooling system to the proper level.

THERMOSTAT

Description

The temperature of the engine coolant is automatically controlled by a thermostat located in a housing connected to the outlet end of the water manifold. A blocking type thermostat Figure 11F-10 is used.

Operation

At coolant temperatures below approximately 160° to 17O°F (71° to 77°C), 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 out the engine and is directed back to the suction side of the water pump via the bypass tube. As the coolant temperature rises above 160° to 170°F (71° to 77°) the thermostat valves start to open, restricting the bypass system, and permit a portion of the coolant to circulate through the radiator. When the coolant temperature reaches approximately 185° to 195°F (85 to 91°C) the thermostat valves are fully open, the bypass 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 (71° to 85°C) or 170° to 195°F (77° to 91°C), remove the thermostat and check it.

NOTE

There are areas where approved fuel (less than 0.5% sulfur) is not commercially available or economically feasible to obtain. It is important to keep the engine cooling system temperature of these engines on the high side of normal to prevent the condensation of sulfur trioxide gas, which combines with combustion water to form sulfuric acid. Therefore, install a 180° or 190°F (82° or 88°C) temperature thermostat and modify the cooling system to provide rapid warm-up in order to maintain coolant temperature at a minimum of 175°F (80°C).

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 (Figure 11F-10 on page 11F-10).

3. Remove the thermostat and clean the outlet elbow.

Inspection

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 restricting the flow of coolant, 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. The incomplete combustion of fuel due to cold operation will result in build-up of carbon deposits on the pistons, rings and valves.

Check the operation of a thermostat as follows:

1. Immerse the thermostat in a container of water (Figure 11F-11).

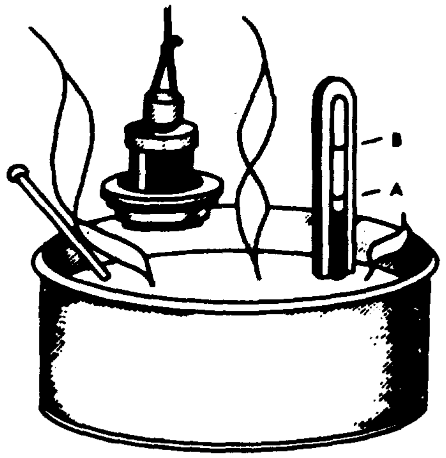

Figure 11F-11. Method of Checking Thermostat Operation

2. Place a thermometer in the container using care not to allow the thermometer to touch the bottom or sides of the container.

3. While slowly agitating the water to maintain an even temperature, apply heat to the container. As the water is heated, the thermostat should begin to open (the opening temperature is usually stamped on the thermostat). The thermostat should be fully open at approximately 185° - 195°F (85° - 91°C) Allow at least 10 minutes for the thermostat to react.

Install Thermostat

1. Affix a new gasket to each side of the thermostat housing.

2. Set new gasket and the thermostat in the housing. Attach the outlet elbow and 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.

RADIATOR

Description

The temperature of the coolant circulating through the engine is lowered by the action of the radiator and the fan. The radiator is mounted in front of the engine so that the fan will draw air through it, thereby lowering and maintaining the coolant temperature to the degree necessary for efficient engine operation.

The life of the radiator will be considerable prolonged if the coolant used is limited to either clean, soft water and a corrosion inhibitor or a mixture of water and a permanent type antifreeze. The use of any other type antifreeze is not recommended.

To increase the cooling efficiency of the radiator, a metal shroud is placed around the fan. The fan shroud must be fitted air tight against the radiator to prevent recirculation of the hot air drawn through the radiator. Hot air which is permitted to pass around the sides or bottom of the radiator and is again drawn through the radiator will cause overheating of the engine.

Another cause of overheating is slippage of the fan drive belts which is caused by incorrect belt tension, worn belts or worn fan belt pulley grooves, or the use of fan belts of unequal length when two or more belts are used. The belt tension and condition of the belts should be checked periodically as stated in the operator's manual.

A radiator that has a dirty, obstructed core or is leaking, a leak in the cooling system, or an inoperative thermostat will also cause the engine to overheat. The radiator must be cleaned, the leaks eliminated, and defective thermostats replaced immediately to prevent serious damage from overheating.

The external cleanliness of the radiator should be checked if the engine overheats and no other causes are apparent.

Cleaning Radiator

The radiator should be cleaned whenever the foreign deposits are sufficient to hinder the flow of air or the transfer of heat to the air. In a hot, dusty area, periodic cleaning of the radiator will prevent a decrease in efficiency and add life to the engine.

The fan shroud and grill should be removed, if possible to facilitate cleaning of the radiator core.

An air hose with a suitable nozzle is often sufficient to remove loose dust from the radiator core. Occasionally, however, oil may be present requiring the use of a solvent, such as mineral spirits, to loosen the dirt. The use of kerosene, or fuel oil is NOT recommended as a solvent. A spray gun is an effective means of applying the solvent to the radiator core. Use air to remove the remaining dirt. Repeat this process as many times as necessary, then rinse the radiator with clean water and dry it with air.

NOTE

Provide adequate ventilation of the working area to avoid possible toxic effects of the cleaning spray.

Another method of cleaning the radiator is the use of steam or a steam cleaning device, if available. If the foreign deposits are hardened, it may be necessary to apply solvents.

The scale deposit inside the radiator is a result of using hard, high mineral content water in the cooling system. The effect of heat on the minerals in the water causes the formation of scale, or hard coating, on metal surfaces within the radiator, thereby reducing the transfer of heat. Some hard water, instead of forming scale, will produce a silt-like deposit which restricts the flow of water. This must be flushed out at least twice a year. More often if necessary.

A drain is provided at the bottom of the oil cooler housing.

To remove the hardened scale, a direct chemical action is necessary. A flushing compound such as salammoniac, at the specified rate of 1/4 pound per each gallon of radiator capacity, should be added to the coolant water in the form of a dissolved solution while the engine is running. Operate the engine for at least

15 minutes, then drain and flush the system with clean water.

Other flushing compounds are commercially available and should be procured from a reliable source. Most compounds attack metals and should not remain in the engine for more than a few minutes. A neutralizer should be used in the cooling system immediately after a descaling solvent is used.

For extremely hard, stubborn coatings, such as lime scale, it may be necessary to use a stronger solution. The corrosive action of a stronger solution will affect the thin metals of the radiator, thereby reducing its operating life. A complete flushing and rinsing is mandatory and must be accomplished skillfully.

After the solvent and neutralizer have been used and the cooling system is flushed, completely drain the entire system again and fill it with clean, soft water plus a corrosion inhibitor or permanent type antifreeze. After filling the cooling system, inspect the radiator and engine for water leaks.

NOTE

When draining or filling, the cooling system must be vented.

After the radiator core has been thoroughly cleaned and dried, reinstall the fan shroud and grill, if removed.

Remove Radiator

Remove radiator as follows:

1. Remove the radiator filler cap and open the drain cock to drain the cooling system. Also open the drain cock on the oil cooler and the engine block.

NOTE

When draining the cooling system, 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 the fan belt guards to the rear of the fan guard and remove the guards.

3. Withdraw screws releasing fan guard from the fan shroud.

4. Loosen the hose clamps at the radiator inlet pipe elbow or hose and remove the elbow or hose.

5. Loosen the hose clamps at the radiator outlet pipe extension tube or hose and remove the tube or hose.

6. Use a chain hoist and a suitable lifting device (through the fill neck or otherwise) and draw the hoisting chain taut to steady the radiator.

7. Remove the bolts, nuts, plain washers, lock washer and bevel washer holding the radiator assembly to the base.

NOTE

Since the shroud is very close to the tips of the fan blades, to prevent damage to these parts great care must be exercised whenever the radiator is removed.

8. Lift the radiator assembly with a chain hoist and lifting hook enough to clear the engine base; then move it away from the engine.

9. The fan shroud and radiator grill may be removed from the radiator by removing the attaching bolts, flat washers and lock washers.

Inspection

Clean all radiator parts thoroughly, removing dirt, scale and other deposits.

Examine the radiator for cracks or other damage. The radiator core fins should be straight and evenly spaced to permit the full flow of cooling air. The core tubes should be clean inside and outside and have no leaks.

If repainting the radiator core becomes necessary, it is recommended that a thin coat of dull black radiator paint or another high quality flat black paint be used. Ordinary oil paints have an undesirable glossy finish and do not transmit heat as well.

Check all radiator hoses and clamps. Replace cracked and deteriorated hoses and damaged clamps.

Install Radiator

Assemble the radiator, grill and shroud. Then mount the assembly on the engine base by reversing the procedure given for removal.

Check the clearance between the tips of the fan blades and radiator shroud after the radiator is in place. There must be sufficient clearance between these parts or damage to the fan and shroud will result when the engine is started. Use shims between the radiator and base, if necessary to obtain the proper clearance.

COOLANT PRESSURE CONTROL CAP

Description

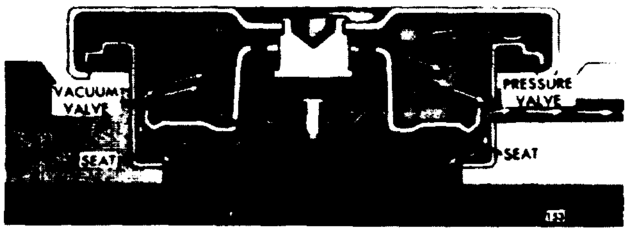

Figure 11F-12. Pressure Control Cap (Pressure Valve Open)

The radiator 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 valves 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 (scaling) from the hot liquid.

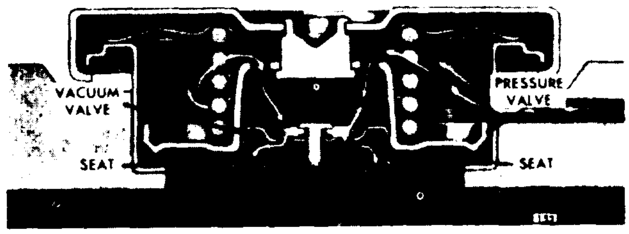

Figure 11F-13. Pressure Control Cap (Vacuum Valve Open)

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.

ENGINE COOLING FAN

Description

The engine cooling fan is belt driven from the crankshaft pulley (Figure 11F-14 on page 11F-15).

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 (see Figure 11F-15 on page 11F-16).

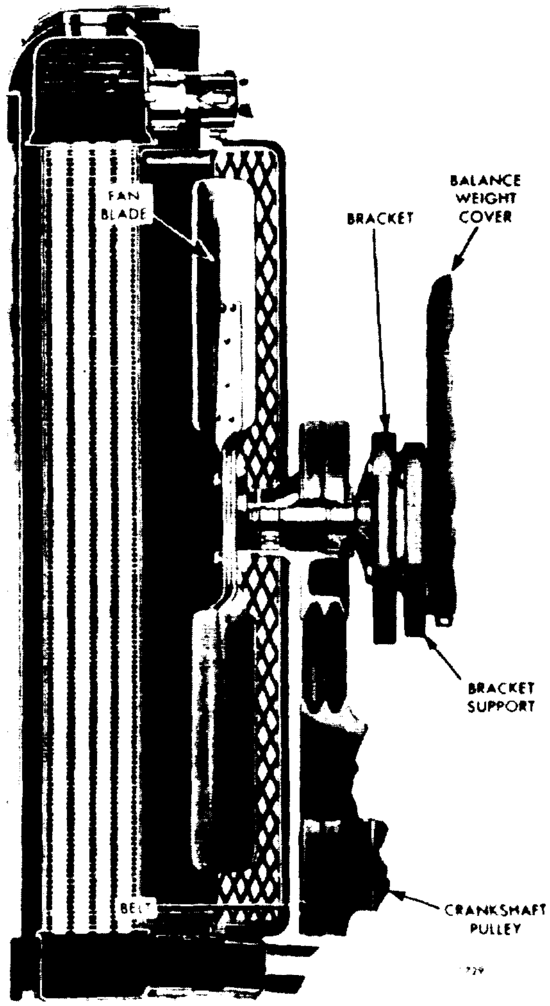

Figure 11F-14. Fan and Fan Hub Assembly

Lubrication

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled.

Fan Belt Adjustment

Adjust the fan belt(s) periodically as outlined in the operator's manual.

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 lock washers. 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.

Remove Fan, Hub and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with 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, lock washers and nuts, then remove the fan and spacer.

NOTE

> If insufficient clearance exists between the fan and radiator, remove the fan, hub and adjusting bracket as an assembly.

3. Remove the two adjusting bolts, lock washers and plain washers, then remove the drive belts.

4. Loosen the adjusting bolts until the bracket is free. Remove the hub and bracket assembly from the engine.

Disassemble Fan, Hub, and Bracket

Refer to Figure 11F-15 on page 11F-16, Figure 11F-17 on page 11F-17, and Figure 11F-16 on page 11F-16 and disassemble the fan, hub and adjusting bracket as follows:

1. Remove the fan attaching bolts and lock washers and detach the fan and the spacer.

2. Remove the fan hub cap.

3. Remove the hub bolt and washer.

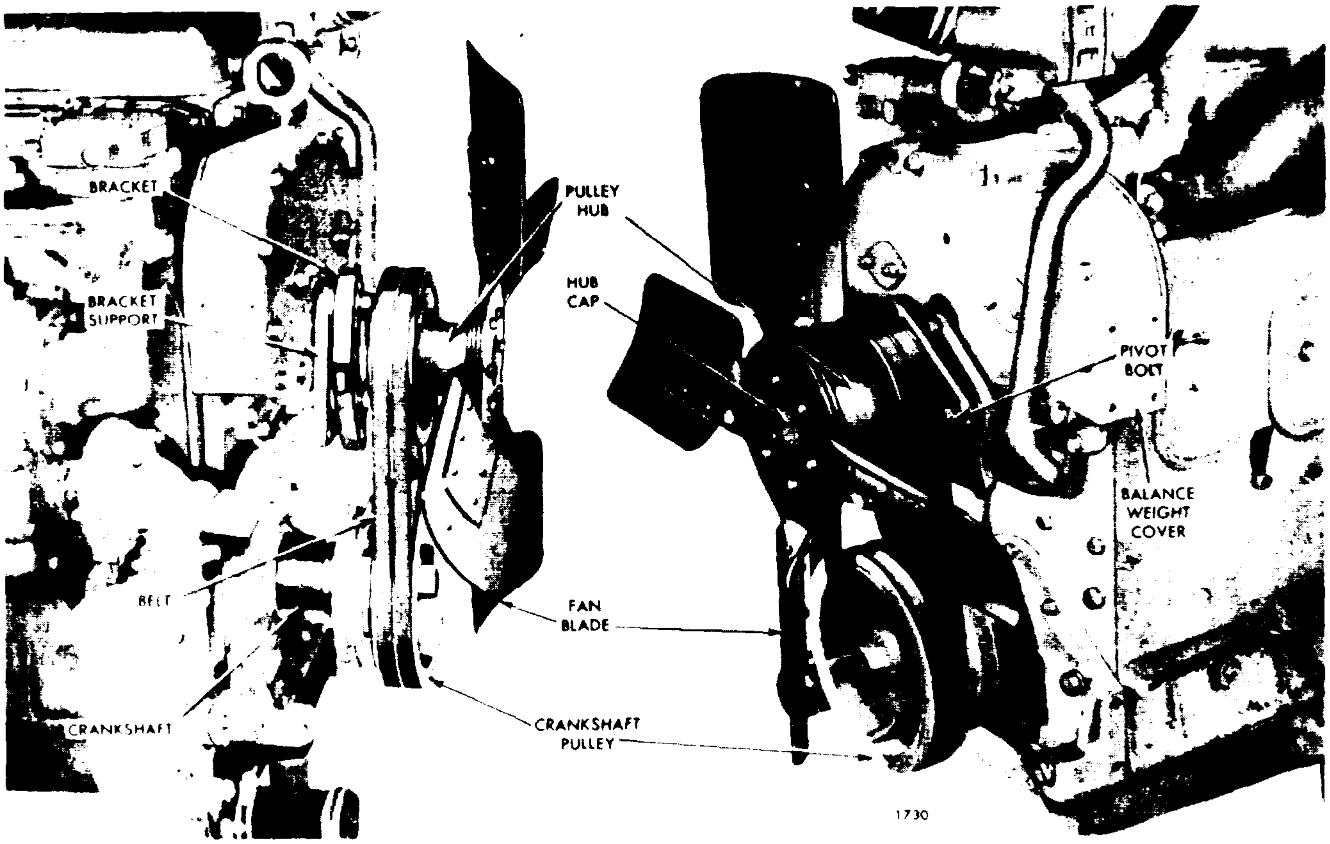

Figure 11F-15. Fan Mounting

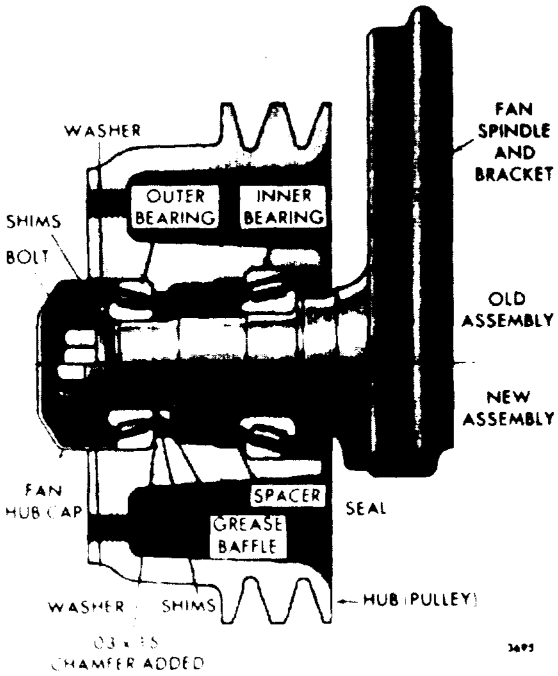

Figure 11F-16. Shaft Type Fan Hub Assembly

4. Withdraw the hub and bearing assembly from the shaft. It may be necessary to the tap the end of the shaft with a soft hammer to loosen the hub assembly.

5. Remove the bearings and oil seal as follows:

A. Remove the ball bearing by tapping alternately around the outer edge of the bearing with a small brass rod and hammer.

B. Drive the oil seal from the hub. Discard the oil seal.

C. Remove the inner (rear) roller in the same manner as outlined in Step A.

Inspection

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

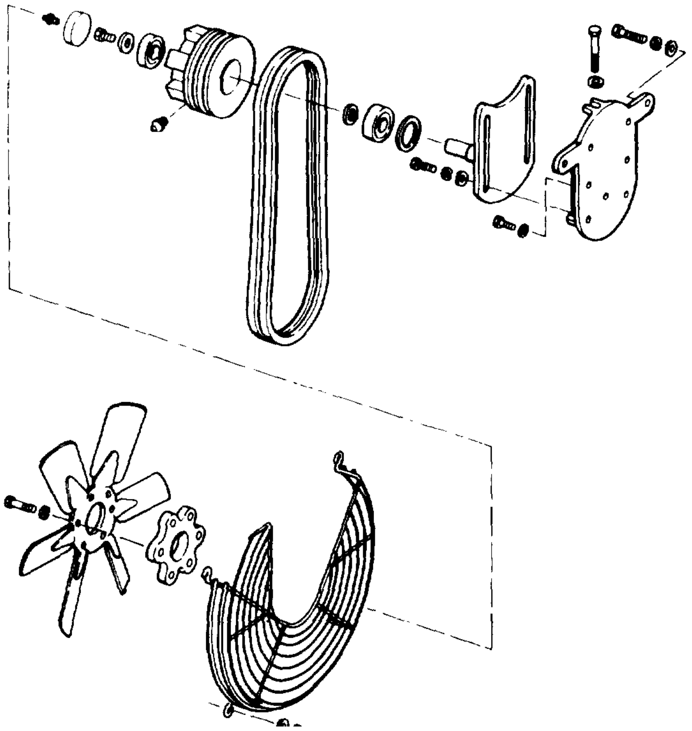

Figure 11F-17. Fan Hub and Adjusting Bracket Details

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 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.

The 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".

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.

Assemble Fan, Hub and Bracket

Assemble the fan hub and bracket shown in Figure 11F-17 and Figure 11F-16 on page 11F-16 as follows:

1. Apply Texaco Premium RB grease, or an equivalent Lithium base multi-purpose grease, to the rollers of both bearings before installing them in the pulley hub.

2. Install the inner (rear) roller bearing assembly, 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.

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. 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.

5. Pack the cavity 20-30% full with grease as outlined in Step 1.

6. Install outer (front) bearing assembly.

7. Secure the hub with the washer and bolt. Tighten the 1/2" - 20 bolt to 83-93 lb-ft (113-126 Nm) torque while rotating the pulley.

8. 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.

9. Secure the fan blade and spacer to the pulley hub with six bolts, nuts, and lock washers. Tighten the nuts to 15-19 lb-ft (20-26 Nm) torque.

Install Fan, Hub and Bracket

1. Attach the fan hub and adjusting bracket assembly to the support bracket on the engine with bolts, lock washers and plain washers. Do not tighten the bolts.

2. Install the drive belts and adjust the belt tension as outlined in the Operators Manuals, Section V. Install the adjusting bracket, bolt and plain washer.

3. Install the fan (and fan spacer) on the hub and secure it with bolts and lock washers.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	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	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	1	No. 6 thru 1 1/2	60,000
None	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	7	1/4 thru 1 1/2	133,000
Bolts and Screws	8	1/4 thru 1 1/2	150,000
Bolts and Screws	None	No. 6 thru 1 1/2	55,000

BOLT IDENTIFICATION CHART

SERVICE TOOLS

TOOL NAME	TOOL NO.
Water pump and fuel pump wrench	J 4242
Water pump drive coupling remover	J 1930
Water pump impeller installer	J 22437

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	(lb-ft)	(Nm)
Water pump coupling bolt	5/16-24	18 min.	24 min.
Water manifold nut	3/8-24	25-30	34-41

STUD TORQUE SPECIFICATIONS

APPLICATION	TORQUE (lb-ft)	TORQUE (Nm)
Water manifold stud	10-25	14-34

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SECTION 11G

EXHAUST SYSTEM

DESCRIPTION

This engine is equipped with an air cooled 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.

EXHAUST MANIFOLD

General

The air cooled exhaust manifold is mounted on the cylinder head (see Figure 11G-1).

An exhaust manifold hold down crab is used. The hold down crab is made of a hardened steel. This will minimize wear and gouging of the manifold, crab and cylinder head mating surfaces, which results in a loss in the torque on the hold down crab nut.

Also a special washer is used at the center portions of the exhaust manifolds. This washer will more accurately control the seating area for the 7/16" nut or bolt.

Remove Exhaust Manifold

Remove the manifold as follows:

1. Disconnect the exhaust pipe 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 nuts be loosened but left on the center stud until all of the other nuts and washers have been removed.

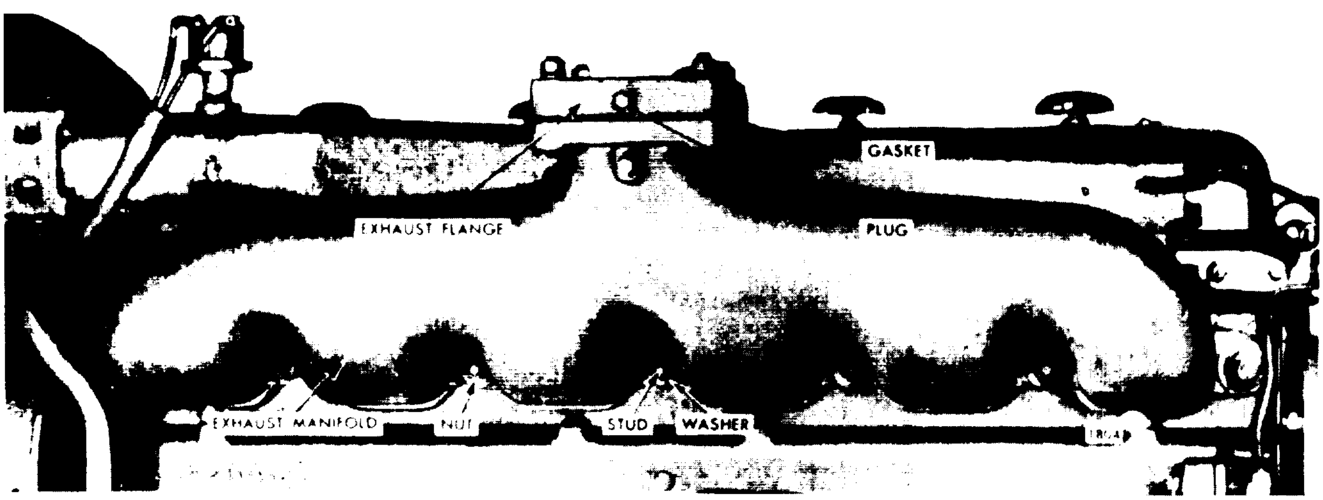

Figure 11G-1. Air Cooled Exhaust Manifold Mounting

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.

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 in to 25-40 lb-ft (34-54 Nm) torque.

Install Exhaust Manifold

Install the exhaust manifold on the cylinder head as follows:

1. Place a new gasket(s) over the studs and up against the cylinder head.

NOTE

> When installing the metal clad exhaust manifold gasket(s), be sure the crimped side of the gasket faces the cylinder head (see Figure 11G-2).

2. Position the exhaust manifold over the studs and against the gasket(s).

3. Install the bevel washers on the studs.

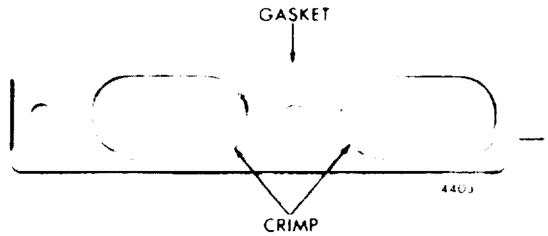

Figure 11G-2. Metal Clad Exhaust Manifold Gasket

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 lb-ft (41-47 Nm) torque.

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 to the manifold. Tighten the brass exhaust manifold outlet flange nuts to 20-25 lb-ft (27-34 Nm) torque.

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SUBSECTION 11H

ENGINE TUNE-UP

GENERAL

This subsection will include tune-up information including governor adjustments, fuel injection timing, throttle linkage adjustments and exhaust valve clearance adjustments.

ENGINE TUNE-UP PROCEDURES

General

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 mechanism, governor, etc. should only be required periodically to compensate for normal wear on parts.

To comply with emissions regulations, injector timing, exhaust valve clearance, engine idle and no-load speeds, and throttle delay or fuel modulator settings must be checked and adjusted, if necessary, at 50,000 miles (80 467 km) intervals (refer to Section 5 of operators manual). The type of governor used depends upon the engine application. Since each governor has different characteristics, the tune-up procedure varies accordingly. The variable speed mechanical governor is used.

The mechanical 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 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 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, perform all of the adjustments, except the valve bridge adjustment 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.

NOTE

> The exhaust valve bridges 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 in Subsection 11B.

Use a new valve rocker cover gasket after the tune-up is completed.

Tune-Up Sequence

CAUTION

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.

EXHAUST VALVE CLEARANCE ADJUSTMENT

General

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, increased valve face wear and valve lock damage.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or valve operating mechanism is replaced or disturbed in any way, the valve clearance must be first 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.

Engines With Four Cylinder Heads

GENERAL. The exhaust valve bridges must be adjusted and the adjustment screws locked securely at the time the cylinder head is installed on the engine. The necessary adjustment procedure is outlined in Subsection 11B.

The exhaust valve bridge balance should be checked when a general valve adjustment is performed. After the bridges are balanced, adjust the valve clearance at the push rod only.

Do not disturb the exhaust valve adjusting screw.

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 Subsection 11A for the engine firing order.

VALVE CLEARANCE ADJUSTMENT (COLD ENGINE)

1. Remove the loose dirt from the valve rocker cover and remove the cover.

2. Place the governor speed control lever in the idle speed position. If a stop lever is provided, secure it in the stop position.

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is full depressed on the particular cylinder to be adjusted.

CAUTION

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 or the bolt may loosen.

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Place a 0.017” feeler gage, J 9708-01, between the end of the exhaust valve

stem and the valve bridge adjustment screw (see Figure 11H-1 on page 11H-3). Adjust the push rod to obtain a smooth pull on the feeler gauge.

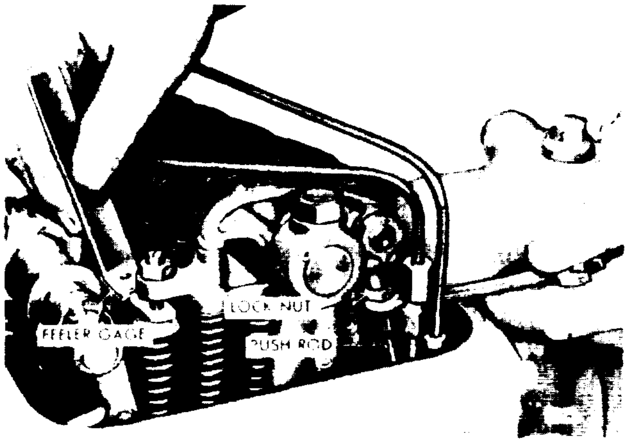

Figure 11H-1. Adjusting Valve Clearance

6. Remove the feeler gage, Hold the push rod with a 5/16” wrench and tighten the lock nut with a 1/2” wrench.

7. Recheck the clearance. At this time if the adjust is correct, the 0.015” gage will pass freely between the valve stem and the adjustment screw. The 0.017” will not pass through, Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

VALVE CLEARANCE ADJUSTMENT (HOT ENGINE). Maintaining normal engine operating temperature is particularly important when making the final exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance when running at full load, may become insufficient.

1. With the engine at normal operating temperature (refer to Subsection 11A), recheck the exhaust valve clearance with feeler gage J 9708-01. At this time, if the valve clearance is correct, the 0.013” gage will pass freely between the valve stem and the valve bridge adjusting screw. The 0.015” feeler gage will not pass through. Readjust the push rod if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing.

CHECK EXHAUST VALVE CLEARANCE ADJUSTMENT

1. With the engine operating 100°F (38°C) or less, check the valve clearance.

2. If a 0.016” feeler gage (J 9708-01) ± 0.004” will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary adjust the push rod.

FUEL INJECTOR TIMING

General

To time an injector properly, the injector follower must be adjusted to a definite height 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 General Specifications in Subsection 11A for the engine firing order.

Time Fuel Injector

After the exhaust valve clearance has been adjusted, time the fuel injectors as follows:

1. Place the governor speed control lever in the idle speed position. If a stop lever is provided, secure it in the stop position.

2. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed.

CAUTION

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 or the bolt may be loosened.

3. Place the small end of the injector timing gage in the hole provided in the top of the injector body with the flat of the gage toward the injector follower. Refer to Figure 11H-2 on page 11H-4.

Injector	Timing Dimension	Timing Gage	Camshaft Timing
N70	1.460"	J 1853	Standard

Figure 11H-2. Timing Fuel Injector

4. Loosen the injector rocker arm push rod lock nut.

5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.

6. Hold the push rod and tighten the lock nut. Check the adjustment and, if necessary, re-adjust the push rod.

7. Time the remaining injectors in the same manner as outlined above.

8. If no further engine tune-up is required, install the valve rocker cover, using a new gasket.

VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

General

After adjusting the exhaust valve and timing the fuel injectors, adjust the governor and the injector rack control levers.

Adjust Governor Gap

With the engine stopped, adjust the governor gap as follows:

1. Disconnect any linkage attached to the governor levers.

2. Remove the governor cover.

3. Place the speed control lever (Figure 11H-3) in the maximum speed position.

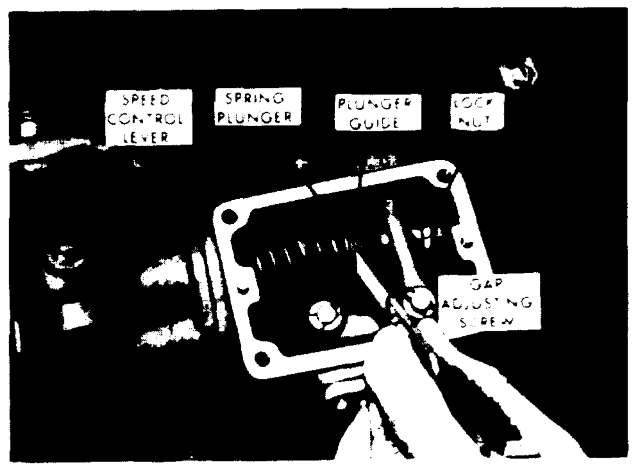

Figure 11H-3. Adjusting Governor Gap

4. Insert a 0.006" feeler gage between the spring plunger and the plunger guide. If required, loosen the lock nut and turn the adjusting screw in or out until a slight drag is noted on the feeler gage.

5. Hold the adjusting screw and tighten the lock nut. Check the gap, and reset it, if necessary.

6. Secure the governor to the governor housing with three regular screws, one special screw and lock washers.

7. Hook the tension retracting spring on the special cover screw and the stop lever (Figure 11H-4 on page 11H-5).

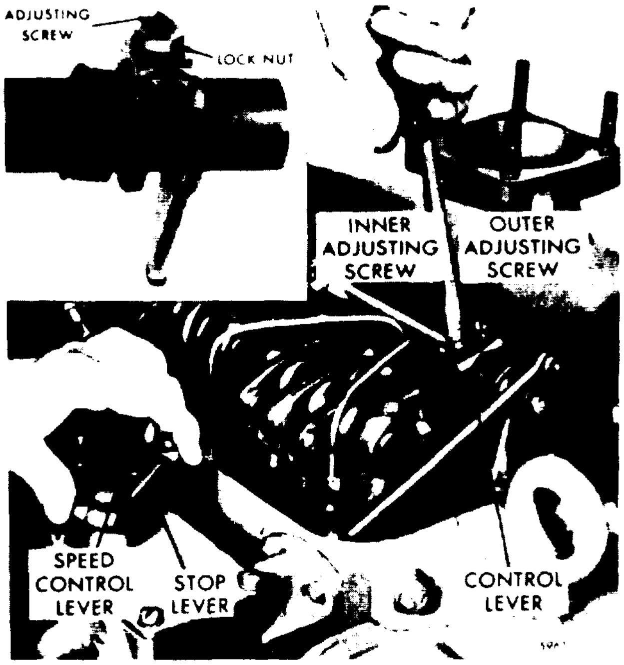

Figure 11H-4. Positioning No. 1 Injector Rack Control Lever

Position Injector Rack Control Levers

The position of the injector control rack 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.

Properly positioned injector rack control levers with the engine at full load will result in the following:

- Speed control lever at the maximum speed position.
- Stop lever in the RUN position.
- High speed spring plunger on the seat in the governor control housing.
- Injector fuel control racks in the full fuel position.

Adjust the No. 1 injector rack control lever (Figure 11H-4) first, to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the stop lever.

2. Loosen the lock nut (Figure 11H-5) and back out the buffer screw approximately 5/8".

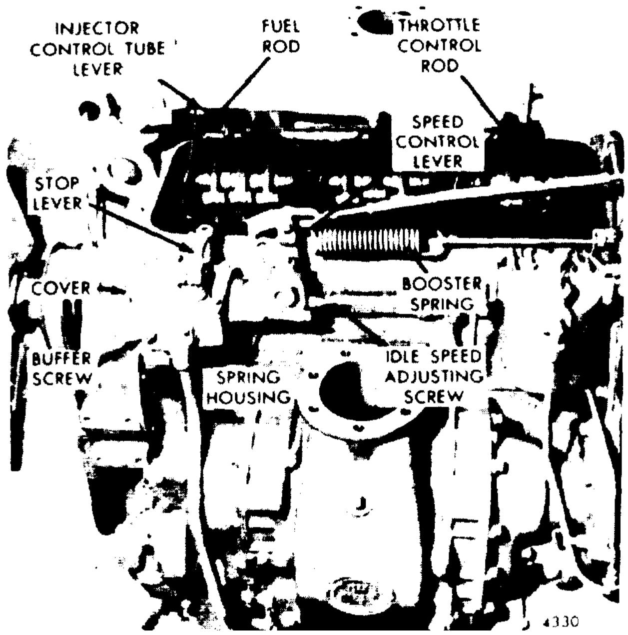

Figure 11H-5. Buffer and Idle Speed Adjusting Screw

3. Loosen all the inner and outer adjusting screws (Figure 11H-4). Be sure all the injector rack control levers are free on the injector control tubes.

4. Move the speed control lever to the maximum speed position.

5. 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

> Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 lb-in (3-4 Nm.)
>
> 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.

6. To be sure the control lever is properly adjusted, hold the speed control lever in the maximum speed position and press down on the injector rack with a screw driver or finger top and note “rotating” movement of the injector control rack (Figure 11H-6) when the speed control lever is in the maximum speed position and, using a screw driver, press downward on the injector control rack. The rack should tilt downward (Figure 11 H-7) and when the pressure of the screw driver is released, the control rack should “spring” back upward.

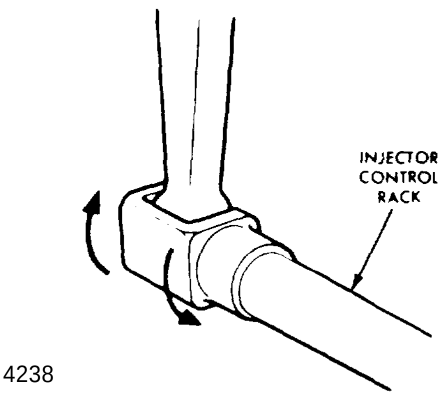

Figure 11H-6. Checking Rotating Movement Of Injector Control Rack

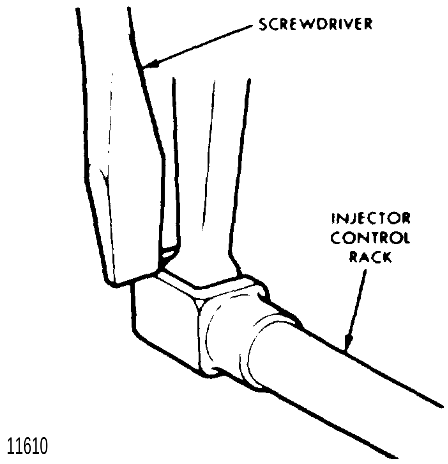

Figure 11H-7. Checking Injector Control Rack "Spring"

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 slightly.

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 slightly.

7. Manually hold the No. 1 injector rack in the full fuel position and turn down the inner adjusting screw (Figure 11H-4 on page 11H-5) of the No. 2 injector until the injector rack has moved into 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 until tight.

8. Recheck the No. 1 injector rack to be sure that it has remained snug on the ball and of the rack control lever while positioning the No. 2 injector rack. If the rack of the No. 1 injector has become loose, back off slightly the inner adjusting screw on No. 2 injector control lever. Tighten the outer adjusting screw.

9. Position the remaining injector rack control levers as outlined in Steps 7 and 8.

Adjust Maximum No-Load Speed

The maximum no-load speed on engines equipped with variable speed governors must not be less than 125 rpm or more than 150 rpm above the recommended full load speed.

With a hand tachometer determine the maximum no-load speed of the engine then, make the following adjustments, if required:

1. Refer to Figure 11H-5 on page 11H-5 and disconnect the booster spring.

2. Remove the two bolts and withdraw the variable speed spring housing and the variable speed spring plunger from inside the spring housing.

A split stop can only be used with a solid stop (Figure 11H-8 on page 11H-7).

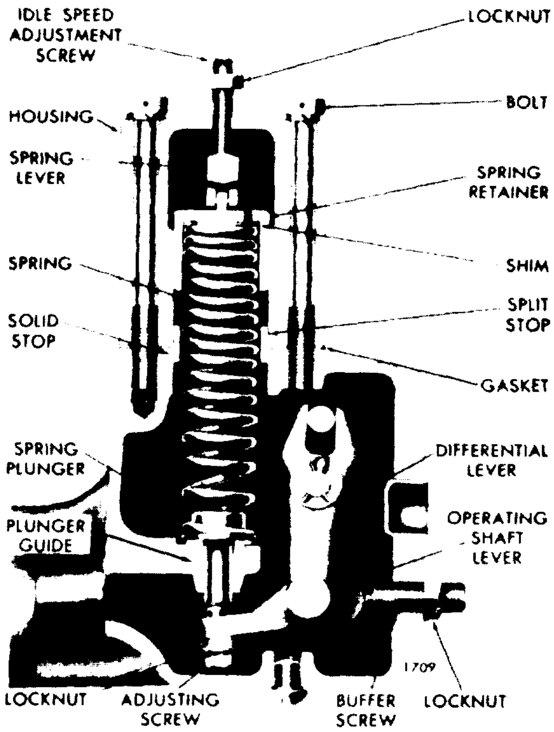

Figure 11H-8. Locating of Stops and Shims

3. Refer to the following table and determine the stops or shims required for the desired full load speeds.

Full Load Speed	Stops	Shims
1450 to 1650 rpm	2	Amount Required to get necessary speed.
1651 to 2150 rpm	1	
2151 to 2300 rpm	0	

4. Install the variable speed spring housing and recheck the maximum no-load speed.

5. If required, add shims to obtain the necessary operating speed.

NOTE

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.

If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

Adjust idle Speed

With the maximum no-load speed properly adjusted, the idle speed may be adjusted as follows:

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 lock nut 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 the engine application.

4. Hold the idle speed adjusting screw and tighten the lock nut.

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. Turn the buffer screw in until the engine is operating at the recommended idle speed. Do not raise the engine speed more than 15 rpm with the buffer screw.

2. Hold the buffer screw and tighten the lock nut.

Adjust Booster Spring

With the engine idle speed set, adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. Refer to Figure 11H-5 on page 11H-5 and loosen the booster spring retaining nut on the speed control lever. Loosen the lock nuts on the eye bolt at the opposite end of the 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 speed 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 lever does return to idle and tighten the lock nuts on the eye bolt. This setting will result in the minimum force required to operate the speed control lever.

ENGINE RUN-IN INSTRUCTIONS

General

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 10° higher than the water inlet temperature. Though a 10° rise across an engine is recommended, it has been found that a 15° 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 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 the thermostat.

The Basic Engine Run-In Schedule is shown in the following table. The horsepower shown is at SAE conditions; dry air density 0.0705 lb/cu. ft (1.129 kg/m^3), air temperature of 85°F (29.4°C), and 500 ft. (152 m) elevation.

BASIC ENGINE RUN-IN SCHEDULE

Speed (rpm)	Time (minutes)	Horsepower
1200	10	28
1800	30	90
*1800	30	110
*2100	30	118
*2300	30	128

*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

Speed (rpm)	Time (minutes)	Horsepower
1200	10 (minimum)	28
2100	30	116
2100	30	130
2100	30	*

*Within ± 5% of rated bhp.

Dynamometer Test and Run-In Procedures

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 basis 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 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.

DYNAMOMETER. The function of the dynamometer is to absorb and measure the engine output. It's 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 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 (lb-ft) on a suitable scale. The values 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 lb-ft
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, shown at the end of this subsection.

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 gage installed in one of the engine main oil galleries.

2. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.

3. Adaptor for connecting a pressure gage or mercury manometer to the engine air box.

4. Water. temperature gage installed in the thermostat housing or water outlet manifold.

5. Adaptor for connecting a pressure gage or water manometer to the crankcase.

6. Adaptor for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.

7. Adaptor for connecting a vacuum gage or water manometer to the blower inlet.

8. Adaptor for connecting a fuel pressure gage to the fuel manifold inlet passage.

9. Adaptor for connecting a pressure gage or mercury manometer to the turbocharger.

In some cases, gages 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 gage be of low range and finely divided if accuracy is desired. This is especially turn of a gage 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 of Preparation for Starting Engine First Time in this subsection.

RUN-IN PROCEDURE. The procedure outlined below will follow the order of the sample Engine Test Report.

1. Pre-Starting

A. Fill the lubrication system as outlined under “Lubrication System” on page 11H-12.

B. Prime the fuel system as outlined under "Fuel System on page 11H-13.

C. A preliminary valve clearance adjustment must be made before the engine is started. See “Valve Clearance Adjustment (Cold Engine) on page 11H-2

D. A preliminary injector timing check must be made before starting the engine. See “Fuel Injector Timing” on page 11H-3

E. Preliminary governor and injector rack adjustments must be made as outlined in “Variable Speed Mechanical Governor And Injector Rack **Control Adjustment” on page 11H-4.**

NOTE

Prior to starting a turbocharged engine, remove the oil supply line at the turbocharger and add clean engine oil to the oil inlet to ensure pre-lubrication of the turbocharger. Reconnect the oil line and idle the engine for at least one minute after starting and before increasing the speed.

2. 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 lb-ft on the torque gage (or 10-15 HP on a horsepower gage). 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 the rear of Subsection 11A, which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack or power.

If the engine is to be run at speeds in excess of 1800 rpm it must be equipped 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 cannot 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.

3. 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.

4. 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.

5. 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 Subsection 11A, 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, Subsection 11A.

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 (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. 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 Subsection 11A. Record these readings on the Engine Test Report.

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 Subsection 11A).

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 confirm 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.

6. 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 (see Section 3 for coolant specifications). The lubricating oil filters should also be changed.

ENGING OPERATING INSTRUCTIONS

Preparation For Starting Engine First Time

GENERAL. Before starting an engine for the first time, carefully read and follow the instructions in this subsection. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

NOTE

When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see Daily Operations in the operators manual.

COOLING SYSTEM. Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Remove the fill cap and fill the cooling system with a coolant specified in Section 3. Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

LUBRICATION SYSTEM. The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum or 25 psi (172 kPa) oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine start-up. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use heavy-duty lubricating oil as specified in the operator manual. Then remove the dipstick, wipe it with a clean cloth, insert and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the full mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, full the crankcase to the proper level with heavy-duty lubricating oil as specified in Section 3. Then prelubricate the upper engine parts by removing the valve rocker cover and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

TURBOCHARGER. Prepare the turbocharger as follows:

1. Clean the area and disconnect the oil inlet line at the bearing housing.

2. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

3. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

WARNING

Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

4. 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 - 69 kPa at idle speed).

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 turbocharged 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 bearing of the turbocharger.

TORQUE CONVERTER. Check the oil level and, if necessary, fill the torque converter supply tank to the proper level with the lubricant specified in Section III.

FUEL SYSTEM. Fill the fuel tank with the fuel specified in Section III.

To ensure prompt starting, fill the fuel system between the pump and the fuel return manifold with fuel. If the engine has been out of service for a considerable length of time, prime the fuel system between the fuel pump and the fuel return manifold, The fuel system may be primed by removing the plug in the top of the fuel filter cover and slowly filling the filter with fuel.

NOTE

The fuel system is filled with fuel before leaving the factory, If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

LUBRICATION FITTINGS. Fill all grease cups and lubricate at all fittings with an all purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

DRIVE BELTS. Adjust all drive belts as recommended in Section V of operators manual.

STORAGE BATTERY. Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly and the electrolyte must be at the proper level.

NOTE

When necessary, check the battery with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

CLUTCH. Disengage the clutch.

Starting

GENERAL. Before starting the engine for the first time, perform the operations listed under “Preparation For Starting Engine First Time” on page 11H-12

Before a routine start, see checks in Section V of operator manual.

Starting at air temperatures below 40°F (4°C) requires the use of a cold weather starting aid. See operators manual.

WARNING

Starting fluid used in capsules is highly inflammable, toxic and possesses anesthetic properties.

The instructions for the use of a cold weather fluid starting aid will vary depending on the type being used. Reference should be made to these instructions before attempting a cold weather start.

INITIAL ENGINE START. Start an engine as follows:

1. Set the speed control lever at part throttle, then bring it back to the desired no-load speed. Make sure the stop lever on the governor cover is in the run position.

2. Press the starting motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

NOTE

To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

Running

OIL PRESSURE. Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. Refer to the Trouble Shooting Charts in Section IV.

WARM-UP. Run the engine at part throttle and no load for approximately five minutes, allowing it to warm-up before applying a load.

If the unit is operating in a closed room, start the room ventilating fan or open the windows, as weather conditions permit, so ample air is available for the engine.

INSPECTION. While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

ENGINE TEMPERATURE. Normal engine coolant temperature is 160-185° (71-85°C).

CRANKCASE. If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached. Allow the oil to drain (approximately twenty minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick. Use only the heavy duty oil specified in Section III.

COOLING SYSTEM. Remove the radiator cap slowly after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water or a permanent type antifreeze.

TURBOCHARGER. Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

AVOID UNNECESSARY ENGINE IDLING. During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

NOTE

> When prolonged engine idling is necessary, maintain at least 800 rpm.

Stopping

NORMAL STOPPING. Stop the engine as follows:

1. Release the load and decrease the engine speed. Put all shift levers in the neutral position.

2. Allow the engine to run at half speed or slower with no load for four or five minutes, then move the stop lever to the stop position to stop the engine.

EXHAUST SYSTEM. Drain the condensation from the exhaust line.

COOLING SYSTEM. Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open.

CRANKCASE. Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.

INSPECTION. Make a visual check for leaks in the fuel, lubricating and cooling systems.

CLEAN ENGINE. Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to Section V of operator's manual and perform all of the daily maintenance operations. Also perform the operations required for the number of hours or miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which may have occurred during the pervious run.

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		RPM	BHP	WATER TEMP.	LUBE OIL PRESS.
	START	STOP				

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		TOP RPM		BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L
START	STOP	NO LOAD	FULL LOAD				

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN. F/L	WATER TEMP. FULL LOAD	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE		IDLE SPEED
				FULL LOAD	IDLE	

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.

SECTION XII

SUPPLEMENTAL OPERATING, MAINTENANCE AND REPAIR PARTS INSTRUCTIONS (SOMARPI)

SUPPLEMENTAL OPERATING MAINTENANCE
AND
REPAIR PARTS INSTRUCTIONS
FOR

CRANE, CRAWLER, 40 TON MODEL 5060

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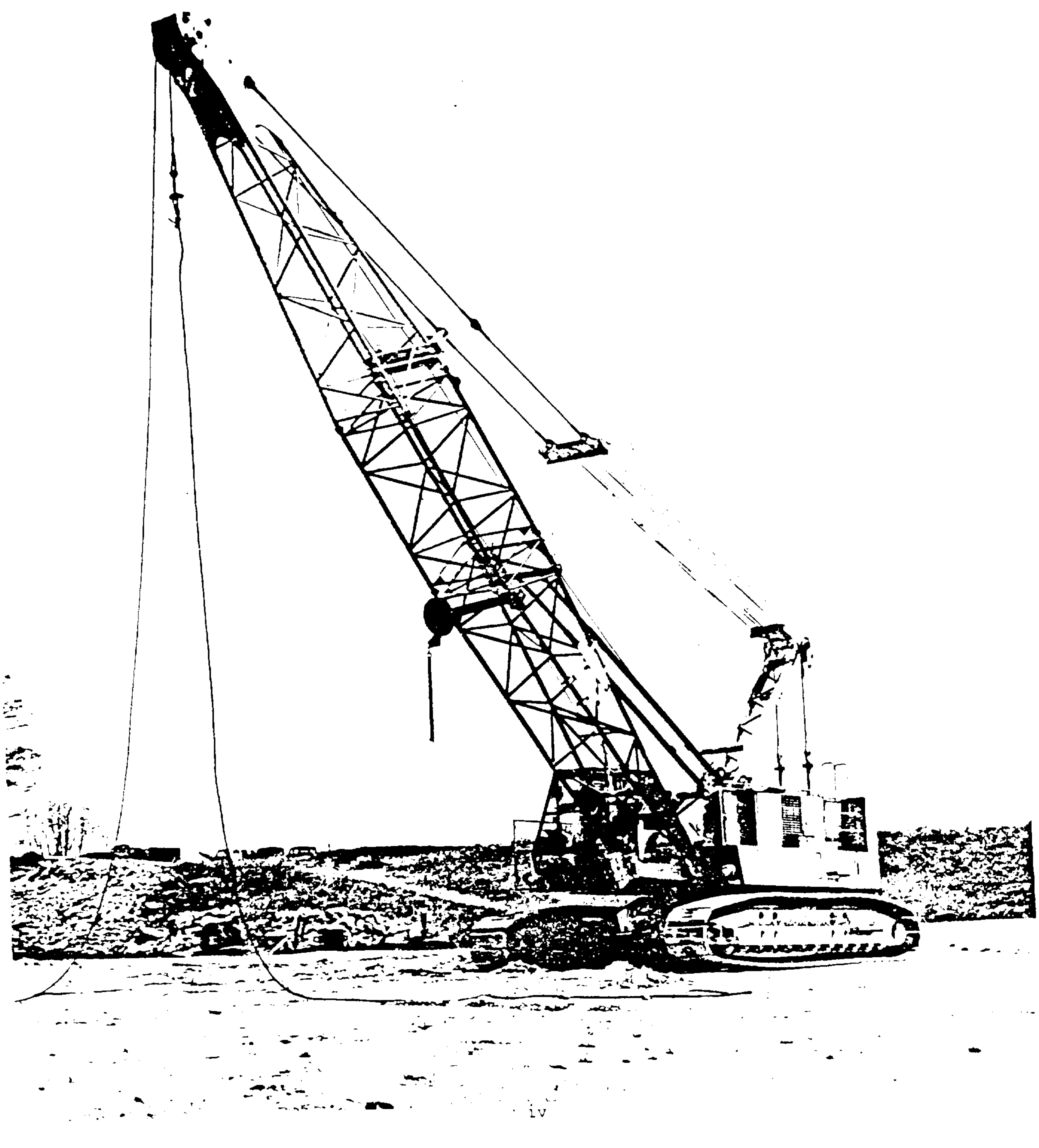

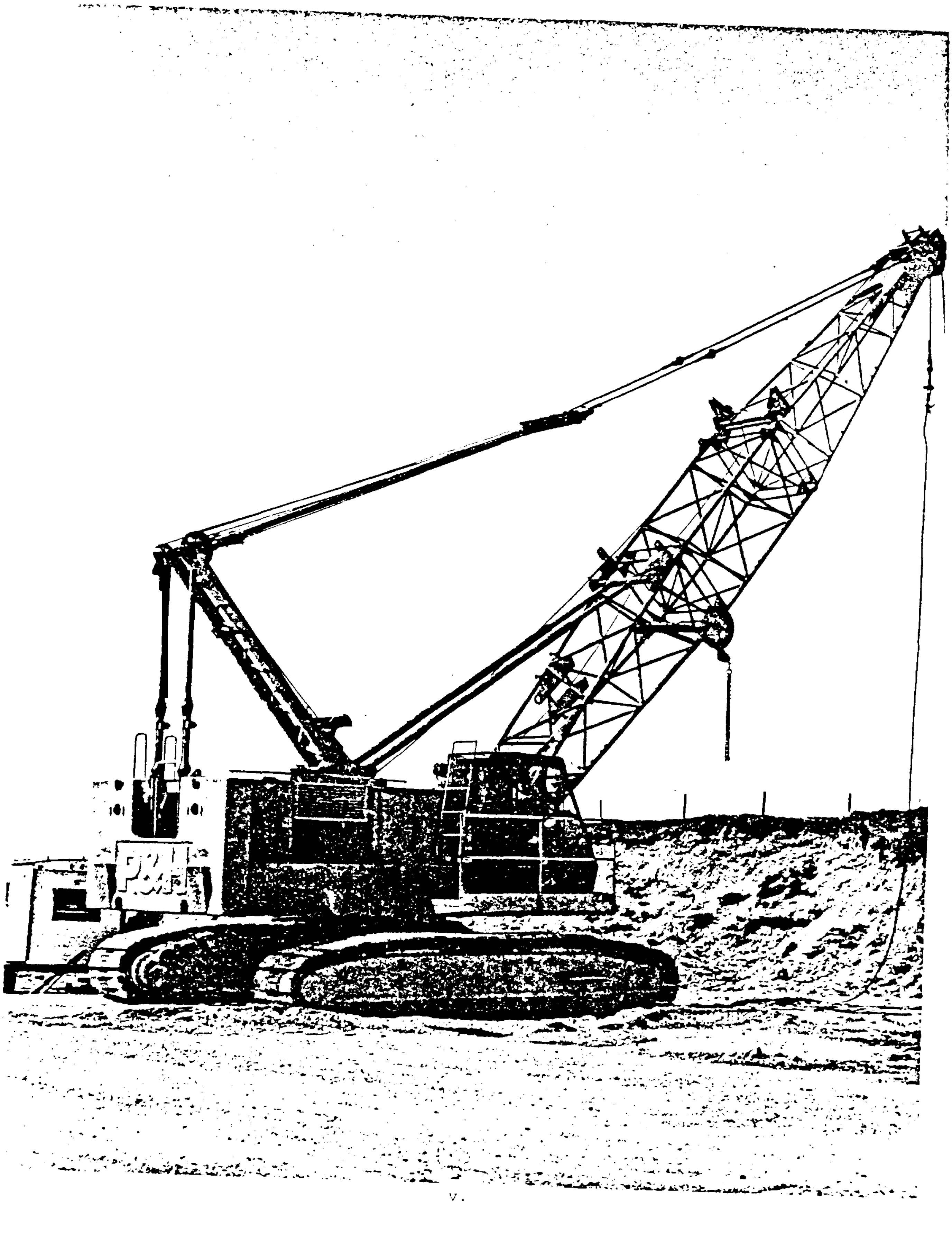
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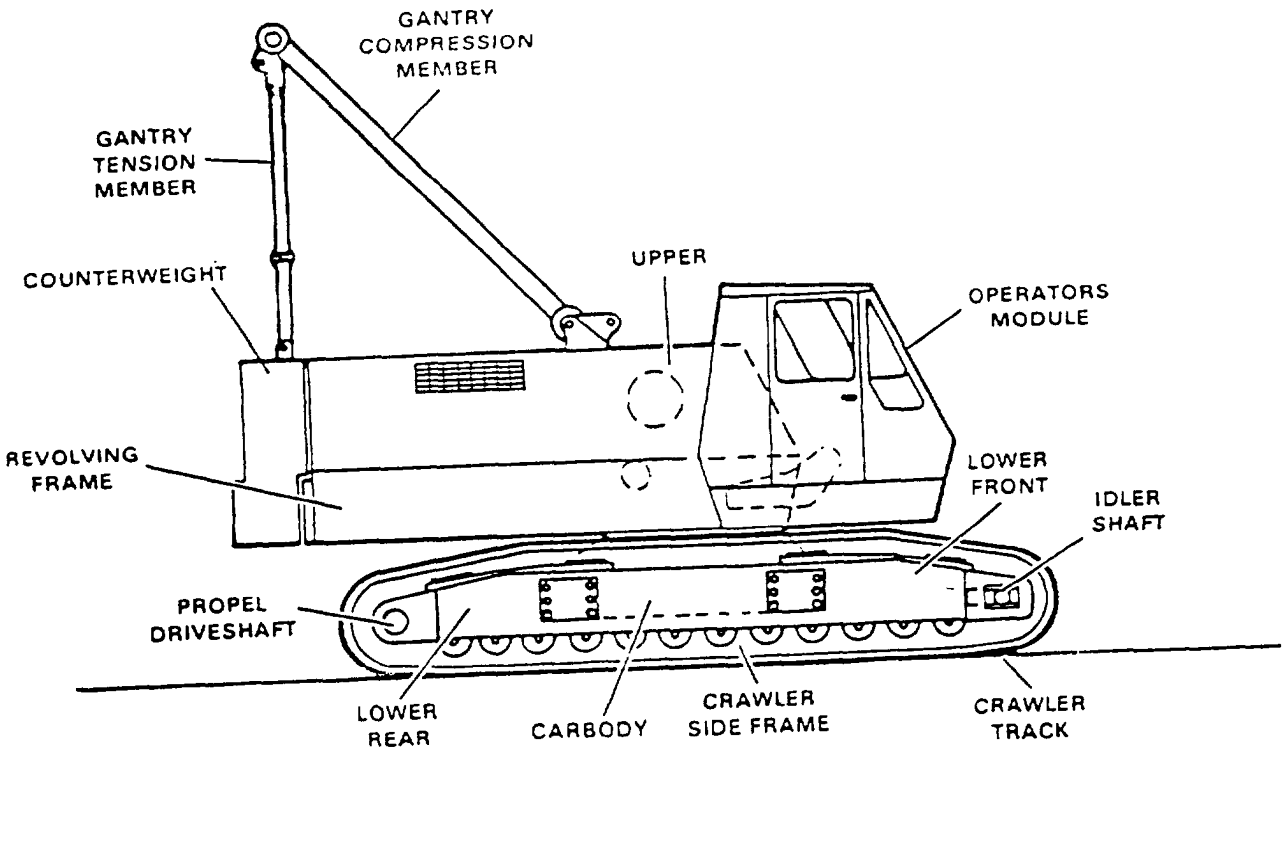
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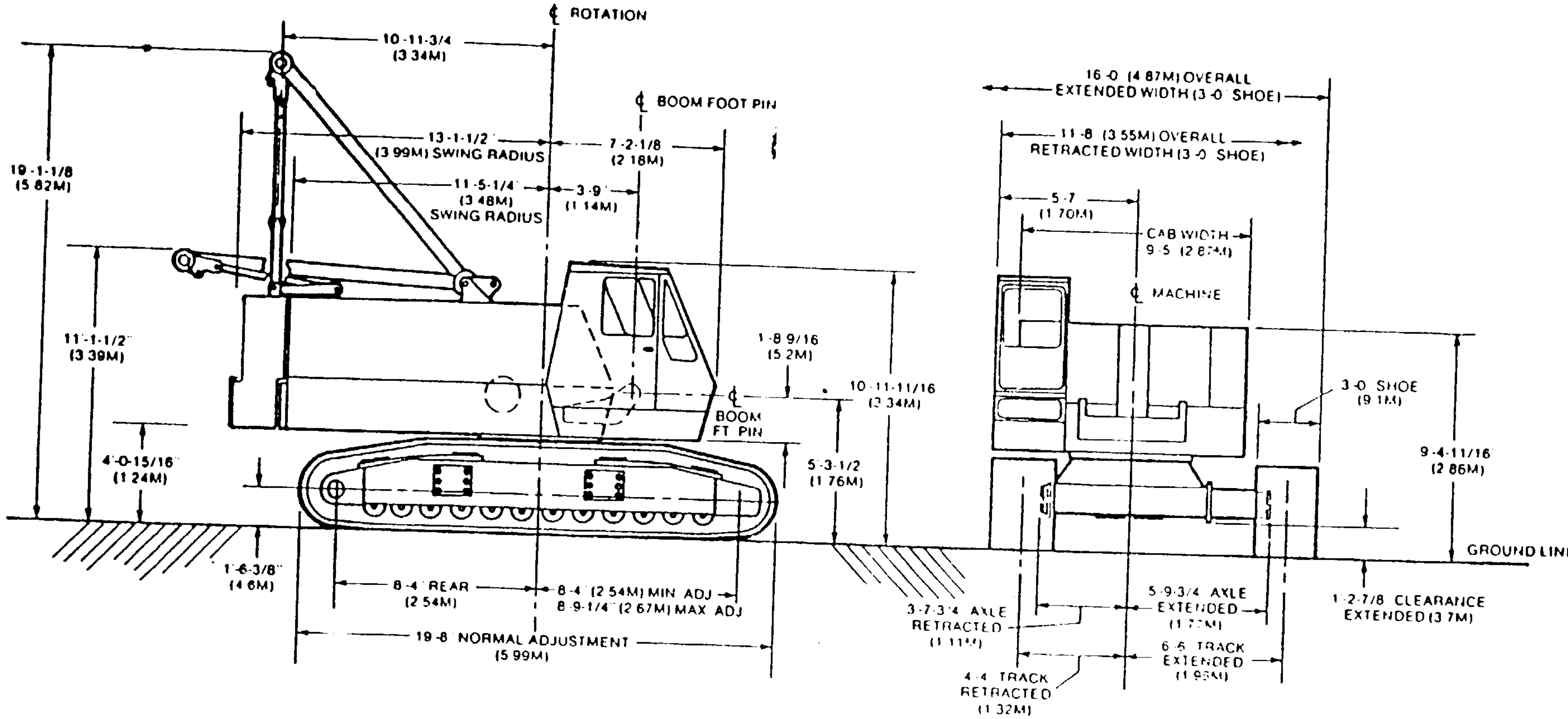

℄ ROTATION
10-11-3/4 (3 34M)
19-1-1/8 (5 82M)
℄ BOOM FOOT PIN
13-1-1/2 (3 99M) SWING RADIUS
7-2-1/8 (2 18M)
11-5-1/4 (3 48M) SWING RADIUS
3-9 (1 14M)
11-1-1/2 (3 39M)
1-8 9/16 (5 2M)
10-11-11/16 (3 34M)
℄ BOOM FT PIN
4-0-15/16 (1 24M)
5-3-1/2 (1 76M)
1-6-3/8 (4 6M)
8-4 REAR (2 54M)
8-4 (2 54M) MIN ADJ
8-9-1/4 (2 67M) MAX ADJ
19-8 NORMAL ADJUSTMENT (5 99M)
16-0 (4 87M) OVERALL EXTENDED WIDTH (3-0 SHOE)
11-8 (3 55M) OVERALL RETRACTED WIDTH (3-0 SHOE)
5-7 (1 70M)
CAB WIDTH 9-5 (2 87M)
℄ MACHINE
3-0 SHOE (9 1M)
9-4-11/16 (2 86M)
GROUND LINE
1-2-7/8 CLEARANCE EXTENDED (3 7M)
5-9-3/4 AXLE EXTENDED
3-7-3/4 AXLE RETRACTED
6-5 TRACK EXTENDED
4-4 TRACK RETRACTED (1 32M)

SECTION I

GENERAL

1. Purpose: To provide user and support personnel Supplemental maintenance and repair parts instructions that have special application to non-developmental items of equipment.

2. Scope: This publication applies to Department of the Army units, organizations/ activities that use and support the Harnischfeger Crane, Crawler, 40 Ton, Model 5060. The expected life of this crane is 20 years.

3. Non-Developmental Item (NDI): This crane has been approved for use by TO & E/ TDA Organizations. The end item will be supported by Commercial/Military Publications and repair parts supplied by the military supply system or local dealers. Transportability/Bridge classification data is available by calling U.S. Army Tank-Automotive Command, DRSTA-MVB, AUTOVON 786-8901.

4. Description: This crane is crawler mounted, 40 ton, Model 5060, and is manufactured by Harnischfeger Corporation at their Escanaba, Michigan plant. The crane is full revolving and has the capability of extending/retracting the side frames to accomodate counterweights for stability and control. The operational and maintenance procedures are covered in the manufacturer's manuals overpacked with each unit, This crane is a friction and hydraulic machine. All upper work functions are performed by friction clutches and brakes. Hydraulic cylinders are used to apply the clutches and planetary brakes. The drum, swing and boom hoist brakes are released by hydraulic cylinders working against the brake's spring actuators.

The engine (4-71-T) serves as the power source for the upper and lower drive systems. Power is transferred through the torque converter into the worm shaft. This shaft drives the boom hoist shaft, maint shaft, and swing shaft by a chain when the master clutch is engaged. However, the drumshafts do not turn the drums or the swing gear until the proper clutch is engaged by the operator.

The engine drives a hydraulic control pump which provides hydraulic power to the control valves in the operator's cab. The control pump supplies hydraulic oil to the crawler extension/retraction valves mounted on the car body. These valves direct oil to the side frames from extension cylinders.

The engine drives a pump mounted at the front of the engine which transmits power to two variable displacement pumps, these pumps supply power to the crawler motors.

5. Publications: Initial publications are commercial manuals and two of each are overpacked with the end item. See Appendix I.

Department of the. Army publications will be forthcoming and will be available through your normal publication supply system.

6. Attachment: Attachments such as Pile drive, Fairlead, Jib, 10' Extensions (inserts), Clamshell/dragline buckets, Shovelfront/Backhoe are now considered major items of supply. They are authorized by TDA/TO&E by line numbers. A list of attachments used with this crane is shown as Append ix H.

7. Personnel:

MOS requirements (AR 611-201)

a. Crane Operator MOS 62F30

b. Mechanic Org. MOS 62B20

c. Mechanic DS/GS MOS 62B30

8. Training: This crane is not entirely a new configuration. Training will be determined by the using organization. Using Commander is to arrange qualified training and may request assistance from support organizations. If further assistance is required a request should be forwarded to Commander, U.S. Army Tank-Automotive Command (TACOM), AMSTA-ML, Warren, MI 48397-5000.

9. Warranty: Warranty period for the model 5060 is 15 months following date of acceptance by the Government. All warranties will be processed through, U.S. Army Tank-Automotive Command, AMSTA-MVB, Warren, MI 48397-5000, AUTOVON 786-8901. (See Appendix K)

10. Reporting Errors and Recommending Improvements: You can help improve this manual. If you find any mistakes or know of a way to improve the procedures, please let us know. Mail your letter or DA Form 2028 direct to: Commander, U.S. Army Tank-Automotive Command, AMSTA-MB, Warren, MI 48397-5000. A reply will be furnished to you.

11. Common Hardware: All common hardware, (consisting *of* cap screws, nuts and washers) is plated, grade 5 throughout this crane. Exception to this only is indicated in the Shop/Part Commercial Manuals. Dimensions, in relation to fractions, is shown on Appendix G.

SECTION II

MAINTENANCE

12. Maintenance Concept:

a. Operator: Operator is limited to performing operator/crew preventive maintenance checks and services.

b. Organizational Maintenance: Organizational maintenance consists of scheduled preventive maintenance services, minor repairs and adjustments in accordance with the Maintenance Allocation Chart.

c. Direct Support Maintenance: Direct Support Maintenance consists of repairs on-site or in direct support unit's shop. Repairs are accomplished with a minimum of tools and test equipment. Maintenance is performed on a repair-and-return-to-user basis, and organizational maintenance repair parts are supplied to using units.

d. General Support Maintenance: General Support Maintenance will repair and return to the supply system designated assembled modules which overflow from or exceed the capability of Direct Support Maintenance.

13. Maintenance Allocation Chart (MAC): See Appendix A 1. Units may exceed their authorized scope and function in the MAC when approved by the Support Maintenance Commander.

14. Shipment and Storage: Refer to the manufacturer's Operating Instructions and Service Manual, and TB 740-97-2.

15. Destruction to Prevent Enemy Use: Refer to TX 750-444-3 for instructions governing destruction of equipment to prevent enemy use.

16. Special Tools and Equipment: See Appendix A2.

17. ·Petroleum Supply List Supplies: See Appendix F for a list of petroleum supplies required for operation.

18. Maintenance Forms and Records:

a. Operational Records: Operational records (DA Forms 2400 and 2401) are optional and may be utilized at the descretion of the using organization.

b. Maintenance Records:

(1) DA Form 2402, Exchange Tag.

(2) DD Form 314, Preventive Maintenance Schedule and Record.

(3) DA Form 2404, Equipment Inspect ion and Maintenance Worksheet.

(4) DA Form 2405, Maintenance Request Register.

(5) DA Form 2407, Maintenance Request.

c. Historical Records:

(1) DA Form 2408, Equipment Logbook Assembly.

(2) DA Form 2408-5, Equipment Control Record.

(3) DA Form 2408-9, Equipment Modification Record.

(4) DA Form 2408-10, Equipment Component Register.

(5) DA Form 2408-14, Uncorrected Fault Record.

(6) DA Form 2408-20, Oil Analysis Log.

19. Lubrication: To insure proper operation of this machine, all points requiring lubrication must be serviced with the correct lubricant, at the proper time interval. All normal wear points which require lubrication are shown in the lubrication chart, Appendix T.

Points not considered to be normal wear points (levers, linkages, pins and so forth) should be lubricated with an oil can once a week. Use a few drops of engine oil on each exposed pin or lever not equipped with grease fittings to prevent rust and to provide the limited lubrication required.

NOTE:

The lubrication recommended in this manual is based on operation of the machine for a period not to exceed eight hours per day, five days per week. If a machine is operated in excess of the above time per day or week, lubrication schedules must be adjusted accordingly.

CAUTION:

Initial factor fill of MPG is of the soap base 12-Hydroxy Lithium Sterate type. Other soaP base greases are not always compatible. Various other soap base greases may be used if experience by the purchaser has shown these greases to be acceptible for the application. The grease systems must be thoroughly purged and the affected parts removed and cleaned before switching from a grease having one type of base to a grease having a different soap base.

All attachment fittings, whether illustrated on the lubrication chart or not, must be lubricated with GAA grease every 8 hours.

20. Quality Deficiency Report (QDR): Reporting of equipment quality related problems, such as new materiel received that is unsatisfactory due to a quality defect/workmanship of materiel. Generally these are found during inspections or while performing maintenance and repair functions. See TM 38-750 for reporting procedure and follow the instructions carefully.

21. Equipment Improvement Recommendations (EIR): EIR are used to report/ suggest any improvements that are found on this equipment, see TM 38-750 for reporting procedures and follow instructions carefully for prompt action.

22. Report of Discrepancy (ROD): ROD is a receiver of supply responsibility and is reported to the managing Inventory Control Point (ICP) or as shown in AR 735-11-2, AR 55-38 or DA PAM 700-3.

23. Cooling System Treatment: Corrosion inhibitor compound is intended for use in Detroit Diesel 4-71-T engine assembly. Inhibitor is used in water and with antifreeze ethylene glycoltype I. It is intended for use at the optimum rate of one ounce of inhibitor to two quarts of water. The ethylene glycol must have a borax base inhibitor. Antifreeze ethylene glycol protects the cooling system per Chart on Appendix D. National Stock Numbers are on Appendix F.

24. Fuel System Icing Inhibitor: Fuel system icing inhibitor will be blended into the fuel in the amount not to exceed 0.15 percent by volume. Icing inhibitor will be added only to diesel fuel regular grade DF-2 and below 32° F. National Stock Numbers are on Appendix F.

25. Wire Rope Specification MS132.1T (P&H):

Vendor: Leschen Wire Rope Co. (75575) or (80967)
609 North Second Street
Saint Joseph, MO 64502

TYPE	STRAND	CORE	
27D	6x26	IWRC	Right alternate lay, preformed extra improved plow steel. One-half inch Diz. Bright uncoated, breaking strength 26,600 lbs. Warrington Seale Construction, Part Number 08511 - (Ref. 1030Z81)
25	6x25F	IWRC	Right Regular lay, preformed extra improved plow steel, bright uncoated (Filler Wire) breaking strength, 58,800 lbs., 3/4 inch Dia. (Ref. 1030273) Part Number 12401-breaking strength 79,600 lbs., 7/8 inch Dia. (Ref. 1030Z77) Part Number 14321-
12	6x31	Fiber	Right Regular lay, preformed improved, plow steel 5/16 inch Dia. (Ref. 1030Z5D5) bright uncoated, breaking strength 8060 lbs. (WSC) Warrington Seale Construction, Part Number 05410-

Wire Rope requirements are as follows:

CRANE, Boom Hoist 1/2" Dia. Type 27D
Part Number 08511-710 (80967) Qty 1 each

JIB, Assy 3/4" Dia. Type 25
Part Number 12401-110 (80967) Qty 1 each

BACKHOE, Assy 3/4" Dia. Type 25
Part Number 12401-125 (80967) Qty 1 each

7/8" Dia. Type 25
Part Number 14321-85 (80967) Qty 1 each

1/2" Dia. Type 27D
Part Number 08511-230 (80967) Qty l each

FAIRLEAD, Assy 7/8" Dia. Type
Part Number 14321-75 (08967) Qty 1 each

3/4" Dia. Type
Part Number 12401-140 (80967) Qty 1 each,

SHOVEL FRONT, Assy 5/16" Dia. Type 12
Part Number 05410-32 (80967) Qty 1 each

1/2 Dia. Type 27D
Part Number 08511-380 (80967) Qty 1 each

7/8" Dia. Type 25
Part Number 14321-290 (80967) Qty 1 each

NOTE: (1) This number after the dash in each part number indicates the number of feet required.

Example:

1. Jib, Assy requires 3/4 type 25 wire rope in two places. One requires 46 feet and the other 61 feet. Together it requires 107 feet, rounded off to 110 feet. Part Number 12401-110 (80967).

2. Shovel Front Assy requires 7/8 type 25 wire rope in three places. One requires 50 feet, one requires 83 feet and one 155 feet. Total requirement is 288 feet rounded off to 290 feet. Part Number 14321-290 (80967).

NOTE: (2) The Boom Hoist Drum will hold safely 710 feet of wire rope. Operation of this drum will require a minimum of 3-full turns of cable on the drum when the boom is lowered to rest on level ground.

26. Troop Installed Item List: The operator requires certain tools and equipment that is not furnished by the manufacturer. Unit commanders responsible for this end item must ensure the operator has adequate tools/equipment to maintain the crane. The following is a minimum requirement of items required for this purpose and are purchased and installed at the user level.

a.	Extinguisher, Fire	4210-00-555-8837	1 ea.
b.	Hammer, Engineer 2 1/2 lb.	5120-00-900-6118	1 ea.
c.	Pliers, Slipjoint 10 in.	5120-00-278-0352	l ea.
d.	Screwdriver 5 in.	5120-00-227-7338	1 ea.
e.	Wrench, Open End, 8 in.	5120-00-240-5328	l ea.
f.	Wrench, Open End, 12 in.	5120-00-264-3769	1 ea.
g.	Brush, Cleaning 9 in.	5120-00-297-6657	1 ea.
h.	Oiler, Hand, 8 oz.	8020-00-297-6657	1 ea.
i.	Case, Rifle	2590-00-045-9611	1 ea.
j.	Log Book Binder	7510-00-889-3494	1 ea.
k.	Cotton Duck Case	7520-00-559-9618	1 ea.
l.	Wrench Torque, 1 in. drive	5120-00-659-9267	l ea.

27. Operation in Extremely Dusty Conditions: When operating in extremely dusty conditions the air cleaner element will become plugged in a short time (see air restrictions gauge). It is recommended that when this condition occurs a rotary type precleaner be used on the top of the air intake in place of the hood rain cap. Precleaner Part Number 660F, FSCM 62797 is an exception item and may be requested through normal supply channels.

SECTION III

REPAIRPARTS SUPPLY

28. General:

a. The basic policies and procedures in AR 710-2 and AR 725-50 are generally applicable to repair parts management for NDI items.

b. Manufacturers' part manuals are furnished with NDI items instead of Department of the Army Repair Parts and Special Tool List (RPSTL).

c. National Stock Numbers (NSN) are initially assigned only to PLL/ASL parts, i.e., engine, starter, gauges, etc. Additional NSN are assigned by the Supply Support Activities as demand warrants.

d. Automated Processing (AUTODIN) of Federal Supply Code Manufacturer (FSCM) part number requisitions, without edit for matching NSN and exception data is authorized.

e. Proper use of Direct Support System (DSS) project codes and weapon system designator codes on parts requisitions is essential.

f. Repair parts are available from commercial sources for CONUS units and may be purchased locally in accordance with AR 710-2 and AR 735-110.

29. Prescribed Load/Authorized Stockage List (PLL/ASL) (See Appendix J):

a. The PLL is a 15 day supply of parts recommended for initial stockage at the organizational level of maintenance. Management of PLL items is governed by AR 710-2 and local command procedures. PLL will be on hand at the using organization on receipt of the end item. Selection of PLL parts for overseas is based upon the receiving command's recommendations after review of TACOM prepared list in Appendix J. CONUS commanders receiving this end item will establish stock through normal requisitioning process,

b. The ASL is an estimated 45 days supply of repair parts for support units and activities. ASL will be on hand at the support activity in sufficient time to allow using organizations time to request PLL supply to support this end item. ASL selection for overseas is based upon the support of PLL which was on the receiving command's recommendations. CONUS commanders in support of this item will establish stocks through normal processes.

SECTION III (cont.)

30. Requisitioning Repair Parts:

a. Using organizations request repair parts using DA Form 2765 Series and will be prepared according to AR 710-2 and local command directives. All requests will have the Weapons System Designator Code "7Y" entered in the 2d and 3rd positions of Block 18, (see Appendix H in AR 710-2).

b. Support activities will use normal MILSTRIP format (DD Form 1348 Series). The support of NDI of equipment will include project codes, (see Appendixes M, N, O, and P) and distribution codes for supply customers in CONUS will use Code "F" in card column 54. Customers OCONUS will use the appropriate code from Appendix P, paragraph P-3a(1), AR 725-50. Weapon System Designator Code "88" (Appendix H, AR 710-2) will be entered in card columns 55 and 56 of all requisitions for parts to support the crane, Model 5060.

31. Submitting requisitions through the Defense Automated Addressing System (DAAS) for NSN parts. DAAS is used to forward support activities MILSTRIP requisitions for NSN parts to the managing supply support activity. Requisitions for part numbered parts will be forwarded through DAAS to the Defense Construction Supply Center (DCSC) (S9C). See Appendix 0.

> NOTE: When the manufacturer's part number and Federal Supply Code for Manufacturer (FSCM) exceed the space in card columns 8 through 22 of A02/AOB requisitions, prepare an AOS/AOE requisition (DD Form 1348-6) and mail it to: Commander, Defense Construction Supply Center, ATTN: DCSC-OSR, Columbus, OH 43215.

32. Source Codes are defined on Appendix s.

APPENDIX A

MAINTENANCE ALLOCATION CHART
FOR
CRANE, CRAWLER, 40 TON
HARNISCHFEGER MODEL 5060

1. General: This Maintenance Allocation Chart designates responsibility for performance of maintenance functions to specific maintenance categories.

2. Maintenance Functions:

a. Inspect: To determine the serviceability of an item by comparing its physical, mechanical and/or electrical characteristics with established standards through examination.

b. Test: To verify serviceability and detect incipient failures by measuring mechanical or electrical characteristics of an item and comparing those characteristics with prescribed standards.

C. Service: Operations required periodically to keep an item in proper operating condition, i.e., to clean (decontaminate), to preserve, to drain, to paint, or to replenish fuel, Lubricants, hydraulic fluids, or compressed air supplies.

d. Adjust: To maintain, within prescribed Limits, by bringing into proper or exact position, or by setting the operating characteristics to specified parameters.

e. Align: To adjust specified variable elements of an item to bring about optimum or desired performance.

f. Calibrate: To determine and cause corrections to be made or to be adjusted on instruments or test measuring and diagnostic equipment used in precision measurement. Consists of comparisons of two instruments, one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared,

g. Install: The act of emplacing, seating, or fixing into position an item, part, or module (component or assembly) in a manner to allow the proper functioning of an equipment or system.

h. Replace: The act of substituting a serviceable Like type part, subassembly, or module (component or assembly) for an unserviceable counter-part.

i. Repair: The application of maintenance services or other maintenance actions to restore serviceability to an item by correcting specific damage, fault, malfunction, or failure in a part, subassembly, module (component or assembly), end item, or system.

j. Overhaul: That maintenance effort (service/action) necessary to restore an item to a completely serviceable/operational condition as prescribed by maintenance standards (i.e., DMWR) in appropriate technical publications. Overhaul is normally the highest degree of maintenance performed by the Army. Overhaul does not normally return an item to like new condition.

3. Column Entries: Columns used in the Maintenance Allocation Chart are explained below:

a. Column 1, Group Number: Column I lists group numbers, the purpose of which is to identify components, assemblies, subassemblies, and modules with the next higher assembly.

b. Column 2, Component/Assemblv: Column 2 contains the noun names of components, assemblies, subassemblies, and modules for which maintenance is authorized.

C. Column 3, Maintenance Functions: Column 3 lists the functions to be performed on the item listed in Column 2.

d. Column 4, Maintenance Category: Column 4 specifies, by the listing of a "work time" figure in the appropriate subcolumn(s) the lowest level of maintenance authorized to perform the function listed in Column 3. This figure represents the active time required to perform that maintenance function at the indicated category of maintenance. If the number or complexity of the tasks within the listed maintenance function vary at different maintenance categories, appropriate "work time" figures will be shown for each category. The number of man-hours specified by the "work time" figure represents the average time required to restore an item (assembly, subassembly, component, module, end item or system) to a serviceable condition under typical field operating conditions. This time includes preparation time, troubleshoot ing time, and quality assurance/quality control time in addition to the time required to perform the specific tasks identified for the maintenance functions authorized in the Maintenance Allocation Chart.

e. Column 5, Tools and Equipment: Column 5 specifies by code, those common tool sets (not individual tools) and special tools, test, and support equipment required to perform the designated function.

f. Column 6, Remarks: Column 6 contains an alphabetic code which leads to the remark in Section IV, Remarks, which is pertinent to the item opposite the particular code.

APPENDIX A, PART 1
MAINTENANCE ALLOCATION CHART
CRANE, 40 TON CRAWLER, MDL 5060 P&H
3810-01-145-8288

(1) Group Number	(2) Component Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools & Equip-ment	(6) Remarks
01	ENGINE								
0100	Engine Assy 1043-8300 (72582)	Inspect		1.0				1	
		Test			3.0				
		Service		0.8					
		Replace			4.0				
		Repair				64.5			
0101	CRANKCASE, BLOCK:								
	Cylinder Block & End Plates	Repair				8.0		1	
	Cylinder Heads, Cover & Oil	Repair		2.0				1	
	Pan	Repair		5.0					
0102	CRANKSHAFT:								
	Crackshaft, Main Bearings	Replace				10.0		1	
	and Caps	Repair				8.0			
	Belt Set, Crankshaft	Service		0.3				1	
	Pully Drive	Replace		0.5					
0103	FLYWHEEL, ASSY:								
	Flywheel & Ring Gear	Replace				6.0			
	Flywheel 5119988 (72582)	Repair				2.5			
0104	PISTON & ROD ASSY'S:								
	Including Rings, Bearings	Replace				11.0			
	and Caps								
0106	ENGINE LUB SYS:								
	Pump Oil 5175986 (72582)	Replace				12.0			
	Filter, Oil: B-96 (12658)	Replace		0.5				1	
	Cooler, Oil								
0108	MANIFOLDS:								
	Exhaust, Manifold 5101838 (72582)	Replace		0.7				1	
03	FUEL SYSTEM:								
0301	Injectors 522877 (72582	Test			1.0			1	
		Replace		2.5					
		Repair			1.5				
0302	PUMP FUEL:								
	Pump Fuel 5199561 (72582)	Test			0.5			1	
		Replace			1.0				
		Repair			2.0				
	Lines & Fittings	Replace		0.9					
0304	AIR CLEANER	Service		0.5				1	
		Replace		0.5					
0305	BLOWER & TURBO ASSY'S:								
	Blower Assy 5138551 (72582)	Replace			1.0			1	
		Repair			3.0				

The subcolumns are as follows:
C--operator/crew
O--organizational
F--direct support
H--general support
D--depot

MAINTENANCE ALLOCATION CHART
CRANE, 40 TON CRAWLER, MDL 5060 P&H
3810-01-145-8288

(1) Group Number	(2) Component Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools & Equip-ment	(6) Remarks
0305	BLOWER & TURBO ASSY'S CONTD								
	Turbocharger Assy	Replace			1.0			1	
	5107616 (72582)	Repair			3.0				
0306	TANK,FUEL, LINES, & FITTINGS								
	Tank, Fuel 2100J971 (27315)	Service		0.3				1	
0308	ENGINE SPEED GOV.							1	
	5144136 (72582)	Adjust			1.0				
		Replace			1.0				
		Repair			1.0				
0309	FUEL FILTERS:							1	
	Strainer (Primary	Replace		0.5					
	TP522 (70040)								
	Filter Ele Secondary:	Replace		0.5				1	
	IDD45 (45152)								
0311	STARTING AID	Replace		1.0				1	
		Repair		0.5					
0312	THOTTLE CONTROL:	Adjust		0.5				1	
	2100J1369-1 (27315)	Replace			1.0				
		Repair			1.0				
	RESERVOIR, THROTTLE	Replace			1.0			1	
	R109-2 (24346)	Repair			1.5				
	CONTROL, THROTTLE	Adjust		0.5				1	
	2100N513F1 (27315)	Replace			0.5				
		Repair			2.0				
04	EXHAUST SYSTEM:							1	
0401	Muffler & Pipes	Replace		1.0					
05	COOLING SYSTEM:								
0501	Radiator Assy								
	642B (84490)	Service		0.2					
		Replace			2.0				
		Repair			2.0				
	Manifold & Thermostats	Replace		1.0				1	
		Repair		0.5					
	Pump Water	Replace			1.0			1	
	5149372 (72582)	Repair			3.0			1	
0505	FAN ASSY:								
	Hub, Shafts & Bearings	Replace			1.0			1	
		Repair			1.0				
	Bolts, Fan 5136271 (72582)	Adjust		0.5				1	
		Replace		0.5					

*The subcolumns are as follows:
C--operator/crew
O--organizational
F--direct support
H--general support
D--depot

MAINTENANCE ALLOCATION CHART
CRANE, 40 TON CRAWLER, MDL 5060 P&H
38810-01-145-8288

(1) Group Number	(2) Component Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools & Equip-ment	(6) Remarks
09	PROPELLER SHAFTS & UNIVERSAL JOINTS								
0900	Properller Shafts	Service		0.2				1	
		Replace		1.0					
		Repair			1.0				
13	TRACK AND SIDE FRAME:								
1305	Track Assy's	Adjust		0.5				1	
	2100P 149-1 (27315)	Replace		3.0					
		Repair			8.0				
18	OPERATORS MODULE/HOUSE:					4.0			
1801	Operator Module	Replace						1	
	2100J 872-7 & 31	Repair							
	Repair as required by direct support facilities								
	Option Panel	Replace			1.0			1	
	9279J11-1 (27315)	Repair			2.0				
	Windshield Wiper Front	Replace		0.5				1	
	2100N414 (27315)	Repair			1.0				
	Windshield Wiper	Replace		0.5				1	
	19418-22-MO24WC (98853)	Repair			1.0				
1806	Seat Assy	Replace		0.5				1	
	8-5007 (62226)	Repair			1.5				
	For repair parts use FSCM (D8173)								
22	ACCESSORY ITEMS:								
2202	Motors, Wiper	Repace		0.5				1	
	190240-25-OMO24WC								
	Heater/Defroster	Replace		1.5				1	
	R-254-24 (62534)	Repair			2.0			1	
	Fan 6032-0051G24 (71741)	Replace		0.5				1	
		Repair			1.5				
24	HYDRAULIC LIFT COMPONENTS:								
2401	Pump Drive 593PFGO	Replace			0.5			1	
	(96105)	Repair			0.5				
	Pump Propel	Replace			0.5			1	
	37Z289 (27315)	Repair				2.0			

The subcolumns are as follows:
C--operator/crew
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H--general support
D--depot

MAINTENANCE ALLOCATION CHART
CRANE, 40 TON CRAWLER, MDL 5060 P&H
3810-01-145-8288

(1) Group Number	(2) Component Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools & Equip-ment	(6) Remarks
06	ELECTRICAL SYSTEM:								
0601	Alternator	Replace		0.8				1	
	1117248 (16764)	Repair			1.5				
	Belts	Adjust		0.3				1	
	5133179 (72582)	Replace		0.5					
0603	Motor Starting:	Test		0.5				1	
	Motor, Starting	Replace		0.5					
	1114854 (16764)	Repair			1.0				
0607	Engine Control Panel								
	Gage, Column	Replace			1.0			1	
	9279J12-1 (27315)	Repair			1.0				
	Console, Side	Replace			1.0			1	
	2100N519 (27315)	Repair			1.0				
	Control Panel Option	Replace			1.0			1	
	9279J11-1&2 (27315)	Repair			2.0				
	Control, Dipper Trip	Replace			1.0			1	
	2100J1414-1 (27315)	Repair			1.5				
0609	LIGHTS:								
	Floodlights 42019 (81493)	Test		0.2				1	
		Replace		0.5					
		Repair		1.0					
0610	SENDING UNITS (WARNING)	Replace		1.5				1	
0612	BATTERIES, BOX & CABLES	Test	0.3					1	
		Service	0.3					1	
		Replace	1.2					1	
07	TORQUE CONVERTER								
0705	CLUTCH, CONTROL	Replace			0.5			1	
		Repair			1.0				
1710	Torque Converter	Service		0.5				1	
	23010052 (73342)	Replace			3.5				
	Hydro-static	Repair				8.0			
0713	Clutch	Adjust			0.5			1	
	6772609 (73342)	Replace				2.0			
		Repair				3.0			
0721	Pump, Charging	Replace			1.5			1	
	6759444 (73342)	Repair				1.5			
	Reservoir Assy	Replace			1.0			1	
	2100N479-1 (27315)	Repair			1.0				
	Element, Filter	Replace		0.5					
	PT-761 (12658)								

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CRANE, 40 TON CRAWLER, MDL 5060 P&H
3810-01-145-8288

(1) Group Number	(2) Component Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools & Equip-ment	(6) Remarks
24	HYDRAULIC LIFT COMPONENTS CONTD:								
2401	Brake Propel	Replace				1.5		1	
	29983 (04720)	Repair				2.0			
	Motor, Propel	Replace				4.0		1	
	23-3114 (14120)	Repair				6.5			
	Gear Box L.H.	Replace				4.0		1	
	P40RIL-165-69514-11 (61038)	Repair				2.5			
	Gear Box R.H.	Replace				4.0		1	
	P40RIL-165-69514-11 (61038)	Repair				2.5			
2402	Hydraulic, Control Valves:								
	Valve, Manual	Replace				0.5		1	
	9510083-65 (14120)	Repair				1.0			
	Valve, Control	Replace				0.5		1	
	62-S21-B (94697)	Repair				2.0			
	Valve, Control	Test		0.2				1	
	CM11N02K00-DDL-21-047	Replace		1.0					
	(32705)	Repair			2.5				
	Valve, Solenoid	Replace							
	2100J1408-1 (27315)	Repair							
	Valve, Direction	Test		0.5				1	
	DG4S4W5012A-24VDC-50-LH	Replace		1.0					
	(32705)	Repair			2.5				
	Valve, Direction CM11MO	Test		0.2				1	
	K00-DDL21-047 (32705)	Replace		1.0					
		Repair			2.5				
	Valve, Direction	Test		0.5				1	
	DG4S4WT012A-24VDC-50-RH	Replace		1.0					
	(32705)	Repair			2.5				
	Swivel, Hyd.	Replace				4.0		1	
	52574 (29783)	Repair				10.0			
	Valve, Combination	Test		0.2				1	
	MCD-1575-24 DT	Replace		1.5					
	(54846)	Repair				4.0			
	Valve, Assy	Replace			2.0			1	
	9236J1-3 (27315)	Repair			3.0				
	Velve, Shuttle	Replace		1.0				1	
	VS2104-2624 (05842)	Repair			2.0				
2403	Hydraulic Control Levers:								
	Accumulator	Replace			0.5			1	
	BSN-20-231 (15573)	Repair			0.5				
2406	Hydraulic Lines & Fittings:								
	Filter	Service		0.5				1	
	HH9020A12UNRBP (06816)	Replace		1.0					

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MAINTENANCE ALLOCATION CHART
CRANE, 40 TON CRAWLER, MDL 5060 P&H
3810-01-145-8288

(1) Group Number	(2) Component Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools & Equip-ment	(6) Remarks
2406	Filter								
	46Z410 (27315)	Replace		0.5				1	
	Element	Repair		1.0					
	HC9020FUN4H (06816)	Replace		0.5				1	
	Element PT-707-HD10 (12658)	Replace		0.4				1	
2407	Hydraulic Cylinders:								
	Cylinder 38Q126 (27315)	Adjust		0.5				1	
		Replace			1.0				
		Repair			1.0				
	Cylinder	Replace			0.5			1	
	CS2301-2023 (05842)	Repair			0.5				
	Cylinder	Replace				1.0		1	
	89-3044-A (18108)	Repair				1.5			
	Cylinder	Replace				1.0		1	
	CS-1801-2804 (05842)	Repair				1.5			
	Cylinder	Replace			0.5			1	
	CS-1901-2719 (05842)	Repair			0.5				
	Cylinder	Replace			0.5			1	
	CS-2301-2023 (05842)	Repair			0.5				
	Cylinder	Replace			0.5			1	
	CS1501-2018 (05842)	Repair			0.5				
	Cylinder	Replace			0.5			1	
	CS1901-2026 (05842)	Repair			0.5				
	Cylinder	Replace			0.5			1	
	38U112D1 27315	Repair			0.5				
	Cylinder	Replace			0.5			1	
	CS1501-2668 (05842)	Repair			0.5				
2408	Reservoirs:								
	Reservoir, Hyd.	Replace			1.0			1	
	2100J1066-1 (27315)	Repair			1.0				
74	CRANE, SHOVEL & EARTH MOVING EQUIPMENT COMPONENTS								
7402	Hoist:								
	Drum, Planetary Boom Hoist	Replace				4.0		1	
	2100J1132-5 (27315)	Repair				6.0			
	Band Assy Plant	Replace			1.0			1	
	2100N458-1 (27315)	Repair			1.0				
	Brake, Main	Replace			4.0			1	
	9215J107-8 (27315)	Repair			4.0				
	Band Assy 2100J1107-1 (27315)	Replace			2.5				
	Brake & Pawl Assy	Service	0.2					1	
	2100J1008-2 (27315)	Adjust		0.5					
		Replace			1.0				
		Repair			1.0				

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MAINTENANCE ALLOCATION CHART
CRANE, 40 TON CRAWLER, MDL 5060 P&H
3810-01-145-8288

(1) Group Number	(2) Component Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools & Equip-ment	(6) Remarks
7402	Hoist Contd								
	Band Assy, Boom Hoist	Replace			1.0			1	
	2100N457-1 (27315)	Repair			1.0				
	Maint Hoist Pawl Assy	Replace				1.0		1	
		Repair				1.0			
7411	Indicator, Drum	Replace				2.0		1	
	5300841 (80800)	Repair				4.0			
7414	Catwalks								
	228J29 (27315)	Replace		1.0				1	
7415	Clutch, Boom Hoist	Test			0.2			1	
	9215J105-2 (27315)	Service		0.2					
		Align		0.5					
		Replace			1.0				
		Repair			2.0				
	Clutch, Main Drum	Test			0.2			1	
	2915J64-6	Service		0.2					
		Align		0.5					
		Replace				1.0			
		Repair				2.0			
	Clutch, Swing	Replace				4.0		1	
	2100J1346-2 (27315)	Repair				4.0			
	Clutch, Swing	Replace				4.0		1	
	2100J1346-1 (27315)	Repair				4.0			
7416	Shaft, Hor Swing R.H.	Service		2.0				1	
	2910J30-6 (27315)	Replace				6.0			
		Repair				4.0			
	Shaft, Worm	Replace				3.5		1	
	2100N503-1 (27315)	Repair				4.0			
	Shaft, Boom Hoist	Replace				4.0			
	2100J1132-1 (27315)	Repair				4.0			
	Shaft, Vertical Swing	Replace				3.0		1	
	2100J1334-1 (27315)	Repair				3.0			
	Shaft, Main Drum	Service		2.0				1	
	2100J974-1 (27315)	Replace				8.0			
	Shaft, Hor Swing L.H.	Service		2.0				1	
	2910J30-7 (27315)	Replace				6.0			
		Repair				4.0			
	Shaft, Intermediate Swing	Service		2.0				1	
	9210J60-3 (27315)	Replace				2.5			
		Repair				2.5			
7417	Brake, 3RD Drum	Replace			0.5			1	
	2100N464-1 (27315)	Repair			0.5				
7419	Turntable								
	Brake, Assy Swing	Replace				6.0		1	
	2100J992-4 (27315)	Repair				6.0			

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MAINTENANCE ALLOCATION CHART
CRANE, 40 TON CRAWLER, MDL 5060 P&H
3810-01-145-8288

(1) Group Number	(2) Component Assembly	(3) Maintenance Function	(4) Maintenance Category C	O	F	H	D	(5) Tools & Equip-ment	(6) Remarks
7420	Shaft, Chain Idler	Replace				2.0		1	
	2100J515F1 (27315)	Repair				2.5			
7422	Control Brake, Module	Replace			3.0			1	
	2100J1129-2 (27315)	Repair			2.5				
	Console, Swing	Replace			4.0			1	
	2100J932-3 (27315)	Repair			3.0				
7423	Gantry	Service		0.5				1	
	2100J953-4&7 (27315)	Replace		3.0					
		Repair		2.0					
7425	Propel Control	Replace			1.0			1	
	2100J984-4 (27315)	Repair			2.0				
	Propel Control	Replace			1.0			1	
	9206N2-1 (27315)	Repair			1.5				
	Roller, Track:	Replace			3.0			1	
	1-007-0090 (14661)	Repair			4.0				
	Idler, Sprocket, Assy	Repair			3.0			1	
	2100J968-2 (27315)	Replace			17.0				
	Sprocket, Assy Drive	Repair			5.0			1	
	2100J969-2 (27315)	Replace			25.0				
7427	Miscellaneous								
	Valves:								
	Valve, Brake Manual	Replace			1.0			1	
	CM-1011-2834 (05842)	Repair			1.5				
	Valve; Pressure Regulator	Replace			1.0			1	
	C5464.900 (05842)	Repair			1.5				
	Valve, Brake Manual	Replace			1.0			1	
	CM-1001-2834 (05842)	Repair			1.5				
	Valve, Regulator	Replace			1.0			1	
	5464-900 (05842)	Repair			1.5				

*The subcolumns are as follows:
C--operator/crew F--direct support D--depot
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APPENDIX A PART 2
MAINTENANCE ALLOCATION CHART
FOR
Crane, Crawler, P&H, 40 Ton, Model 5060

All maintenance functions can be accomplished with the tools contained in the following tool sets, test sets and those furnished with the crane.

TOOL AND TEST EQUIPMENT REQUIREMENTS

TOOL OR TEST EQUIPMENT REFERNECE CODE	MAINTEN-ANCE CATEGORY	NOMECLATURE	NATIONAL/NATO STOCK NUMBER	TOOL NUMBER	FSCM OR LINE NUMBER
1	F, H	Shop Eq Fuel & Elec Sys Eng; SC4910-95-CLA-01	4910-00-754-0714		T30414
	F, H	Shop Set, Fuel & Elec Sys Supp No 2 SC4910-95-CLA-65	4910-00-390-7775		T30688
	F, H	Test, Set Diesel Injector; SC4910-IL.	4910-00-317-8265		
	F,H	Shop Eq Auto Maint & Repair, Org Supp No 1 (less power) SC4910-95-CL-A73	4910-00-754-0653		W32867
	F,H	Shop Eq Mach Shop Trq-Mtd SC3470-95-CL-A02	3740-00-754-0708		T15644
	F,H	Tool Kit, Machinist SC5280-95-CL-A02	5280-00-511-1950		W44512
	O,F,H	Shop Eq Weld Set SC3470-95-CLA08	3740-00-357-7268		T16714
	F,H	Tool Kit, Body & Fender Repair SC5180-90-CLN-34	5180-00-754-0643		W33689
	F,H	Multimeter AN/USM-223	6625-00-999-7465		M80242
	O	Tool Kit, Auto Supp No 1 SC4910-95-CL-A73	4910-00-754-0853		W32867
	O	Tool Set, Veh Full Tracked Supp No 2 SC4940-95-CL-A08	4940-00-754-0743		W65747

MAINTENANCE ALLOCATION CHART
FOR
Crane, Crawler, P&H, 40 Ton, Model 5060

TOOL AND TEST EQUIPMENT REQUIREMENTS					
TOOL OR TEST EQUIPMENT REFERNECE CODE	MAINTEN-ANCE CATEGORY	NOMECLATURE	NATIONAL/NATO STOCK NUMBER	TOOL NUMBER	FSCM OR LINE NUMBER
	H	Shop Set, Internal Combustion, Engine Repair SC4910-95-CL-A59	4910-00-262-7532		T15618
	F,H	Shop Eq Contact Maint. Trk-Mtd SC4940-95-CL-B04	4940-00-294-9518		T10138
	F,H	Shop Eq Gen-Pur Repr, Semitrl Mtd SC4940-95-CL-B02	4940-00-287-4894		T10549
	F,H	Shop Eq Org Repr Light Trk-Mtd SC4940-97-CLEO4	4940-00-294-9516		T13152
	F,H	Tool Kit, Auto Fuel & Elec Sys Repr SC4910-95-CL-A50	4910-00-754-0655		W32456
	O,F,H	Tool Kit, Auto Maint: Org Maint Common No 1 SC4910-95-CL-A50	4910-00-754-0654		W32593
	F,H	Tool Kit, Auto Maint Org Maint. Common No 2 SC4910-95-CL-A72	4910-00-754-0654		W32720
	O,F,H	Tool Kit, Auto Mech; Light Wt SC5180-90-CLN26	5180-00-177-7033		W33004
	O,F,H	Tool Kit, Master Mechanic: Eq Maint & Repair SC5180-90-CL-N05	5180-00-699-5273		W45060
	O,F,H	Tool Kit, Rigging	5180-00-596-1513		W50266

MAINTENANCE ALLOCATION CHART
FOR
Crane, Crawler, P&H, 40 Ton, Model 5060

TOOL AND TEST EQUIPMENT REQUIREMENTS					
TOOL OR TEST EQUIPMENT REFERNECE CODE	MAINTEN-ANCE CATEGORY	NOMECLATURE	NATIONAL/NATO STOCK NUMBER	TOOL NUMBER	FSCM OR LINE NUMBER
2	F,H	Wrench Set, Socket 3/4" Dr. Hex	5130-00-351-5135		
3	F,H	Wrench Torque, 3/4 Dr. 100-500 Foot Pounds	5120-00-542-5577		
4	F,H	Wrench Torque, 2500 Foot Pounds Model PD-2501	5120-00-482-2543		
5	F,H	Multimeter, Digital AC-DC 0-1000 KV G2100, CIMRON MDL	6625-00-879-4626		
6	F,H	Fuel Pipe Socket		J8932-01	33287
7	H	Cylinder Liner Hold Down Clamp		J21793-B	33287
8	H	Cylinder Liner Remover Set		J1918-02	33287
9	F,H	Water Pump & Fuel Pump Wrench		J4242	33287
10	O,F,H	Strap Wrench		J24783	33287
11	F,H	Compressor Wheel Nut		J21223-02	33287
12	F,H	Compressor Wheel Remover		J9496	33287
13	F,H	Turbocharger Tool Kit		J29149	33287
14	O,F,H	Cutter, Wire Rope	5110-00-224-7058	GGG-C-800	81348
15	O,F,H	Marline, Spike	5120-00-224-9443	MIL-M-15926	81348

APPENDIX B

PREVENTATIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

OPERATOR/ORGANIZATIONAL MAINTENANCE CHECKS AND SERVICES

MAINTENANCE FORMS AND RECORDS.

Every mission begins and ends with the paperwork. There isn't much of it, but you have to keep it up. The forms and records you fill out have several uses:

1. They are a record of the usage, service, transfers and modifications made on your equipment.

2. They are used as a checklist when you want to know what is wrong with the equipment and whether those faults have been fixed after its last use.

See TM 38-750 for the required information on the forms and records.

PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

1. When you do your PMCS, take along the tools you will need, you will always need a rag or two.

WARNING

Dry cleaning solvent P-D-680 (SD-2) is toxic and flammable. Wear protective goggles and gloves. Use SD-2 only in a well ventilated area. Do not use near open flame or excessive heat. If you become dizzy while using cleaning solvent, get fresh air immediately and medical aid. If contact with skin or clothing is made, flush with water. If contact with eyes is made, flush with water and get medical aid immediately.

WARNING

Do not spill fuel, coolant, or other liquids upon exposed parts of your body. Exposed parts of the body should not come in contact with metal during cold weather, as serious and painful injury may result.

WARNING

Under no circumstances should a circuit breaker be prevented from tripping by any means. Overloaded electrical circuits can cause extensive damage to the machine and/or injury to personnel.

a. Keep it clean: Dirt, grease, oil and debris only get in the way and may cover up a serious problem. Clean as you work and as needed. Use dry cleaning solvent (SD-2) on all metal surfaces. Use soap and water to clean rubber or plastic material.

b. Bolts, Nuts and Screws: Check them for obvious looseness, missing, bent or broken condition. You cannot try them all with a tool, of course, but look for chipped paint, bare metal or rust around bolt heads. If you find one you think is loose, tighten it. Report it to Organizational Maintenance if you can't tighten it.

c. Welds: Look for loose or chipped paint, rust or gaps where parts are welded together. If you find a bad weld, report it to Organizational Maintenance.

d. Electric Wires and Connectors: Look for cracked or broken insulation, bare wires and loose or broken connectors. Report damage or loose wiring to Organizational Maintenance.

e. Hoses and Fluid Lines: Look for wear, damage and leaks. Check for loose clamps and fittings. Wet spots show leaks, of course, but a stain around a fitting or connector can mean a leak. If a leak comes from a loose fitting or connector, tighten it. If something is broken or worn out, report it to Organizational Maintenance.

2. It is necessary for you to know the definitions of the types/classes of leakage and how it determines the status of your equipment.

a. Leakage definitions are as follows:

CLASS I Seepage of fluid (as indicated by wetness or discoloration not great enough to form drops).

CLASS II Leakage of fluid great enough to form drops (but not enough to cause drops to drip from the item being checked/inspected).

CLASS III Leakage of fluid great enough to form drips that fall from the item being checked/inspected.

CAUTION

Equipment operation is allowable with minor leakage (Class I or II). Of course, consideration must be given to the fluid capacity in the item/system being checked/inspected.
When operating with Class I or II leaks, continue to check fluid levels as required in your PMCS. Class III leaks should be reported to your supervisor or to Organizational Maintenance.

b. Learn and remember the definitions of Class I, II and III leaks - WHEN IN DOUBT, NOTIFY YOUR SUPERVISOR!

OPERATOR/CREW AND ORGANIZATIONAL MAINTENANCE CHECKS AND SERVICES.

1. Do your (B) PREVENTIVE MAINTENANCE just before you operate the equipment. Pay attention to the Cautions and Warnings.

2. Do your (D) PREVENTIVE MAINTENANCE during operation. (During operation means to monitor the equipment while it is actually being used.)

3. Do your (A) PREVENTIVE MAINTENANCE right after operating the equipment. Pay attention to the Cautions and Warnings.

4. Do your (W) PREVENTIVE MAINTENANCE weekly.

5. Do your (M) PREVENTIVE MAINTENANCE once a month.

6. If something doesn't work, troubleshoot it with the instructions in your manual or notify your supervisor,

7. Always do your PREVENTIVE MAINTENANCE in the same order, so it gets to be a habit. Once you have had some practice, you will spot anything wrong in a hurry.

8. If anything looks wrong and you cannot fix it, write it on your DA Form 2404. If you find something seriously wrong, report it to Organizational Maintenance RIGHT NOW!

OPERATOR/CREW PREVENTIVE MAINTENANCE CHECKS AND SERVICES

B BEFORE D-DURING A-AFTER W-WEEKLY M-MONTHLY

APPENDIX B - PART 1

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY AVAILABLE IF:
						NOTES: All PMCS listed within are based on DA PAM 750-40, Reliability Centered Maintenance (RCM) Logic. Perform weekly as well as before PMCS if: a. You are the assigned operator but have not operated the equipment since the last weekly. b. You are operating the equipment for the first time. WARNING: Your safety and the safety of those around you depends upon YOU using care and good judgement in the operation of this machine. Know the positions and functions of ALL CONTROLS before attempting to operate the equipment. Do not operate the equipment in an enclosed area unless exhaust gases are piped outside. Inhalation of exhaust fumes can cause serious illness or death. Read and observe all warnings and cautions in the front of your operators manual before starting this machine. GENERAL: Perform all daily and/or weekly lubrication of the Crane, Crawler, 40 Ton, as called out in the operators manual and this SOMARPI.	

OPERATOR/CREW PREVENTIVE MAINTENANCE CHECKS AND SERVICES

B BEFORE D-DURING A-AFTER W-WEEKLY M-MONTHLY

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY, AVAILABLE IF:
1	X					Lubricate levers, linkages, pins, etc. with an oil can to prevent rust and lubrication required. Insure the crane is on level ground when checking oil levels. See lubrication order in Appendix T.	
2						ENGINE: (4-71-T)	
	X					A. Check dipstick for proper oil level. Maintain the oil as near the full mark as possible at all times.	
	X					B. Check for valve cover leaks.	Class III leak
3						TURBOCHARGER:	
	X					A. Check the oil inlet and outlet lines for leaks or severely crimped, bent or loose lines to the oil flow.	Class III leak, Crimped or bent oil lines.
	X					B. Check for loose mountings or loose connections on ducts.	
		X				C. Check for unusual noise, smoke or vibrations.	Any unusual noise, smoke or vibrations.
4						FUEL LINES:	
	X					Check fuel lines from the injectors to the fuel tank for leaks.	Class III leak
5						AIR CLEANER:	
		X				A. Check indicator gage and if the red flag is at the top your element requires changing.	If red flag appears
	X					B. Check ejector valve for damage or plugging and clean dirt from trap.	
	X					C. Check duct connections for loose connections.	

OPERATOR/CREW PREVENTIVE MAINTENANCE CHECKS AND SERVICES

B-BEFORE D-DURING A-AFTER W-WEEKLY M-MONTHLY

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/ AVAILABLE IF:
6						BATTERIES **WARNING** Do not get battery electrolyte on your skin, clothing or in your eyes. It is an acid which can cause injury. Keep all sparks and flames from batteries, because battery gas is explosive. **CAUTION** In cold weather operations, charge batteries immediately after adding water. Water must combine with the electrolyte by means of charging. Delay in charging can result in freezing water. Be careful not to overfill when servicing batteries.	
			X			a. Check level of electrolyte. If level of electrolyte is belwo top of battery plates, add distilled water to cover the plates.	
			X			b. Inspect batteries and battery box for damage	Batteries are missing or damaged or if engine will not crank.
			X			c. Check battery cables and clamps for loose connections/corrosion	
7						FAN AND ALTERNATOR BELTS:	
			X			Check for loose or damaged belts	Belts are broken or missing.
8						INSTRUMENT PANEL:	
						Check gauges and warning lights for operation:	
		X				Tachometer: See if needle moves when moving the throttle	Needle does not move.

OPERATOR/CREW PREVENTIVE MAINTENANCE CHECKS AND SERVICES

B BEFORE   D-DURING   A-AFTER   W-WEEKLY   M-MONTHLY

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/AVAILABLE IF:
9						RADIATOR:	
				X		A. Check coolant level and add water/antifreeze to fill top reservoir.	
				X		B. Clean radiator exterior of foreign material and check for leaks.	Class III leak; engine may overheat
10						CONVERTER:	
	X					Check the torque converter for proper oil level and maintain at high level mark.	
11						RESERVOIR	
	X					Check for proper oil level. Keep as close to the high level mark as possible at all times.	
12						INDICATOR HIGH PRESSURE FILTER:	
	X					Check indicator on top of filter for read indicator.	Indicator is red
13						LIGHTS:	
		X				Check all lights for safe operation.	

ITEM NO	B	D	A	W	M	ITEM TO BE INSPECTED / PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/AVAILABLE IF:
14						THROTTLE OIL RESERVOIR:	
	X					Check reservoir oil level and maintain at top level mark.	
15						BRAKE, PAWLS, AND CLUTCHES:	
		X				A. Brakes: Apply all brakes, check each for proper adjustment.	Brake will not hold load.
				X		B. Pawls: Engage all pawls and check each for proper engagement. Ref: page 5-8 & 5-9.	Pawls will not engage.
		X				C. Clutches: Engage all clutches and check each for proper engagement.	Clutch will not engage.
16						TRACKS:	
	X					A. Check for rocks or foreign material.	
			X			B. Clean tracks at the end of the day.	
	X					C. Check the ground under crane unit for any Class III spots or leaks.	Class III leak.
						WARNING: HYDRAULIC SYSTEMS OPERATE AT A VERY HIGH PRESSURE. THE HYDRAULIC OIL, EVEN FROM A VERY SMALL LEAK, CAN GO THROUGH YOUR SKIN AND CAUSE SERIOUS INFECTION. IF THE OIL GOES THROUGH YOUR SKIN SEE A DOCTOR IMMEDIATELY.	
	X					D. Check track extending cylinders for any obstructions or leaks. Ref: TM 5-350	Class III leak.

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED — PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/AVAILABLE IF:
						INSTRUMENT PANEL (Cont'd)	
		X				Clutch Engage Light: Green light will be lit when the engine clutch is engaged.	If light fails to come on.
						Caution: After start-up the warning device will remain activated until the engine oil pressure rises to the normal pressure. If oil pressure does not reach normal within 15 seconds after start-up shut down the engine immediately and correct the cause of the low oil pressure.	
		X				Oil Pressure Gauge: Gauge should not read between 45 and 70 psi during operation. At low idle there should be approximately 10 psi.	If pressure is not between 45-70 PSI
		X				Water Temperature Gauge: Guage should read between 185° - 200°F during normal operation.	Temperature exceeds 200°F.
		X				Converter Temperature Gauge: The temperature range is 200 - 220°F. Temperature must never exceed 235°F.	Temperature exceeds 235°F.
		X				Converter Pressure Gauge: Pressure should be approximately 30 psi. Wide variations from this pressure indicates a problem in the torque converter. At idle, pressure should be approximately 15 psi.	Variation to pressure is noted.
		X				Hydraulic Pressure Gauge: Normal pressure is 1500 psi with a working range of 1400 - 1700 psi.	Pressure is other than normal range.
						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 COLLANT SYSTEM CAN RESULT IN LOSS OF COOLANT AND POSSIBLE PERSONAL INJURY (SCALDING) FROM THE HOT LIQUID.	

ITEM NO	B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/AVAILABLE IF:
17						FUEL TANK:	
	X					To remove sediment, drain from the fuel tank a small amount of fuel (approximately one cup).	
18						WIRE ROPE AND FITTINGS	
						<u>WARNING</u>:	
	X					WHEN WORKING WITH WIRE ROPE USE LEATHER GLOVES.	
						Inspect the wire rope, rope sockets and fittings for damage, wear, corrosion, fatigue and rope lubrication.	a. In running ropes, there are six randomly distributed broken wires in one rope lay or three broken wires in one strand in one rope lay. b. In pendants or standing ropes, there is more than one broken wire in one rope lay. c. A loss of 1/3 the original diameter of outside wires by abrasion, scrubbing or peening is found.

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/ AVAILABLE IF:
						WIRE ROPE AND FITTINGS (Cont'd)	d. There is rope deterioration from rust or corrosion. e. There is severe kinking or crushing or evidence of "birdcaging." f. Obvious reduction in wire rope diameter exists. g. There is evidence of heat damage from any cause. h. Four percent of total wires that make up one strand e.g. 6x7 is unsafe with three broken wires in one strand. 6x19 is unsafe with six broken wires in one strand. Ref: TM 5-725
19						UNIVERSAL JOINT:	
				X		Check the four bearing assemblies for lack of grease (appear dry).	
20						DRIVE SHAFT, PROPEL:	
				X		Check propel drive shaft oil level, should be up to the level opening.	

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY, AVAILABLE IF:
21						HOOK BLOCK:	
				X		Check for distortion, cracks, excessive wear, damage or malfunctioning latch.	Cracks, distortions, excessively worn or malfunctioning latch.
22						BOOM EXTENSIONS:	
	X					A. Check for bent cord angles, broken, bent or missing lattice.	Bent cord angle, bent, broken or missing lattice (lacings).
				X		B. Check sheaves, pins and roller for wear or tight conditions.	
	X					C. Check for missing boom base pins.	One missing pin.

ITEM NO	Q	S	A	B	H	MI	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED, OR ADJUSTED AS NEEDED PERFORM ALL OPERATOR PMCS FIRST
							NOTE: GENERAL LUBRICATION AND OPERATOR'S CHECKS MUST BE ACCOMPLISHED PRIOR TO ORGANIZATIONAL PREVENTATIVE MAINTENANCE CHECKS AND SERVICES (MPCS)
1							ENGINE: (4-71-T) Ref. Manufacturer's Operator's Manual.
	X						A. Fan/Alternator Belts: Check and adjust. Ref: Manufacturer's PMCS, Page 5-17
	X						B. Service Lubrication Oil/Filters: Follow lubrication Order instructions until end of the warranty period, then use TB43-0210 Oil Analysis Program, Ref: PMCS, Page 5-17.
							C. Cooling System:
	X						1. Check condition of hoses and clamps. Ref: PMCS, Page 5-21.
	X						2. Check thermostat and seals to insure they are opening and closing properly to maintain operating temperature. Ref: PMCS, Page 5-21.
	X						3. Check fan hub and if it has a grease fitting, lubricate the bearing with one shot of GGA grease for each 700 hours of operation. (Check log book records for last reading and service). Repack bearing every 4000 hours. Ref: PMCS, Page 5-2.
		X					4. Check for contaminants. If it requires cleaning, it should be cleaned with a good quality cleaning compound. Rinse the system thoroughly and fill system with soft water. Add antifreeze/inhibitor as stated on lubrication guide. Ref: PMCS, Page 5-23. Ref: TB 750-651

ORGANIZATIONAL PREVENTIVE MAINTENANCE CHECKS AND SERVICES

Q-QUARTERLY S-SEMIANNUALLY A-ANNUALLY B-BIENNIALLY H-HOURS MI-MILES

APPENDIX B - PART 2

ITEM NO	INTERVAL Q	S	A	B	H	MI	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED, OR ADJUSTED AS NEEDED PERFORM ALL OPERATOR PMCS FIRST
							ENGINE: (Cont'd)
		X					D. Exhaust Manifold: Check manifold retaining nut, flange clamps and connections for cracks and tightness (22 - 24 foot pound torque). Ref: PMCS, Page 5-21.
		X					E. Crankcase Breather: Clean breather on top of valve cover. Ref: PMCS, Page 5-23.
							WARNING: Compressed air used for cleaning purposes will not exceed 30 psi. Use only with effective chip guarding and personnel protective equipment (goggles/shield/gloves, etc.).
		X					F. Air Box Check Valve: Clean with solvent and blow out lines with compressed air. Ref: PMCS, Page 5-26.
							G. Blower Screen: Clean in fuel oil and dry with compressed air. Ref: PMCS, Page 5-26.
2							GOVERNOR:
	X						Lubricate governor speed control shaft. Install a temporary grease fitting in place of the plug at the end of the shaft. Remove governor cover and observe when greasing is completed, then remove grease fitting and replace plug and governor cover.
3							PROPEL DRIVE SHAFT:
		X					Change oil and refill until oil runs out of the level plug. Ref: PMCS, Page 5-24.
4							TORQUE CONVERTER:
		X					Check converter mounting bolts to insure they are not loose. Ref: PMCS, Page 5-26.

ITEM NO	INTERVAL Q	S	A	B	H	MI	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED, OR ADJUSTED AS NEEDED PERFORM ALL OPERATOR PMCS FIRST
5							DRIVE CHAIN CASE:
		X					Change oil as recommended by the manufacturer until the end of the warranty period, then use TB43-0210 Oil Analysis Program. Ref: PMCS, Page 5-23.
							WARNING
							Use caution when removing hot oil. Remove drain plug carefully. Ref: PMCS, Page 5-23.
6							PROPEL AND CONTROL SYSTEM:
		X					Change oil as recommended by the manufacturer until the end of the warranty period, then use TB43-0210 Oil Analysis Program. Ref: PMCS, Page 5-23.
7							TRACKS:
	X						Check track tension, make adjustment if necessary. Ref: PMCS, Page 5-19.
8							GEAR CASE, PROPEL:
	X						Check propel gear case, oil level should be just up to the bottom of the level opening.
9							PUMP, PROPEL:
	X						Check and ensure oil level is at the full mark at all times.
10							DRIVE CHAIN CASE:
	X						Check and ensure the oil is just up to the bottom of the level plug opening.

APPENDIX C

ITEMS FURNISHED WITH CRANE

NAME	QTY	FSCM	PART NUMBER
Adapter, Grease Assembly	1	27315	44Z386
Hose, Bleeder	1	27315	44Z683
Gun, Grease	1	95879	4041B
Hose, Grease Gun	1	95879	6652A
Hose, Grease Gun	1	95879	1189A
Socket, 1 5/8" with 1" Drive	1	55719	IM523
Chain Link	2	27315	20Z59202
Puller, Shear Washer	1	27315	921T1
Handle, Wrench	1	27315	221T8
Spacer, Boom Hoist Clutch	1	27315	18T6700D16
Sling Assembly	2	27315	923OP2
Chain Tightener	1	27315	1OON1042
Socket, 2"	1	27315	21Z115D21
Socket, 2 3/4"	1	27315	21Z115D33
Safety Handbook	1	27315	240

APPENDIX D

Cooling System Capacity in Quarts	Anti-Freeze Coolant Require* (in Quarts)												
	2	3	4	5	6	7	8	9	10	11	12	13	
5	-12°	-62°											
6	0°	-34°											
7	6°	-17°	-54°										
8	10°	- 7°	-34°	-69°									
9		0°	-21°	-50°									
10		4°	-12°	-34°	-62°								
11		8°	- 6°	-23°	-47°								
12		10°	0°	-15°	-34°	-57°							
13			3°	- 9°	-25°	-45°	-66°						
14			6°	- 5°	-17°	-34°	-54°						
15			8°	0°	-12°	-26°	-43°	-62°					
16			10°	2°	- 7°	-19°	-34°	-52°					
17				5°	- 4°	-14°	-27°	-42°	-58°				
18				7°	0°	-10°	-21°	-34°	-50°	-65°			
19				9°	2°	- 7°	-16°	-28°	-42°	-56°			
20				10°	4°	- 3°	-12°	-22°	-34°	-48°	-62°		
21					6°	0°	- 9°	-17°	-28°	-41°	-54°	-68°	
22					8°	2°	- 6°	-14°	-23°	-34°	-47°	-59°	
23					9°	4°	- 3°	-10°	-19°	-29°	-40°	-52°	
24					10°	5°	0°	- 7°	-15°	-24°	-34°	-46°	

Anti-Freeze	25%	33%	40%	50%	60%	68%
Protects To	+10°	0°	-12°	-34°	-62°	-90°

NOTE: Do Not Use Without Some Water.
68% Concentration Gives Maximum Protection.

* Use at least 33% concentration for protection against rust and corrosion.

MAINTENANCE AND OPERATING SUPPLY LIST

NOMENCLATURE: CRANE, CRAWLER 40 TON	MAKE: Harnischfeger	MODEL: 5060

MFR PART NO:	NSN: 3810-01-145-8288	SERIAL NO. RANGE: 52728 TO 52742	DATE: July 1983

(1) COMPONENT APPLICATION	(2) MFR PART NO. OR NAT'L STOCK NO.	(3) DESCRIPTION	(4) QTY REQ F/INITIAL OPN	(5) QTY REQ F/8 HRS OPN	(6) NOTES
Wire Rope	8415-00-274-2433	Gloves, Leather KK-G-476	2 Pr.	2 Pr.	Used when working with wire rope.
Oil Sampling	8125-01-082-9697	Bottle, Sampling	none	none	Gil analysis program
.	6515-00-727-0008	'Syringe	none	none	"
.	4720-00-580-6055	Tubing 3/8 inch Dia.	none	none	"
	8105-00-290-0340	Sack, Shipping	none	none	"
	8105-00-837-7754	Bag, plastic	none	none	"
Cleaning		Solvent, Dry Cleaning SO-2 (P-D630)			
	6850-00-664-5635	1 Qt. Can			
	6850-00-281-1985	1 Gal. Can			
	6850-00-264-9038	5 Gal. Can			
	6850-00-285-8012	55 Gal. Drum			
	6850-01-053-254	Cleaning Compound, Engine 1 Pt. Can			1500 (17995)

(1) COMPONENT APPLICATION	(2) MFR PART NO. OR NAT'L STOCK NO.	(3) DESCRIPTION	(4) QTY REP F/INITIAL OPN	(5) QTY REQ F/8 HRS OPN	(6) NOTES
Cleaning		Kerosene			
	9140-00-242-6749	5 Gal. Can	1	1	Use as required
	9140-00-242-6751	55 Gal. Drum	none	none	
Cleaning	7920-00-148-9666	Rags; Wiping Oil 50 lb. bale	1	1	Use as required

APPENDIX F

PETROLEUM SUPPLY LIST

CRANE, CRAWLER 40 Ton Harnischfeger Model 5060

3810-01-145-8288 Serial No. Range 52728 to 52742

Purchased on Contract DAAE07-82-C-6749

Grease, Multipurpose Auto (MPG)

Military (GAA)

Specification	Range	Container	NSN
MIL-G-10924	-12° C to 52° C	Cart - 14 oz.	9150-00-935-1017
		Can 1.75 lb.	9150-00-190-0904
		Can 6.5 lb.	9150-00-190-0905
		Can 35 lb.	9150-00-190-0907
		DR 120 lb.	9150-00-530-7369

Diesel Fuel (Grade 2)

32° and above

Specification	Range	Container	NSN
Federal Spec. VVF800 Graded F2RE	32°F & above	Bulk	9140-00-286-5294
		5 Gal.	9140-00-286-5295
		55 Gal.	9140-00-286-5297

For Winter use below 32°F use Fuel Grade 1 or add De-Icing additive

Graded DF-1WI, Winter use below 32°F	Bulk	9140-00-286-5286
	5 Gal.	9140-00-286-5287
	55 Gal.	9140-00-286-5289
Additive Fuel De-Iceing MIL-I-27686, NATO Code S-748 Use with Fuel Grade 2 only	4 oz. Aerosol	6850-01-016-1914
	5 Gal Can	6850-00-753-5061
	55 Gal Drum	6850-00-060-5312

Cooling System Treatment

Specification	Container	NSN
Antifreeze, Engine Cooling System MIL-A-46153B used 32°F to -40°F	1 gal.	6850-00-181-7929
	5 gal.	6850-00-181-7933
	55 gal.	6850-00-181-7940
MIL-A-11755D used -40°F to -90°F	55 gal.	6850-00-174-1806
Federal Spec: 0-1-490 Corrosion inhibitor, Cooling System	6 oz. Can	6850-00-753-4967
	8.5 oz. Can	6850-00-584-2707
	12 oz. Can	6850-01-076-8810

Brake Fluid Silicone
Military (BFS)

Specification	Container	NSN
NIL-B-46176 Brake Fluid	1 gal.	9150-01-102-9455
" " "	5 gal.	9150-01-123-3152
Decal for Master Cylinder	ea.	7690-01-111-2265 12302516 (19207)
TB 43-0002-87		

Gear Oil (GO)

Specification	Range	Wt.	Container	NSN
MIL-L-2105C	-10° & below	75W	qt.	9150-01-035-5390
			5 gal.	9150-01-035-5391
	-10° & above	80W-90	qt.	915c-01-035-5392
			5 gal.	9150-01-035-5393
			55 gal.	9150-01-035-5394
	above 90°F	85W-140	qt.	9150-01-048-4591
			5 gal.	9150-01-035-5395
			55 gal.	9150-01-035-5396

Open Gear and Wire Rope Lubricant (OG)
Military (CW-11)

Specification	Container	NSN
Federal Spec VVL751	5 lb.	9150-00-234-5197
	35 lb.	9150-00-261-7891
	120 lb.	9150-00-530-7293

Hydraulic Torque Converter Fluid
Military (OE10)

Specification	Range	Wt.	Container	NSN
MIL-L-2104C	-13°F to 95°F	10	1 qt.	9150-00-189-6727
			5 gal.	9150-00-186-6668
			55 gal.	9150-00-191-2772
	140°F & above	30	1 qt.	9150-00-186-6681
			5 gal.	9150-00-188-9858
			55 gal.	9150-00-188-9859

Oil Engine Lubrication (MO)
Military (OE/HDO)

Specification	Range	Grade	Container	NSN
MIL-L-2104D	Sub-zero and up and starting aids	30	1 qt.	9150-00-186-6681
			5 gal.	9150-00-188-9858
			55 gal.	9150-00-189-6729
MIL-L-2104D	Sub-zero and up and starting aids	40	1 qt.	9150-00-189-6730
			5 gal.	9150-00-188-9860
			55 gal.	9150-00-188-9862

CONVERSION CHART

	Manufacturer	Military
Chassis Grease	CG	GAA
Hvy Duty Extreme Pressure	EP	GAA
Hydraulic Brake Fluid	HBF	Brake Fluid (Auto)
Hydraulic Oil-SAE 10MS	HO	OE/HDO 10
Extreme Pressure Gear Lube	EPGL	G090/80
Open Gear Lube	OG	CW-11
Motor Oil	MO	OE/HDO
Ball & Roller Bearing Grease	BG	GAA
Extreme Pressure Grease	EPG	GAA
Wheel Bearing Grease	WBG	Wheel Bearing Grease
Multi-Purpose Grease	MPG	GAA

- DECIMALS - FRACTIONS - MILLIMETERS

Fraction	DECIMAL	mm
1/64	.0156	0.396
1/32	.0312	0.793
3/64	.0468	1.190
1/16	.0625	1.587
5/64	.0781	1.984
3/32	.0937	2.381
7/64	.1093	2.778
1/8	.125	3.175
9/64	.1406	3.571
5/32	.1562	3.968
11/64	.1718	4.365
3/16	.1875	4.762
13/64	.2031	5.159
7/32	.2187	5.556
15/64	.2343	5.953
1/4	.250	6.350
17/64	.2656	6.746
9/32	.2812	7.143
19/64	.2968	7.540
5/16	.3125	7.937
21/64	.3281	8.334
11/32	.3437	8.731
23/64	.3593	9.128
3/8	.375	9.525
25/64	.3906	9.921
13/32	.4062	10.318
27/64	.4218	10.715
7/16	.4375	11.112
29/64	.4531	11.509
15/32	.4687	11.906
31/64	.4843	12.303
1/2	.500	12.700
33/64	.5156	13.096
17/32	.5312	13.493
35/64	.5468	13.890
9/16	.5625	14.287
37/64	.5781	14.684
19/32	.5937	15.081
39/64	.6093	15.478
5/8	.625	15.875
41/64	.6406	16.271
21/32	.6562	16.668
43/64	.6718	17.065
11/16	.6875	17.462
45/64	.7031	17.859
23/32	.7187	18.256
47/64	.7343	18.653
3/4	.750	19.050
49/64	.7656	19.446
25/32	.7812	19.843
51/64	.7968	20.240
13/16	.8125	20.637
53/64	.8281	21.034
27/32	.8437	21.431
55/64	.8593	21.828
7/8	.875	22.225
57/64	.8906	22.621
29/32	.9062	23.018
59/64	.9218	23.415
15/16	.9375	23.812
61/64	.9531	24.209
31/32	.9687	24.606
63/64	.9843	25.003
1	1.000	25.400

TAP DRILL SIZES

Nominal size and number threads per inch	Commercial tap drill to produce approx. 75% full thread	Decimal equivalent of tap drill
0—80	3-64	0.0469
1—64	53	0.0595
72	53	0.0595
2—56	50	0.0700
64	50	0.0700
3—48	47	0.0785
56	45	0.0820
4—40	43	0.0890
48	42	0.0935
5—40	38	0.1015
44	37	0.1040
6—32	36	0.1065
40	33	0.1130
8—32	29	0.1360
36	29	0.1360
10—24	25	0.1495
32	21	0.1590
12—24	16	0.1770
28	14	0.1820
1/4—20	7	0.2010
28	3	0.2130
5/16—18	F	0.2570
24	I	0.2720
3/8—16	5-16	0.3125
24	Q	0.3320
7/16—14	U	0.3680
20	25-64	0.3906
1/2—13	27-64	0.4219
20	29-64	0.4531
9/16—12	31-64	0.4844
18	33-64	0.5156
5/8—11	17-32	0.5312
18	37-64	0.5781
3/4—10	21-32	0.6562
16	11-16	0.6875
7/8—9	49-64	0.7656
14	13-16	0.8125
1—8	7-8	0.8750
14	15-16	0.9375
1 1/8—7	63-64	0.9844
12	1 3-64	1.0469
1 1/4—7	1 7-64	1.1094
12	1 11-64	1.1719
1 3/8—6	1 7-32	1.2187
12	1 19-64	1.2969
1 1/2—6	1 11-32	1.3437
12	1 27-64	1.4219
1 3/4—5	1 9-16	1.5625
2—4 1/2	1 25-32	1.7812
2 1/4—4 1/2	2 1-32	2.0312
2 1/2—4	2 1-4	2.2500
2 3/4—4	2 1-2	2.5000
3—4	2 3-4	2.7500
3 1/4—4	3	3.0000
3 1/2—4	3 1-4	3.2500
3 3/4—4	3 1-2	3.5000
4—4	3 3-4	3.7500

PIPE THREAD SIZES

1/8...	27	0.405
1/4...	18	0.540
3/8...	18	0.675
1/2...	14	0.840
3/4...	14	1.050
1...	11 1/2	1.315
1 1/4...	11 1/2	1.660
1 1/2...	11 1/2	1.900
2...	11 1/2	2.375
2 1/2..	8	2.875
3...	8	3.500
3 1/2..	8	4.00
4...	8	4.500

MACHINE SCREW SIZES

1/16-64	3/64
5/64-60	1/16
3/32-48	49
7/64-48	43
1/8-32	3/32
1/8-40	38
9/64-40	32
5/32-32	1/8
11/64-32	9/64
3/16-24	26
3/16-32	22
13/64-24	20
7/32-24	16
15/64-24	10
1/4-20	7
1/4-28	3
5/16-18	F
5/16-24	I
3/8-16	5/16
3/8-24	Q
7/16-14	U
7/16-20	25/64
1/2-12	27/64
1/2-13	27/64
1/2-20	29/64
9/16-12	31/64
9/16-18	33/64
5/8-11	17/32
5/8-18	37/64
11/16-11	19/32
11/16-16	5/8
3/4-10	21/32
3/4-16	11/16
13/16-10	23/32
49/54	7/8-9
13/16	7/8-14
53/64	15/16-9
7/8	1-8
15/16	1-14
63/64	1 1/8-7
1 1/64	1 1/8-12
1 7/64	1 1/4-7
1 11/64	1 1/4-12
1 13/64	1 3/8-6
1 19/64	1 3/8-12
1 11/32	1 1/2-6
1 27/64	1 1/2-12
1 29/64	1 5/8-5 1/2
1 9/16	1 3/4-5
1 11/16	1 7/8-5
1 25/32	2-4 1/2

TAP DRILL SIZES

BASED ON APPROXIMATELY 75% FULL THREAD

THREAD	DRILL
1/16-64	3/64
5/64-60	1/16
3/32-48	49
7/64-48	43
1/8-32	3/32
1/8-40	38
9/64-40	32
5/32-32	1/8
11/64-32	9/64
3/16-24	26
3/16-32	22
13/64-24	20
7/32-24	16
15/64-24	10
1/4-20	7
1/4-28	3
5/16-18	F
49/54	7/8-9
13/16	7/8-14
53/64	15/16-9
7/8	1-8
15/16	1-14
63/64	1 1/8-7
1 1/64	1 1/8-12
1 7/64	1 1/4-7
1 11/64	1 1/4-12
1 13/64	1 3/8-6
1 19/64	1 3/8-12
1 11/32	1 1/2-6
1 27/64	1 1/2-12
1 29/64	1 5/8-5 1/2
1 9/16	1 3/4-5
1 11/16	1 7/8-5
1 25/32	2-4 1/2
5/16-24	I
3/8-16	5/16
3/8-24	Q
7/16-14	U
7/16-20	25/64
1/2-12	27/64
1/2-13	27/64
1/2-20	29/64
9/16-12	31/64
9/16-18	33/64
5/8-11	17/32
5/8-18	37/64
11/16-11	19/32
11/16-16	5/8
3/4-10	21/32
3/4-16	11/16
13/16-10	23/32

LETTER SIZES

Size	Drill Diameter
A	234
B	238
C	242
D	246
E	250
F	257
G	261
H	266
I	272
J	277
K	281
L	290
M	295
N	302
O	316
P	323
Q	332
R	339
S	348
T	358
U	368
V	377
W	386
X	397
Y	404
Z	413

Twist Drill Sizes

Size	Drill Diameter
1	2280
2	2210
3	2130
4	2090
5	2055
6	2040
7	2010
8	1990
9	1960
10	1935
11	1910
12	1890
13	1850
14	1820
15	1800
16	1770
17	1730
18	1695
19	1660
20	1610
21	1590
22	1570
23	1540
24	1520
25	1495
26	1470
27	1440
28	1405
29	1360
30	1285
31	1200
32	1160
33	1130
34	1110
35	1100
36	1065
37	1040
38	1015
39	0995
40	0980
41	0960
42	0935
43	0890
44	0860
45	0820
46	0810
47	0785
48	0760
49	0730
50	0700
51	0670
52	0635
53	0595
54	0550
55	0520
56	0465
57	0430
58	0420
59	0410
60	0400
61	0390
62	0380
63	0370
64	0360
65	0350
66	0330
67	0320
68	0310
69	0292
70	0280
71	0260
72	0250
73	0240
74	0225
75	0210
76	0200
77	0180
78	0160
79	0145
80	0135

DECIMAL EQUIVALENTS OF PARTS OF AN INCH

1/64 .015625	33/64 .515625
1/32—.03125	17/32—.53125
3/64 .046875	35/64 .546875
1/16—.0625	9/16—.5625
5/64 .078125	37/64 .578125
3/32—.09375	19/32—.59375
7/64 .109375	39/64 .609375
1/8—.125	5/8—.625
9/64 .140625	41/64 .640625
5/32 15625	21/32—.65625
11/64 .171875	43/64 .671875
3/16—.1875	11/16—.6875
13/64 .203125	45/64 .703125
7/32 21875	23/32 .71875
15/64 234375	47/64 .734375
1/4 .25	3/4—.75
17/64 .265625	49/64 .765625
9/32—.28125	25/32—.78125
19/64 .296875	51/64 .796875
5/16—.3125	13/16—.8125
21/64 .328125	53/64 .828125
11/32—.34375	27/32—.84375
23/64 .359375	55/64 .859375
3/8—.375	7/8—.875
25/64 .390625	57/64 .890625
13/32—.40625	29/32—.90625
27/64 .421875	59/64 .921875
7/16—.4375	15/16—.9375
29/64 .453125	61/64 .953125
15/32—.46875	31/32—.96875
31/64 .484375	63/64 .984375
1/2—.5	1—1.

TAP DRILLS

American Std. and Unified Form Threads

Tap Drill Size is approximately 75% Thread

THREAD Nom Size	Pitch Series	Drill Size	Drill Dec.	THREAD Nom Size	Pitch Series	Drill Size	Drill Dec.
0-80	NF	3/64	.047	9/16-12	NC UNC	31/64	.484
1-64	NC	53	.060	12	NF UNF	33/64	.516
72	NF	53	.060	5/8-11	NC UNC	17/32	.531
2-56	NC	50	.070	18	NF UNF	37/64	.578
64	NF	50	.070	3/4-10	NC UNC	21/32	.656
3-48	NC	47	.079	16	NF UNF	11/16	.688
56	NF	45	.082	7/8-9	NC UNC	49/64	.766
4-40	NC UNC	43	.089	14	NF UNF	13/16	.813
48	NF	42	.094	1-8	NC UNC	7/8	.875
5-40	NC	38	.102	14	NS	15/16	.938
44	NF	37	.104	1 1/8-7	NC UNC	63/64	.984
6-32	NC UNC	36	.107	12	NF UNF	1 3/64	1.047
40	NF	33	.113	1 1/4-7	NC UNC	1 7/64	1.109
8-32	NC UNC	29	.136	12	NF UNF	1 11/64	1.172
36	NF	29	.136	1 3/8-6	NC UNC	1 7/32	1.219
10-24	NC UNC	25	.150	12	NF UNF	1 19/64	1.297
32	NF UNF	21	.159	1 1/2-6	NC UNC	1 11/32	1.344
12-24	NC	16	.177	12	NF UNF	1 27/64	1.422
28	NF	14	.182	1 3/4-5	NC UNC	1 9/16	1.563
1/4-20	NC UNC	7	.201	2-4 1/2	NC UNC	1 25/32	1.781
28	NF UNF	3	.213	2 1/4-4 1/2	NC UNC	2 1/32	2.031
5/16-18	NC UNC	F	.257	2 1/2-4	NC UNC	2 1/4	2.250
24	NF UNF	I	.272	2 3/4-4	NC UNC	2 1/2	2.500
3/8-16	NC UNC	5/16	.313	3-4	NC UNC	2 3/4	2.750
24	NF UNF	Q	.332	3 1/4-4	NC UNC	3	3.000
7/16-14	NC UNC	U	.368	3 1/2-4	NC UNC	3 1/4	3.250
20	NF UNF	25/64	.391	3 3/4-4	NC UNC	3 1/2	3.500
1/2-13	NC UNC	27/64	.422	4-4	NC UNC	3 3/4	3.750
20	NF UNF	29/64	.453				

DECIMAL EQUIVALENTS OF LETTER SIZE DRILLS

Letter	Inches	Letter	Inches	Letter	Inches
A	0.234	J	0.277	S	0.348
B	0.238	K	0.281	T	0.358
C	0.242	L	0.290	U	0.368
D	0.246	M	0.295	V	0.377
E	0.250	N	0.302	W	0.386
F	0.257	O	0.316	X	0.397
G	0.261	P	0.323	Y	0.404
H	0.266	Q	0.332	Z	0.413
I	0.272	R	0.339		

American National Pipe Threads

THREAD NOMINAL SIZE	DRILL SIZE	DRILL DECIMAL	THREAD NOMINAL SIZE	DRILL SIZE	DRILL DECIMAL
1/8-27	R	.339	1 1/2-11 1/2	1 47/64	1.734
1/4-18	7/16	.437	2 -11 1/2	2 7/32	2.218
3/8-18	37/64	.578	2 1/2- 8	2 5/8	2.625
1/2-14	23/32	.719	3 - 8	3 1/4	3.250
3/4-14	59/64	.921	3 1/2- 8	3 3/4	3.750
1 -11 1/2	1 5/32	1.156	4 - 8	4 1/4	4.250
1 1/4-11 1/2	1 1/2	1.500			

APPENDIX H

Attachments Currently Used With This Crane Are As Follows:

DESCRIPTION	NSN	LINE NUMBER
Lead Section, Top 15'	3815-00-983-8029	L49089
Lead Section, Lower 10'	3815-00-22l-2215	L48815
Catwalk, Piledriving, 3 parts	3815-00-190-3308	D76085
Clamshell Bucket	3815-00-378-8700	C29764
Dragline Bucket	3815-00-585-2685	C31134
Fairlead	3815-01-153-1861	H32047
10' Insert	3815-01-153-1853	C05046
Jib 15'	3815-01-153-1847	C05612
Backhoe	3815-01-153-1867	B12585
Shovel Front	3815-01-153-1855	T40771
Concrete Bucket	3815-01-146-7183	C30586
Hammer, Pile Driving	3895-00-769-5308	K04697
Ball, Wrecking	3815-00-222-1877	B22717
Tagline	3815-00-249-8391	V10141

Adapters for pile driver are bracketed on the boom. They are considered as repair parts to the crane and are not a separate item of supply under line number A12564.

APPENDIX I

EQUIPMENT PUBLICATIONS

DA EQUIPMENT PUBLICATIONS

NOMENCLATURE	EQUIPMENT PUBLICATION NUMBER	DATE
Utilization of Construction Equipment	TM5-331B	May 68
Safe Use of Cranes, Crane Shovel, and Draglines	TB 385-101	Jan 71
Procedures for Licensing Operators of Construction Equipment	TB 600-2	Sep 78
RPSTL	TM 5-3810-303-24P	1984

OTHER THAN OFFICIAL DA EQUIPMENT PUBLICATIONS

NONMENCLATURE	EQUIPMENT PUBLICATION NUMBER OR TYPE	DATE	SOURCE OF SUPPLY
Operation	Operator's Manual	overpack with crane	DCSC
Org Maintenance	Shop Manual	overpack with crane	DCSC
Direct & General	Shop Manual	overpack with crane	DCSC
Repair Parts	Parts Manual	overpack with crane	DCSC

INITIAL RECOMMENDATION
PRESCRIBED LOAD LIST (PLL)
AUTHORIZED STOCKAGE LIST (ASL)
APPENDIX J

END ITEM: CRANE, CRAWLER 40 TON	MAKE: HARNISCHFEGER	MODEL: 5060

MFR PART NO: 5060	PCCN: CCM471	NSN: 3810-01-145-8288	SERIAL NUMBER RANGE 52728 TO 52742	DATE. 11 Mar 83

SMR CODE	NATIONAL STOCK NUMBER	PART NUMBER	FSCM	PART DESCRIPTION	PLISN	U/M	QTY OF PARTS REQ'D FOR NO. OF END ITEMS PLL 1-5	ASL 1-5	ASL 6-20	ASL 21-50
PAOZZ	2910-01-007-0978	P11-7332	18265	ELEMENT, AIR CLEANER	AAAJ	EA	1	1		
PAOZZ	2940-01-019-4513	B-96	12658	ELEMENT, OIL FILTER	AAAK	EA	1	1		
PAOZZ	2910-00-371-2846	TP522	70040	ELEMENT, FUEL PRIMARY	AAAL	EA	1	1		
PAOZZ	4330-01-025-6853	1DD45	45152	ELEMENT, FUEL SECONDARY	AAAM	EA	1	1		
PAOZZ	4330-00-947-5807	PT707HD10	12658	ELEMENT, HYD RESERVOIR	AAAN	EA	2	2		
PAOZZ	4330-01-117-7455	HC902FUN4H	06816	ELEMENT, HIGH PRES FILTER	AAAP	EA	1	1		
PAOZZ	3030-01-074-6591	5136271	72582	BELT-V, FAN	AAAQ	EA	1	1		
PAOZZ	3030-00-268-1337	5133179	72582	BELT-V, ALT	AAAR	EA	1	1		
PAOZZ	2540-01-125-0307	BD721011-20	24956	BLADE, WINDSHIELD WIPER	AAAS	EA	2	2		
PAOZZ	5925-01-021-3784	W58XB1A4A-1	79405	BREAKER 10 AMP	AAAT	EA	1	1		
PAOZZ	5925-01-058-4971	W58XB1A4A-15	79405	BREAKER 10 AMP	AAAU	EA	1	1		
PAOZZ	5925-00-920-6824	CDM40	82647	BREAKER	AAAV	EA	1	1		
PAOZZ	6240-00-155-7848	303	08108	BULB, LIGHT CONSOLE	AAAW	EA	1	1		
PAOZZ	6240-00-155-7866	356	08108	BULB, LIGHT CLUTCH IND	AAAX	EA	1	1		
PAOZZ	6240-00-060-4707	1309	08108	BULB, DOME LIGHT	AAAY	EA	1	1		

INITIAL RECOMMENDATION
PRESCRIBED LOAD LIST (PLL)
AUTHORIZED STOCKAGE LIST (ASL)
APPENDIX J

END ITEM: CRANE, CRAWLER 40 TON	MAKE: HARNISCHFEGER	MODEL: 5060
MFR PART NO: 5060	NSN: 3810-01-145-8288	SERIAL NUMBER RANGE 52728 TO 52742
		DATE: 11 Mar 83

SMR CODE	NATIONAL STOCK NUMBER	PART NUMBER	FSCM	PART DESCRIPTION	PLISN	U/M	QTY OF PARTS REQ'D FOR NO. OF END ITEMS			
							PLL	ASL		
							1-5	1-5	6-20	21-50
PAOZZ	6240-00-155-8714	313	08108	BULB, GAUGE PANEL	AAAZ	EA	1	1		
PAOZZ	6240-00-643-0687	MS17165-4578	96906	BULB, FLOOD LIGHT	AABA	EA	1	1		
PAOZZ		MS52130-17	96906	HOSE, RADIATOR, 2 ID x 3½ LG	AABB	EA	4	4		

PAGE ______ OF ______

APPENDIX K
WARRANTY GUIDELINES

1. A warranty period of 15 months applies to 40 Ton Crawler Crane, Contract Number DAAE07-82-C-6749 manufactured by Harnischfeger Corporation after delivery to the Government. This warranty applies to the end item components and all supplies furnished under the contract.

2. Using units must report all warranty claims to the National Maintenance Point (NMP) as indicated in paragraph 3a.

3. General information:

a. DA Form 2407 (prepared in accordance with warranty claim actions in TM 38-750) will be used to submit warranty claims actions for end items when components, parts or assemblies are defective and are covered by a manufacturer's warranty. End items under warranty are identified by a decal plate on the vehicle. Contractural warranty clauses are in commercial manual. All warranty actions settled or unsettled will be reported to the National Maintenance Point (NMP) on DA Form 2407.

b. Maintenance activities in support of organizational maintenance are the responsible points of contact between the originator of warranty claims and the National Maintenance Point (US Army Tank-Automotive Command, ATTN: DRSTA-MVB, AUTOVON 786-8901, Warren, MI 48090) which serves as the DA Representative with the contractor in warranty matters.

NOTE: In certain instances, the originating organization and the support activity are one and the same.

C. Before you take your equipment to a dealer for repair, whether or not it was necessary for you to go through the NMP (TACOM), check with your local procurement office to see if a funds commitment document is needed. Sometimes, even. though the majority of the repairs are covered by the warranty, there may be a small charge for normal maintenance costs, i.e., oil filters, oil, etc. Further the cause of damage could be determined by the dealer to be directly related to "operator abuse". In that case, the Government may be obligated to pay for teardown services even if the repairs are no longer desired, or for the complete cost, if repairs are to be completed by the dealer.

d. When the equipment is given to the dealer for repairs, find out how long the work will take, the extent of the problem, if possible, and the charges, if any, which may be involved. Leave the name and telephone number of the person to be contacted for pickup of the equipment and specifically state that he should be called as soon as the repairs are finished. In addition state he should be telephoned if unexpected problems, costs, and/or delays are encountered. Get the name and telephone number of the Service Manager, for any required follow-up purposes.

e. When you arrive to pickup your equipment after completion of services, make certain that you know exactly what repairs were performed and/or parts replaced. This is required for overall problems trend evaluation by the NMP and must be identified upon completion of warranty services.

f. Telephone the NMP at TACOM, AUTOVON 786-8901 if:

(1) Your equipment requires repairs and you cannot obtain these services using the procedures listed above.

(2) The length of time required for repairs may seriously hamper your mission, or if the dealers overall response to your requirements are not satisfactory.

(3) You have any questions regarding warranty procedures - either in general or about a specific job. Do not wait until your problems become critical.

g. <u>Do not attempt to conduct negotiations regarding a breach of warranty</u>. This is a function of the Contracting Officer, through the NMP at TACOM.

4. Contractural Warranty Clauses.

a. <u>Warranty</u>. 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. Further, if the Government, prior to placing vehicles in service, elects to place quantities of such newly delivered vehicles in Government depot storage, the contractor agrees that the time period of the warranty will not begin to run for such stored vehicles until each vehicle is withdrawn from Government storage or until six months from date of acceptance, whichever occurs first. The Government, prior to placing each new vehicle in storage and again at time of its withdrawal, shall notify the contractor thereof and identify each vehicle at its time in and out of storage. Vehicles designed as Production Samples shall be treated as vehicles placed in storage for warranty purposes

If a Safety Recall defect occurs during vehicles warranty period, the contractor agrees to extend the term or the warranty by a period of time equal to the time period required to make necessary safety defect corrections. Additionally, to the extent the contractor or his supplier(s) provide to commercial customers a greater warranty for the supplies furnished herein, 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.

b. Remedies.

(1) New Replacement Supplies. With respect to defective supplies, wherever located, the warranty shall include the furnisheding, 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 desfective within the warranty period.

(2) Corrective Action Options. In addition the Government shall have the option (a) to return the vehicles 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 vehicle or parts to the Contract'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 vehicle 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 located within the 50 states, when the Government elects to correct them itself, the cost of labor involved in the correction of defects shall be borne by the contractor and shall be computed at the contractor's then prevailing hourly rate for such services in that geographical area, based upon the number of labor hours appearing in the contractor's flat rate time schedule manual, or the Government's actual cost, whichever is less. With respect to defective supplies located outside the 50 states, when the Government elects to correct them itself, the cost of labor involved shall be borne by the contractor at then prevailing hourly rate in the geographical area for such services based upon the number of labor hours appearing in the contractor's flat rate time schedule manual or the Government's actual cost, whichever is less. Additionally, the contractor shall be responsible for reasonable costs of disassembly/reassembly of items necessarily removed in connection with repair or replacement on vehicles wherever located.

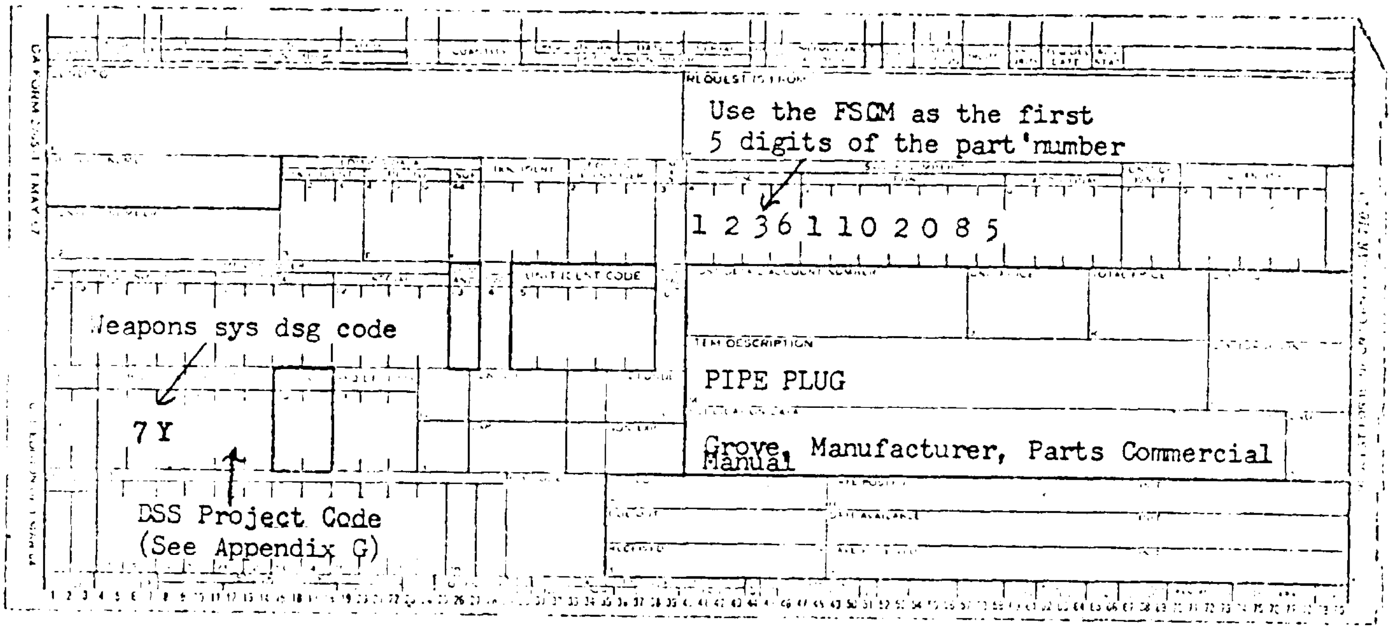
C. Notification. If the Government elects to have warranty repair or replacement performed by the contractor, the Government shall deliver the vehicle to contractor's local facility or dealership for warranty corrective repair or replacement. Receipt for such vehicle by the contractor's local facility or dealership will be deemed proper notification by the Government of any breach of the warranty provided by this provision. If the Government elects to effect warranty repairs or replacement itself, the contractor shall be notified in writing of any breach in 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 breach. 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 paragraph (c) above the contractor shall, notwithstanding any disagreement regarding the existence of breach of warranty, comply with any Contracting Officer directions related to such correction or replacement. After the notice of breach, 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 (c) 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 (b) above, the contract price will be equitable 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.

d. Corrected or Replaced Supplies. Any supplies or parts thereof corrected or furnished in replacement pursuant to this clause shall also be subject to all the provisions of this clause to the same extent as supplies initially delivered.

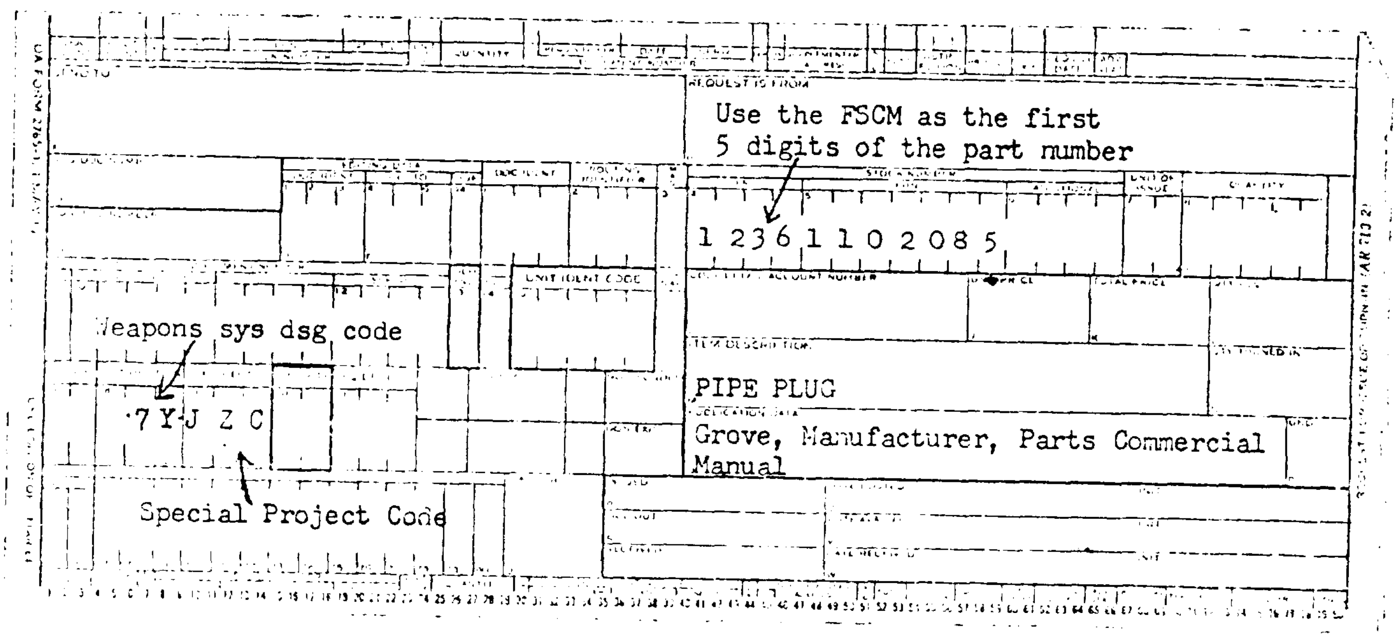
APPENDIX L

SAMPLE FORMAT - DA FORM 2765 PART NUMBER REQUEST

(CONUS REQUESTER)



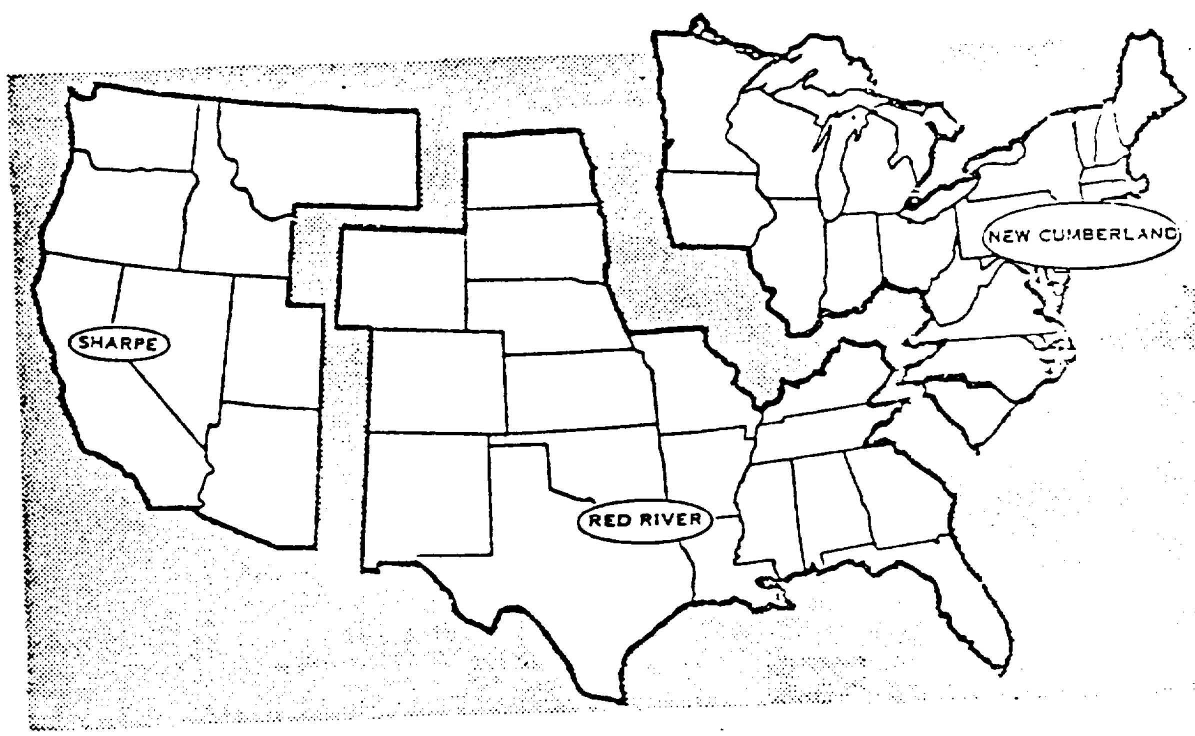
(OCONUS REQUESTER)



APPENDIX M

DSS PROJECT CODES

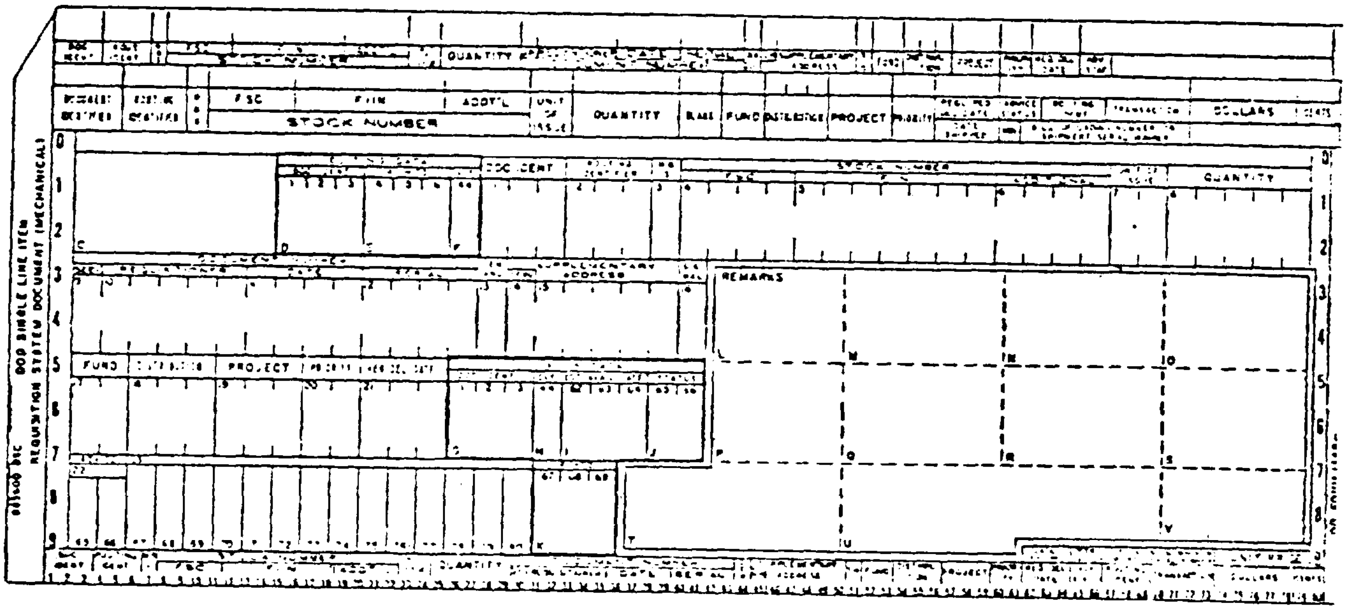
Geographic Location	ASL	NSL
CONUS (Eastern US)	XDC	NSC
CONUS (Central US)	XDA	NSA
CONUS (Western US)	XDB	NSB



Designated distribution depot support areas.

APPENDIX N

SAMPLE FORMAT - MILSTRIP REQUISITION(NSN)

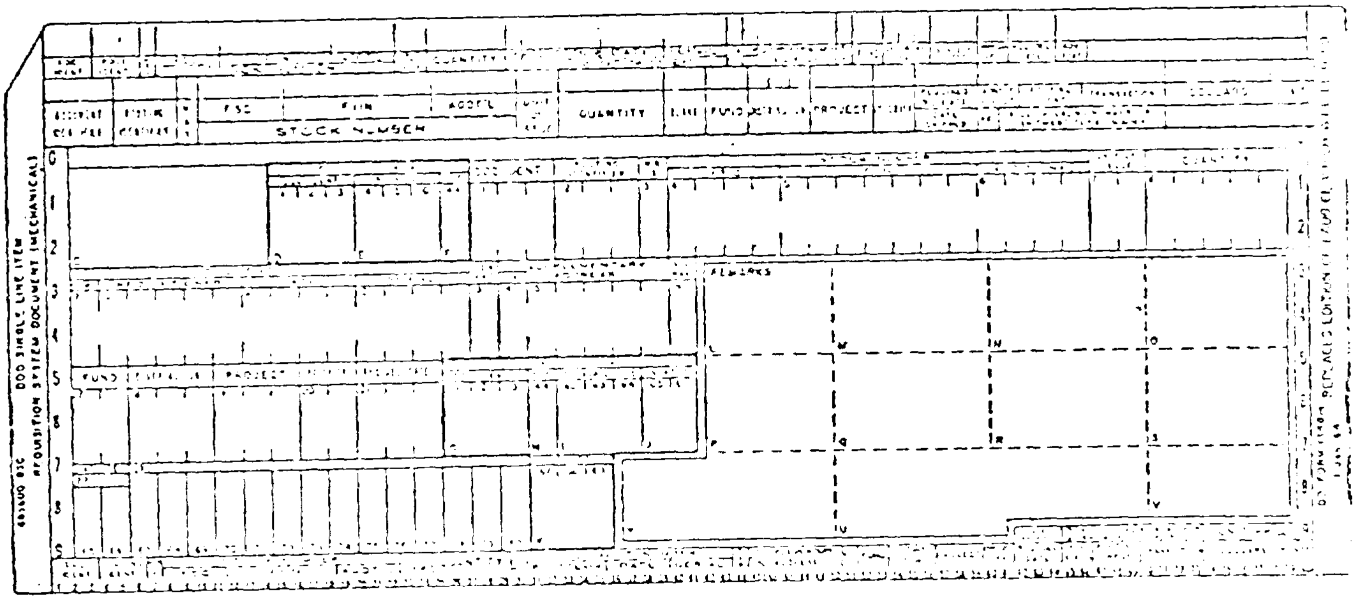


Card Column	Description of Data	Mandatory Entry for CCE
1-3	Document Identifier Code	AØA - CONUS AØ1 - OCONUS
4-6	Rauting Identifier Code	
7	Media/Status Code	
8-22	NSN	
23-24	Unit of Issue	
25-29	Quantity	
30-43	Document Number	
44	Demand Code	
45-50	Supplementary Address	
51	Signal Code	
52-53	Fund Code	
54-56	Distribution Code CC-54	"F" for CONUS; see AR 725-50 for OCONUS
	CC-55-56	*Weapon System Code
57-59	Project Code	DSS Code
60-61	Priority Code	
62-64	Required Delivery Dare	
65-55	Advice Code	

*Weapons System Designator code for Crane is 7Y

APPENDIX O

SAMPLE FORMAT – MILSTRIP REQUISITION FOR (NON–NSN)



Card Column	Description of Data	Mandatory Entry for CCE
1-3	Document Identifier Code	AØB - CONUS AØ2 - OCONUS
4-6	Routing Identifier Code	Always S9C
7	Media/Status Code	
8-22	FSCM and Part Number	
23-24	unit of Issue	
25-29	Quantity	
30-43	Document Number	
44	Demand Code	
45-50	Supplementary Address	
51	Signal Code	
52-53	Fund Code	
54-56	Distribution Code CC-54	"F" for CONUS; see AR 725-50 for OCONUS
	CC-55-56	* Weapon System Code
57-59	Project Code	DSS Code (CONUS) "JZC" (OCONUS)
60-61	Priority Code	
62-64	Required Delivery Date	
65-66	Advice Code	

*Weapons System Designator Code for Crane is 7Y

APPENDIX O (Continued)

CARD COLUMN	DESCRIPTION OF DATA	MANDATORY ENTRY
67-69	Blank	
70	Identification code applicable to entry in cc 71-80 A - Technical Order or Technical Manual B - End Item Identification C - Noun Description D - Drawing or Specification Number	
71-80	Reference Identification	Identification of reference specified in CC 70

APPENDIX P

SAMPLE FORMAT - MILSTRIP REQUISITION (NON-NSN) (MANUAL)

DOCUMENT IDENTIFIER | ROUTING IDENTIFIER | M S | MANUFACTURER'S CODE AND PART NUMBER * (FSCM | PART NUMBER) | UNIT OF ISSUE | QUANTITY | DOCUMENT NUMBER (SERV | REQUISITIONER | DATE | SERIAL)

DEMAND | SUPPLEMENTARY ADDRESS (SERV) | SIGNAL | FUND CODE | DISTRIBUTION CODE | PROJECT CODE | PRIORITY | REQUIRED DELIVERY DATE | ADVICE CODE | BLANK | REJECT CODE (FOR USE BY SUPPLY SOURCE ONLY)

IDENTIFICATION DATA

* 1. MANUFACTURER'S CODE & PART NO. *(When they exceed Card Columns 8 thru 22)*

2. MANUFACTURER'S NAME

3. MANUFACTURER'S CATALOG IDENTIFICATION AND DATE

4. TECHNICAL ORDER NUMBER

5. TECHNICAL MANUAL NUMBER

6. NAME OF ITEM REQUESTED

7. DESCRIPTION OF ITEM REQUESTED

7a. COLOR

7b. SIZE

8. END ITEM APPLICATION AND SOURCE OF SUPPLY

8a. MAKE

8b. MODEL NUMBER

8c. SERIES

8d. SERIAL NUMBER

9. REMARKS

FOLD LINE

DD FORM 1 JAN 71 1348-6

NON-NSN REQUISITION *(MANUAL)*

INSTRUCTIONS

This form will only be used in those cases where the manufacturer's code and part number exceed the spaces allocated in card columns 8 - 22 of the requisition,

CARD COLUMN	DESCRIPTION OF DATA	MANDATORY ENTRY FOR CCE
1 - 3	Document Identifier Code	AØE - CONUS AØ5 - OVERSEAS
4 - 6	Routing Identifier Code	Always S9C
7	Media Status Code	
8 - 22	FSCM and Port Number	Leove Blank Enter in Block 1 under Identification Data
23 - 24	Unit of Issue	
25 - 29	Quantity	
30 - 43	Document Number	
44	Demand Code	
45 -50	Supplementary Address	
51	Signal Code	
52 - 53	Fund Code	
54-56	Distribution Code CC 54	"F" for CONUS. (See AR 725-50 for overseas.)
	CC-55-56	Weapon System Code
57 - 59	Project Code	DSS CODE (CONUS) "JZC" (OCONUS)
60 - 61	Priority Code	
62 - 63	Required Delivery Date	
65 - 66	Advice Code	
67 - 80		Blank

IDENTIFICATION DATA - Lower half of DD Form 1348-6, complete blocks 1 thru 9.

APPENDIX Q

REQUISITION FORMAT

NON-NSN REQUISITION FORMAT

CARD COLUMN	DESCRIPTION	ENTRY CONUS	ENTRY OCONUS
1-3	Document Identifier Code	AOB	AO2
4-6	Routing Identifier Code	S9C	S9C
8-22	Part Number	Enter the Federal Supply Code for the Manufacturer, followed by the part number.	
54-56	Distribution Code:		
54	Control Activity	F	AR 725-50
55-56	Weapons System Designator Code		
57-59	Project Code	BGW	JZC

APPENDIX R

NSN FORMAT

CARD COLUMN	DESCRIPTION	ENTRY CONUS	ENTRY OCONUS
1-3	Document Identifier Code	AOA	AO1
8-22	National Stock Number	Enter the Applicable 13 Digit NSN	
54-56	Distribution Code	Same as Table 1, above.	
57-59	Project Code	Not Required	

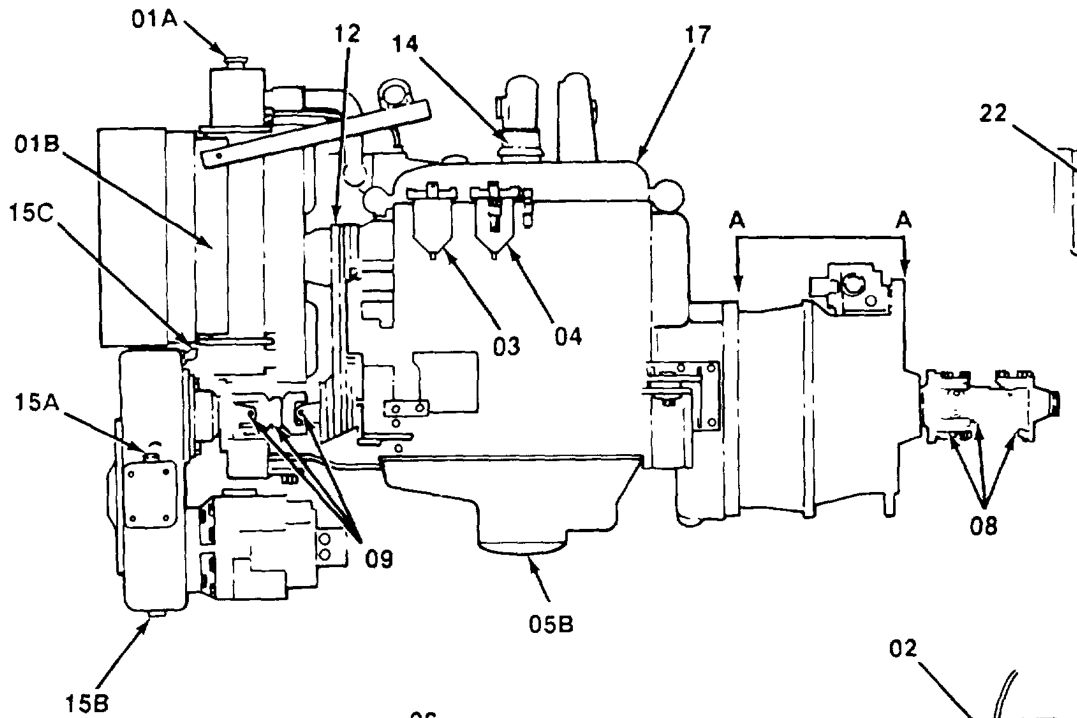
APPENDIX S

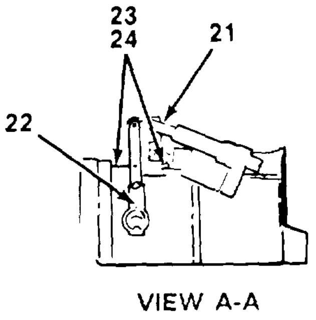
Source Codes Below Are Defined As Follows:

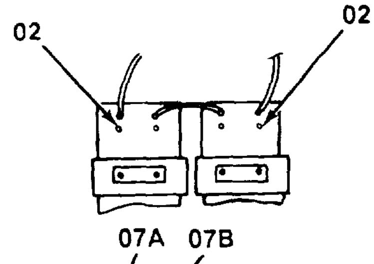
CODE	DEFINITION
PA	Item procured and stocked for anticipated or known usage.
PB	Item procured and stocked for insurance purposes because essentiality dictates that a minimum quantity be available in the supply systems.
PC	Item procured and stocked and which otherwise would be coded PA except that it is deteriorative in nature.
PD	Support item, excluding support equipment, procured for initial issue or outfitting and stocked only for subsequent or additional initial issues or outfittings. Not subject to automatic replenishment.
PE	Support equipment procured and stocked for initial issue or outfitting to specified maintenance repair activities.
PF	Support equipment which will not be stocked but which will be centrally procured on demand.
PG	Item procured and stocked to provide for sustained support for the life of the equipment. It is applied to an item peculiar to the equipment which because of probable discontinuance or shutdown of production facilities would prove uneconomical to reproduce at a later time.
KD	An item of depot overhaul/repair kit and not purchased separately. Depot kit defined as a kit that provides items required at the time of overhaul or repairs.
KF	An item of a maintenance kit and not purchased separately. Maintenance kit defined as a kit that provides an item that can be replaced at organizational or intermediate levels of maintenance.
KB	Item included in both a depot overhaul/repair kit and a maintenance kit.
MO	Item to be manufactured or fabricated at organizational level.
MF	Item to be manufactured or fabricated at Direct Support maintenance levels.

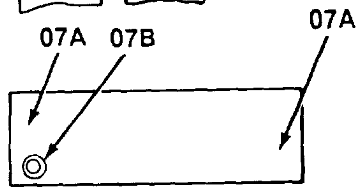
APPENDIX S

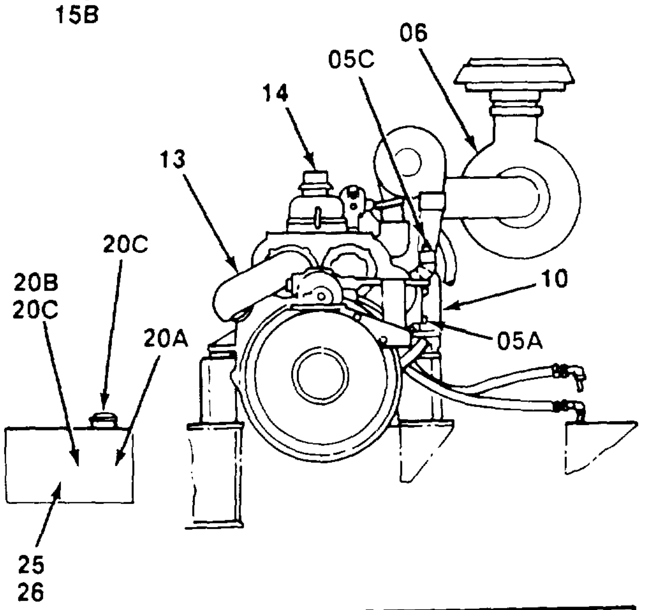
CODE	DEFINITION
MH	Item to be manufactured or fabricated at General Support maintenance levels.
MD	Item to be manufactured or fabricated at Depot maintenance level.
AO	Item to be assembled at organizational level.
AF	Item to be assembled at Direct Support maintenance levels.
AH	Item to be assembled at General Support maintenance levels.
AD	Item to be assembled at Depot maintenance levels.
XA	Item is not procured or stocked because the requirements for the item will result in the replacement of the next higher assembly.
XB	Item is not procured or stocked. If not available through salvage, requisition.
XC	Installation drawing, diagram, instruction sheet, field service drawing, that is identified by manufacturers' drawing/part number.
Col. T. Group	Enter the functional group number for each part in accordance with TB 750-93-1, Functional Grouping Codes: Combat, Tactical, and Support Vehicles and Special Purpose Equipment.











CAPACITY CHART			
SERVICE POINT	IDENTIFICATION	US	METRIC
1A	COOLING SYSTEM	5.75 GAL.	21.8 LITERS
5C	DETROIT DIESEL 4 71 T CRANKCASE WITH FILTER	20.0 QTS.	18.9 LITERS
7B	FUEL TANK	76.5 GAL.	289.6 LITERS
16	PROPEL AND CONTROL RESERVOIR	22.0 GAL.	83.3 LITERS
20	TORQUE CONVERTER RESERVOIR	17.0 GAL.	64.3 LITERS
2	BATTERY	500.0 OZ.	14.8 LITERS
15C	PROPEL PUMP TRANSMISSION	2.3 GAL.	8.7 LITERS

LUBRICATION IDENTIFICATION CHART			
MILITARY SYMBOL	LUBRICANT TYPE	WT	MIL SPEC
OE/HDO	ENGINE OIL Sub-zero and up and starting aids	30 or 40	L2104D
GAA	GREASE AUTO 12°C TO 52°C		G-10924
GO	GEAR OIL 10°F & BELOW 10°F & ABOVE ABOVE 90°F	75 80 90 85 140	L2105C
OE/HDO	TORQUE CONVERTER FLUID 13°F to 95°F 14°F & ABOVE	10 30	L2104D
CW-11	OPEN GEAR LUBE		FED SPECS VV-L751
BFS	BRAKE FLUID SILICONE		MIL-B-46176
AFC	ANTI-FREEZE 32°F to 40°F 40°F to 90°F		MIL-A-46152B MIL-A-11755D

NOTE: THE INFORMATION ON THIS CHART IS INTENDED TO SUPPLEMENT THE ORIGINAL MANUFACTURER'S RECOMMENDATIONS.

TA5015644

☆U.S. GOVERNMENT PRINTING OFFICE: 1990 743-024/20143

APPENDIX T

MODEL 5060 POWER PLANT LUBRICATION (DDA-471T)					
TIME INTERVAL	SERVICE POINT	IDENTIFICATION	REQUIRED SERVICE	LUBRICANT MILITARY ABBREVIATION	NUMBER OF SERVICE POINTS
10 HOURS OR DAILY	1A	RADIATOR COOLANT	CHECK LEVEL	50/50 SOLUTION	1 FILLER CAP
	5A	ENGINE CRANKCASE	CHECK LEVEL	MO	OIL LEVEL DIPSTICK R.H. SIDE (Rear)
	6.	AIR CLEANER- ENGINE	CHECK SERV.INDICATOR		See Note for Service Point 6.
	7A	FUEL TANK	DRAIN SEDIMENT		DRAIN PLUG BOTTOM OF TANK.
	7B	FUEL TANK	REFILL	SEE ENGINE MANUAL	FILL PORT
	16A				
	20A	HYDRAULIC RESERVOIR TORQUE CONVERTER	CHECK LEVEL	OE/HDO	LEVEL INDICATOR ON RT. SIDE MACH.
	23.	SHAFT BEARING	LUBE	GAA	L.H. SIDE OF TORQUE CONVERTER
	24.	CLUTCH BEARING	LUBE	GAA	L.H. SIDE OF TORQUE CONVERTER
50 HOURS OR WEEKLY	1B	RADIATOR CORE- EXTERNAL	BLOW OUT DIRT		
	2	BATTERIES	CHECK ELETROLYTE LEVEL		2 BATTERIES R.H. REAR OF MACH.
	8.	PROP SHAFT TO GEAR AND CHAIN CASE	LUBE	GAA	(ONE ON EACH END AND ONE ON SLIP JOINT)
100 HOURS OR SEMI-MONTHLY					
	9.	PROP SHAFT TO PROPEL TRANSMISSION	LUBE	GAA	3 FITTINGS FRONT OF ENGINE.
250 HOURS OR MONTHLY	3.	ENGINE FUEL FILTER	CHANGE ELEMENT		ELEMENT- L.H. SIDE OF ENGINE.
	4.	ENGINE FUEL STRAINER	CHANGE ELEMENT		ELEMENT L.H. SIDE OF ENGINE
	5B.	CRANKCASE ENGINE	DRAIN		1 DRAIN COCK - BOTTOM.
	5C.	CRANKCASE, ENGINE	REFILL	OE/HDO	1 FILLER PORT R.H. SIDE OF ENGINE. (REAR)
	10.	LUBE OIL FILTER (FULL FLOW)	CHANGE ELEMENT		1 ELEMENT R.H. SIDE OF ENGINE
	11.				
	12	FAN BELTS	ADJUST TENSION	SEE ENGINE MANUAL	1 BELT ASSEMBLY
	13.	ENGINE ALTERNATOR BELTS	ADJUST TENSION	SEE ENGINE MANUAL	1 BELT ASSEMBLY
	15A	PROPEL PUMP TRANSMISSION	CHECK LEVEL	GO*	R.H. SIDE OF ENGINE.
	17	ENGINE THROTTLE CABLE	CHECK		
500 HOURS OR QUARTERLY	18.				
	19				
1000 HOURS OR SEMI-ANNUALLY	14.	BREATHER ENGINE CRANKCASE	CLEAN		1 TOP OF ENGINE
	15B	PROPEL PUMP TRANSMISSION	DRAIN		1 DRAIN PLUG
	15C.	PROPEL PUMP TRANSMISSION	REFILL	GO*	1 FILL PORT TO RIGHT OF RADIATOR.
	16B.				
	16C				
	20B	HYDRAULIC RESERVOIR TORQUE CONVERTER	DRAIN		1 DRAIN PLUG
	20C.	HYDRAULIC RESERVOIR TORQUE CONVERTER	REFILL	OE/HDO	1 FILL PORT
	21	SWITCH HOUSING CLUTCH	LUBE SHAFT	GAA	LIGHT COAT OF LUBRICANT ON SHAFT.
	22.	CLUTCH ADJUSTMENT	CHECK		TOP OF TORQUE CONVERTER
	23.	THROWOUT BEARING	LUBE	GAA	2 FITTINGS
	25.	STRAINER - TORQUE CONVERTER	CLEAN		HYDRAULIC RESERVOIR TORQUE CONVERTER SUCTION
	26	FILTER - TORQUE CONVERTER	CHANGE ELEMENT		HYDRAULIC RESERVOIR - TORQUE CONVERTER RETURN

NOTE (SERVICE POINT 6) WHEN THE INDICATOR FLAG REACHES THE TOP IT WILL LOCK INTO POSITION THE FILTER CARTRIDGE SHOULD THEN BE REPLACED.

TA 272-421

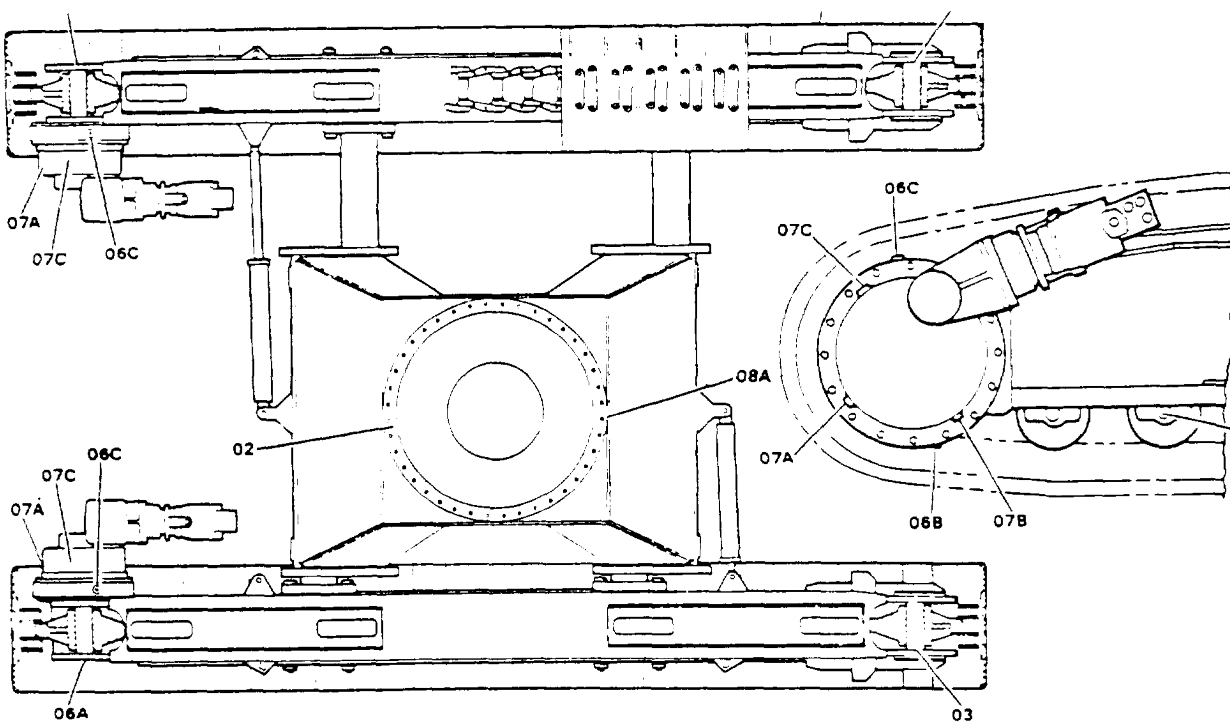
APPPENDIX T

MODEL 5060 LOWER LUBRICATION CHART					
TIME INTERVAL	SERVICE POINT	IDENTIFICATION	REQUIRED SERVICE	LUBRICANT TYPE MILITARY ABBREVIATION	NUMBER OF SERVICE POINTS
10 HOURS OR DAILY	01				
	02	SLEWING RING GEAR	CW-11	GO	OPEN GEAR LUB
	03	IDLER SPROCKET	LUBE	GAA	1 FITTING. EACH SIDE
	04	TRACK ROLLERS	LUBE	GO	12 PLUGS. EACH SIDE
	05				
100 HOURS OR SEMI-MONTHLY	06A	PROPEL DRIVESHAFT	CHECK OIL LEVEL		PLUG AT OUTSIDE END OF DRIVESHAFT
	07A	GEAR CASE	CHECK OIL LEVEL		PLUG AT SIDE OF GEAR CASE
	08A	SLEWING RING	LUBE	GAA	8 FITTINGS
1000 HOURS	06B	PROPEL DRIVESHAFT	DRAIN	GO	DRAIN PLUG BOTTOM OF GEAR CASE HOUSING
	07B	GEAR CASE	DRAIN	GO	DRAIN PLUG BOTTOM OF GEAR CASE
	06C	PROPEL DRIVESHAFT	REFILL	GO	FILL PLUG AT TOP OF GEAR CASE HOUSING
	07C	GEAR CASE	REFILL	GO	VENT AND FILL PLUG TOP OF GEAR CASE

NOTE WHEN TRAVELING MORE THAN AN HOUR, ENTIRE LOWER SHOULD BE LUBRICATED EVERY HOUR

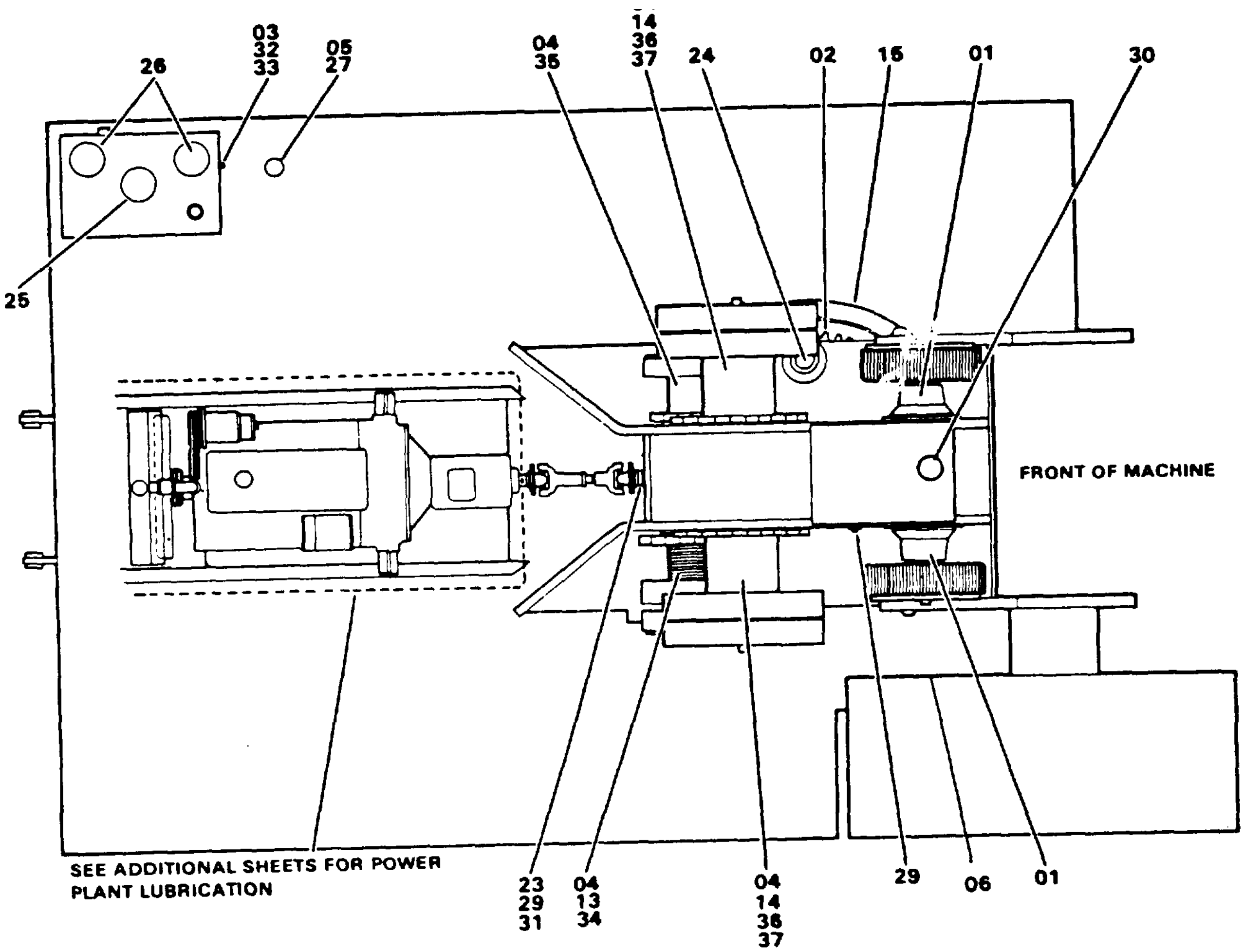
USE OIL CAN TO APPLY SEVERAL DROPS OF OIL WEEKLY TO ALL PINS AND LEVERS NOT EQUIPPED WITH GREASE FITTINGS.

CAPACITY CHART			
SERVICE POINT	IDENTIFICATION	U.S.	METRIC.
7C	PROPEL GEAR CASE	[illegible] GAL	[illegible] LITERS



TA 272-422

APPENDIX T



** CAPACITY CHART			
SERVICE POINT	IDENTIFICATION	U.S.	METRIC.
30	GEAR AND CHAIN CASE	7 GAL.	26.5 LITERS

MODEL 5060 UPPER LUBRICATION CHART

TIME INTERVAL	SERVICE POINT	IDENTIFICATION	REQUIRED SERVICE	LUBRICANT MILITARY ABBREVIATION	NUMBER OF SERVICE POINTS
10 HOURS OR DAILY	1	HORIZONTAL SWING SHAFT	LUBE	GAA	2 FITTINGS, 1 EACH SIDE
	2	SWING GEAR	LUBE	CW11	ALL GEAR TEETH (Small Amounts)
	3	HYDRAULIC FLUID RESERVOIR	CHECK LEVEL	OE	SIGHT GAGE - RESERVOIR
	4	PAWL	LUBE	GAA	4 FITTINGS, 1 EACH PAWL
	5	HIGH PRESSURE FILTER	CHECK CONDITION		VISUAL INDICATOR - TOP OF FILTER ASSY
	6	THROTTLE RESERVOIR	CHECK LEVEL		VISUAL CHECK.
	7				
	8				
50 HOURS OR WEEKLY	9				
	10				
	11				
	12	PLANETARY BEARING	LUBE	GAA	2 FITTINGS, 1 EACH PLANETARY
	13	BOOM HOIST DRUM SHAFT	LUBE	GAA	1 FITTING
	14	POWER LOWERING	LUBE	GAA	6 FITTINGS, 3 EACH SIDE
	15	SLEWING RIM	LUBE	GAA	8 FITTINGS
	16	360 (Degree) SWING LOCK	LUBE	GAA	1 FITTING
	17				
	18				
	19				
	20				
	21				
	22	ALL PINS AND LEVERS W/O FITTINGS	LUBE	OE HDO	Use Oil Can (See Note 4)
200 HOURS OR MONTHLY	23	GEAR AND CHAIN CASE LEVEL PLUG	CHECK LEVEL	GO	1 PLUG(3/4" N P T PLUG)
	24	SWING BRAKE HOUSING	LUBE	GAA	1 FITTING
	25	PUMP INLET FILTER (Controls)	CHANGE FILTER ELEMENT AND CLEAN BOWL		(1 FILTER INSIDE HYD RESERVOIR)
	26	PUMP INLET FILTERS (PROPEL)	CHANGE FILTER ELEMENT AND CLEAN BOWL		(2 FILTERS INSIDE HYD RESERVOIR)
	27	PUMP OUTLET FILTER (Controls)	CHANGE FILTER ELEMENT AND CLEAN BOWL		(1 FILTER LEFT REAR OF MACHINE)
	28				
1000 HOURS OR SEMI-ANNUALLY	29	GEAR AND CHAIN CASE DRAIN PLUGS	DRIVE AND FLUSH W/KEROSENE		2 PLUGS(-1-1/2 N P T PLUGS)
	30	GEAR AND CHAIN CASE FILLER PLUG	REFILL**	GO	1 FILLER CAP
	31	GEAR AND CHAIN CASE LEVEL PLUG	CHECK LEVEL	GO	1 PLUG -3/4 " N P T Plug)
	32	HYDRAULIC RESERVOIR	DRAIN*		1 PLUG (3/4" N P T Bottom of Hyd Reservoir)
	33	HYDRAULIC RESERVOIR	REFILL	OE/HDO	FILLER CAP TOP HYD RESERVOIR
	34	BOOM HOIST DRUM SHAFT	SEE NOTE B	GAA	4 BEARINGS
	35	THIRD DRUM SHAFT	SEE NOTE B	GAA	2 BEARINGS
	36	HOIST DRUM SHAFT	SEE NOTE B	GAA	4 BEARINGS, 2 EACH SIDE
	37	POWER LOWERING	SEE NOTE B	GAA	4 BEARINGS, 2 EACH SIDE
	38				
	39				
	40				

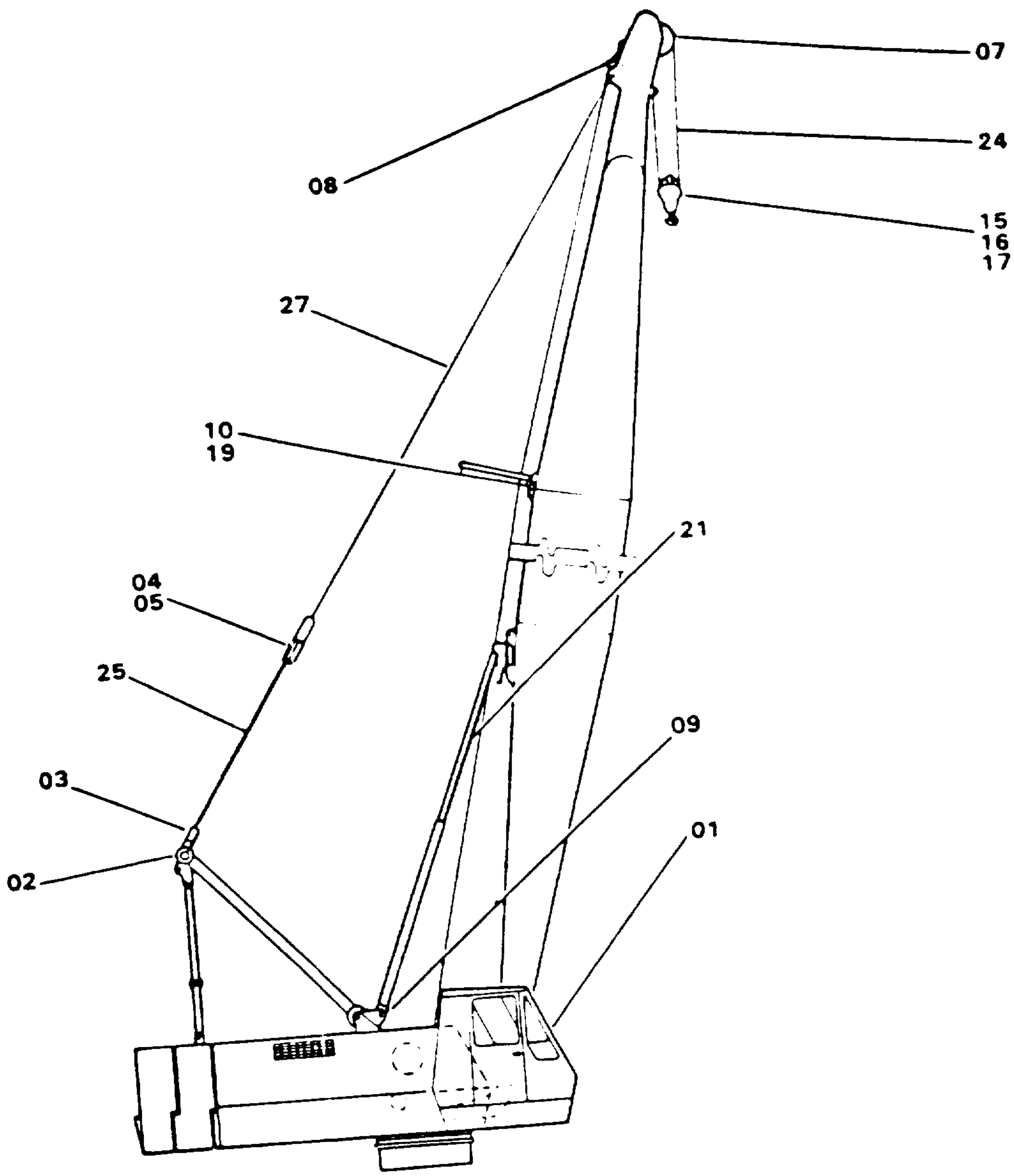
NOTES: The information of this drawing is intended to supplement the original manufactures recommendations. Points to be lubricated with an oil can are not designated. Use a few drops of motor oil every week on each pin or lever not equipped with a grease fitting.

NOTE A. Grease slewing rim liberally, grease should appear between the upper and lower rims the entire circumference of the slewing rim. Also, grease slewing rim daily if service conditions are severe.

NOTE B Remove, Clean, and replace bearings.

MODEL 5060 ATTACHMENTS LUBRICATION CHART					
TIME INTERVAL	SERVICE POINT	IDENTIFICATION	REQUIRED SERVICE	LUBRICANT MILITARY ABBREVIATION	NUMBER OF SERVICE POINTS
10 HOURS OR DAILY	01	BOOM FOOT PINS	LUBE	GAA	2 FITTINGS
	02	GANTRY PEAK SHEAVES	LUBE	GAA	2 FITTINGS
	03	LOWER SPREADER	LUBE	GAA	4 FITTINGS
	04	UPPER SPREADER SHEAVE PINS	LUBE	GAA	6 FITTINGS
	07	BOOM POINT SHEAVE ASSEMBLY	LUBE	GAA	1 FITTING, EACH SHEAVE
	08	BOOM POINT IDLER SHEAVES	LUBE	GAA	2 FITTINGS
	09	BOOM HOIST IDLER SHEAVE	LUBE	GAA	1 FITTING
	10	UPPER CABLE ROLLER ASSEMBLY	LUBE	GAA	2 FITTINGS
	15	SINGLE SHEAVE HOOK BLOCK	LUBE	GAA	2 FITTINGS
	16	THREE SHEAVE HOOK BLOCK	LUBE	GAA	4 FITTINGS
	17	FIVE SHEAVE HOOK BLOCK	LUBE	GAA	6 FITTINGS
	19	FLIPPER SHEAVES	LUBE	GAA	2 FITTINGS
1000 HOURS OR SEMI-ANNUALLY					
	21	BOOM BACKSTOPS	LUBE	CW-11	O D OF MALE TUBES
	22	ALL PINS W/O GREASE FITTINGS	LUBE	OE/HDO	
SEE NOTE	24	MAIN HOIST WIRE ROPE	LUBE	CW-11	
	25	BOOM HOIST WIRE ROPE	LUBE	CW-11	
	27	BOOM SUSPENSION LINE	LUBE	CW-11	

NOTE: THE TIME INTERVAL DEPENDS ON HOW THE ROPE IS USED, THE LOADS IT HANDLES, FREQUENCY OF OPERATION AND EXPOSURE TO CORROSIVE INFLUENCES



A1505

TA 272-424

By Order of the Secretary of the Army:

JOHN A. WICKHAM, JR.
General, United States Army
Chief of Staff

Official:

ROBERT M. JOYCE
Major General, United States Army
The Adjutant General

Distribution:

To be distributed in accordance with DA Form 12-25B, Organizational, D/S, G/S Maintenance Requirements for Crane, 40 Ton, Crawler Mounted.

* U.S. GOVERNMENT PRINTING OFFICE: 1984-754-045:7153

TEAR ALONG PERFORATED LINE

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS

SOMETHING WRONG WITH THIS PUBLICATION?

FROM: (PRINT YOUR UNIT'S COMPLETE ADDRESS)

Your complete address

DATE SENT

Date you filled in form

PUBLICATION NUMBER	PUBLICATION DATE	PUBLICATION TITLE
TM 5-XXXX-XXX-XX	Date of TM	Title of TM

BE EXACT. . PIN-POINT WHERE IT IS

PAGE NO	PARA-GRAPH	FIGURE NO	TABLE NO	IN THIS SPACE TELL WHAT IS WRONG AND WHAT SHOULD BE DONE ABOUT IT:
75		183		Change illustration. Reason: Tube end shown assembled on wrong side of lever cam.
105	3-12			This paragraph says to refer to chapter 6 for repair of auxiliary engine, but procedures are not in chapter 6. Please add procedures or give correct reference.

SAMPLE

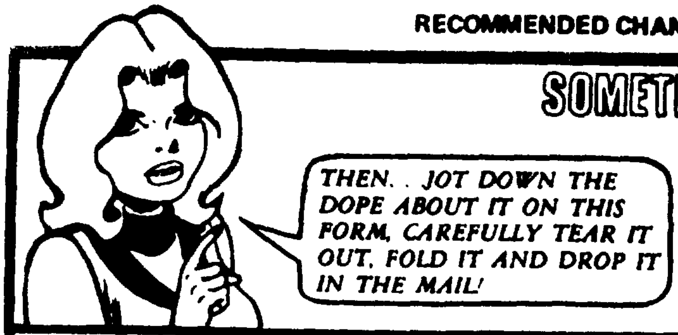
PRINTED NAME GRADE OR TITLE AND TELEPHONE NUMBER	SIGN HERE
JOHN SMITH, SP4 798/XXXX	

DA FORM 1 JUL 79 2028-2

PREVIOUS EDITIONS ARE OBSOLETE.

P.S.—IF YOUR OUTFIT WANTS TO KNOW ABOUT YOUR RECOMMENDATION MAKE A CARBON COPY OF THIS

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS



SOMETHING WRONG WITH THIS PUBLICATION?

FROM: (PRINT YOUR UNIT'S COMPLETE ADDRESS)

DATE SENT

PUBLICATION NUMBER	PUBLICATION DATE	PUBLICATION TITLE
TM 5-3810-303-24	13 August 1984	Crane 40 Ton P&H Mdl 5060

BE EXACT. . .PIN-POINT WHERE IT IS

PAGE NO.	PARA-GRAPH	FIGURE NO.	TABLE NO.	IN THIS SPACE TELL WHAT IS WRONG AND WHAT SHOULD BE DONE ABOUT IT:

TEAR ALONG PERFORATED LINE

PRINTED NAME, GRADE OR TITLE, AND TELEPHONE NUMBER	SIGN HERE:

DA FORM 1 JUL 79 2028-2

PREVIOUS EDITIONS ARE OBSOLETE.

P.S.--IF YOUR OUTFIT WANTS TO KNOW ABOUT YOUR RECOMMENDATION MAKE A CARBON COPY OF THIS AND GIVE IT TO YOUR HEADQUARTERS.

REVERSE OF DA FORM 2028-2

TEAR ALONG PERFORATED LINE

FILL IN YOUR UNIT'S ADDRESS

FOLD BACK

DEPARTMENT OF THE ARMY

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U.S. Army Tank Automotive Command
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Warren, Michigan 48090

THE METRIC SYSTEM AND EQUIVALENTS

LINEAR MEASURE

1 Centimeter = 10 Millimeters = 0.01 Meters = 0.3937 Inches
1 Meter = 100 Centimeters = 1000 Millimeters = 39.37 Inches
1 Kilometer = 1000 Meters = 0.621 Miles

WEIGHTS

1 Gram = 0.001 Kilograms = 1000 Milligrams = 0.035 Ounces
1 Kilogram = 1000 Grams = 2.2 Lb.
1 Metric Ton = 1000 Kilograms = 1 Megagram = 1.1 Short Tons

LIQUID MEASURE

1 Milliliter = 0.001 Liters = 0.0338 Fluid Ounces
1 Liter = 1000 Milliliters = 33.82 Fluid Ounces

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 = 1000 Cu. Millimeters = 0.06 Cu. Inches
1 Cu. Meter = 1,000,000 Cu. Centimeters = 35.31 Cu. Feet

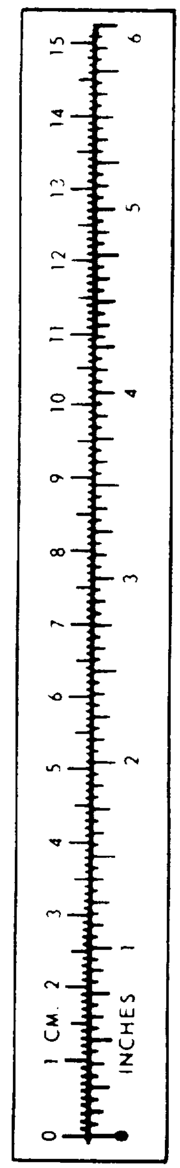
TEMPERATURE

$\frac{5}{9}(°F - 32) = °C$
212° Fahrenheit is equivalent to 100° Celsius
90° Fahrenheit is equivalent to 32.2° Celsius
32° Fahrenheit is equivalent to 0° Celsius
$\frac{9}{5}(°C + 32) = °F$

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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