TM 5-3895-359-14&P

TECHNICAL MANUAL

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

MIXER, ROTARY TILLER, SOIL STABILIZATION REWORKS MODEL HDS-E DIESEL ENGINE DRIVEN (DED) NSN 3895-01-141-0882

HEADQUARTERS DEPARTMENT OF THE ARMY

20 AUGUST 1985

SAFETY PAGE

WARNING

Adjustments on services which require a running engine, require two men working; one at controls and one at service point to help prevent accidental movement of controls.

WARNING

Before starting engine or operating any of the components, ensure that no loose bars, tools or other parts are lying in or on any of the equipment as they could cause bodily injury to personnel or serious damage to equipment.

WARNING

Never wear loose clothing or hanging appendages from person or clothing, while inspecting, running engine, moving shafts, or like machinery.

WARNING

Explosive gas may remain in or around the batteries for several hours after they have been charged. Make certain no sparks or flame are present near the batteries which could ignite this gas and cause an explosion. Failure to observe this precaution could result in injury or death to personnel and damage to equipment.

WARNING

When repairing or testing operation of hydrostatic drive components, raise rear wheels off the ground or remove hydrostatic motor from traction drive axle. Failure to do so could result in accidental vehicle movement, resulting in personnel injury or death.

WARNING

When cleaning asphalt and emulsion system with rotor in operation, be sure no personnel are behind the machine as they may be hit with flying material from the rotor assembly.

WARNING

Operation of this equipment presents a noise hazard to operating personnel. The noise level exceeds the allowable limits for unprotected personnel. Wear ear muffs or ear plugs which were fitted by a trained professional.

WARNING

Wear gloves or other skin protective equipment when working with cleaning solvents.

WARNING

Eye protective equipment must be worn when cleaning asphalt and emulsion system, working on high pressure hydraulic lines and scraping rust and loose paint.

Make certain any lifting device used has a capacity equal to, or greater than the weight being lifted. Failure to observe this precaution could result in injury or death to personnel and damage to equipment.

WARNING

Dry cleaning solvent, SD-2 is potentially dangerous. Do not use near open flame or heat.

WARNING

Attach a Warning Tag on the unit tongue and engine start switch if unit is under repair or needs work. Even a minor defect can become a serious problem.

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Washington, DC *20 August 1985*

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REPORTING OF ERRORS

You can 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, US Army Tank Automotive Command, ATTN: AMSTA-MB, Warren, MI48397-5000. A reply will be furnished direct to you.

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

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SECTION 1 OPERATION

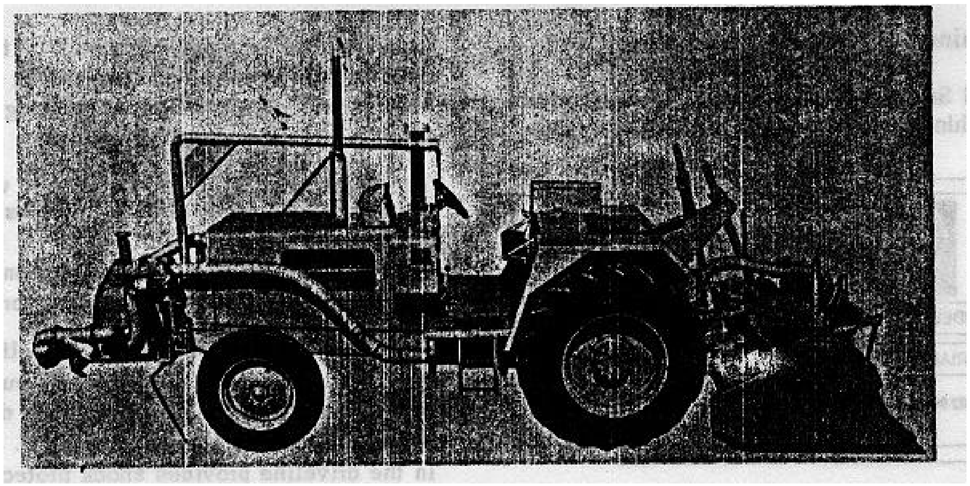


Figure 1-1. General View, Model HDS-E Standard Pulvi-Mixer With Asphalt Emulsion Handling System.

Warranty

We warrant to the original user that all construction machinery products of our manufacture will be free from defects in material and workmanship and will possess the characteristics represented in writing by us. Any claim under the above warranty must be made within a period of fifteen (15) months from date of delivery to the user. Upon satisfactory demonstration of the merits of the claim, we will, within a reasonable time, make any necessary repairs or corrections, or at our option, replace defective parts free of charge. Charges for correcting defects will not be allowed, nor can we accept goods returned for credit, unless we are notified in writing and the return or correction is authorized by us in writing. This warranty will not apply to any product which shall have been repaired or altered outside of our factory in any way so as, in our judgment, to affect its stability or reliability, nor which has been subjected to misuse, neglect or accident. NO FURTHER WARRANTIES, INCLUDING WARRANTIES OF MERCHANTABILITY OR OF FITNESS FOR PURPOSE ARE MADE BY US, and this paragraph sets forth the full extent of our liability arising from the manufacture, use or sale of our products. No allowance will be made for delays or loss of profit, nor for any other consequential damages or injuries, whether based on tort or contract.

Damage Claims

REXWORKS Inc. assumes no responsibility for delays or damage to merchandise while in transit. Our responsibility ceases upon delivery of shipment to the transportation company, from whom a receipt is received showing that shipment was in good condition and properly packed when delivered to them; therefore, claims for parts lost or broken in transit should be made by you to the transportation company.

General Machine Description

The Model and Serial Number plate is affixed to the firewall of the machine and facing the operator. See Figure 1-2.

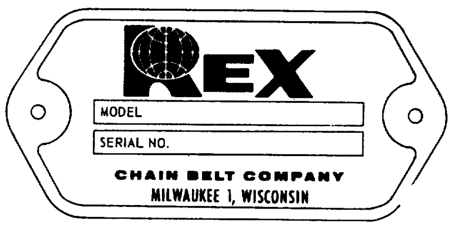


Figure 1-2. Number Plate

The Hydrostatic Self-Propelled Stabilizer is a machine designed specifically for use in pulverizing the subgrade prior to the addition of a suitable binder, or merely blending in the case of purely mechanical stabilization.

Stabilization means the mechanical mixing of the coarse and fine aggregate into a homogeneous mixture. This mixture is stable because the voids that normally exist where coarse materials are lying adjacent to one another separated from the fines, are eliminated.

The machine's performance accomplishes many functions such as:

Mixing of the bituminous wearing surface.

Stabilization of asphalt roads and shoulders.

Stabilizing airport runways, taxiways, earth dams and embankments.

Construction material reduction, moisture introduction, aeration of material and land clearing.

Use in all types of road stabilization using bitumen, cement, lime, chlorides and other stabilizing additives.

The mixing of additives at the most ideal location within the mixing chamber.

The machine consists of a series of major components each of which is dependent upon the others to perform the final function for which the machine was designed.

The engine is probably the most important component, since it is the source of all power for the machine. A 4 cylinder diesel engine is used as standard power.

The traction drive is accomplished hydrostatically. The engine drives a variable displacement hydraulic pump off the front of the engine crankshaft, which in turn drives a fixed displacement hydraulic motor. The hydraulic motor is mounted on a two speed transmission or nose box which is part of the planetary rear axle, thus the speed of the vehicle is infinitely variable in two ranges. Low or working range 0-2 1/2 mph; high or traveling range 0-15 1/2 mph.

The planetary rear axle is equipped with brakes which are operated individually by two master cylinders. In addition to the hydraulic brakes on the axle, the hydrostatic system has inherent dynamic braking which will probably be used more than the brakes on the axle.

The work of pulverization is accomplished by the rotor which is driven by the engine through a clutch, two speed transmission and jack axle differential which evenly divides the power to the rotor. A shear coupling in the driveline provides shock protection for the drive train.

The standard tines, 103 1/2 bevel edge type, are arranged on the rotor to form a spiral pattern, and to overlap by 3/,6" to insure the cutting of a flat bottom.

The spiral pattern allows four tines in any longitudinal row to cut simultaneously.

The maximum cutting width of the rotor is 6'-6 1/4".

Maximum cutting depth 0 10 1/2".

The mixing chamber or hood assembly is composed of the following components: hood, hydraulically operated tailboard, hood lift bar assembly, tailboard wear plate, skis and hood adjusting bolts. The hood confines the material while mixing to control pulverization and thoroughness of mixture or integration of materials. Raising the tailboard permits aeration of mixture to reduce moisture content. Hood adjusting bolts are provided to obtain the right angle of skis for floation of hood assembly on the materials being mixed.

The wear plate attached to the tailboard provides strike-off of mixed material for proper contour and compaction. A lifting bar is attached to the hood for raising with the crane.

The crane is used to lift the rotor and/or hood assembly from material for turn-arounds or maneuvers during mixing passes, parking, loading and unloading the machine.

The crane is pivoted at the bottom and actuated by a double acting hydraulic cylinder which receives oil under pressure from the hydraulic pump through a control valve at the operator's location. The crane lifts the hood and rotor by means of the rotor and hood lifting bars.

The hydraulic system consists of the following components.

A. Hydraulic pump for power steering The pump is a vane type, and is mounted on the left front side of the engine and is belt driven. This pump supplies oil to the power steering ram only.

B. Hydraulic pump for crane, tailboard and spray bar This pump is a positive displacement, gear type and is mounted at the rear of the engine off the accessory drive opposite the engine tachometer. This pump supplies oil to the crane and tailboard rams, and to the spray bar ram.

C. Hydrostatic pump, traction drive Pump is located at the front of the engine and driven off the engine crankshaft. The pump is of variable displacement type and supplies oil under pressure to the hydrostatic motor.

D. Hydrostatic motor, fixed displacement Mounted on the 2 speed trans. or nose box of the rear axle differential, motor receives oil from the hydrostatic pump and drives the rear axle assembly.

E. Oil reservoir The oil reservoir is located to the left side of the engine dash assembly just below the hydraulic control valve and supplies and receives oil for the entire hydraulic system, except power steering.

F. Hydraulic control valve A two spool dual control valve is used. The valve spools are 4-way type and the valve has an "open center" or neutral position which permits the oil to be pumped unrestricted from the reservoir thru the pump and control valve back to the reservoir.

V.P.I. Fluid Handling System

The V.P.I. is an electrically instrumented system provisioned with gauges and a liquid control to visually indicate to the operator the performance of the fluid handling system.

It operates on an electrical balance principle that integrates the fluid rate of flow with the stabilizer travel speed, fulfilling the need for more accurate control and faster dispersion of liquid, (emulsified asphalt, water or asphalt cutbacks).

Volumes of liquid up to 500 gallons per minute can be obtained and controlled with extreme accuracy. This system minimizes the number of re-mix passes, advances the travel speeds, which also benefits the tank trucks resulting in fewer problems that otherwise might be encountered at slower travel speeds.

Diesel Engine 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.

The Two-Cycle Principle

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively, as shown in Fig. 1-3. 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 that 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 (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.

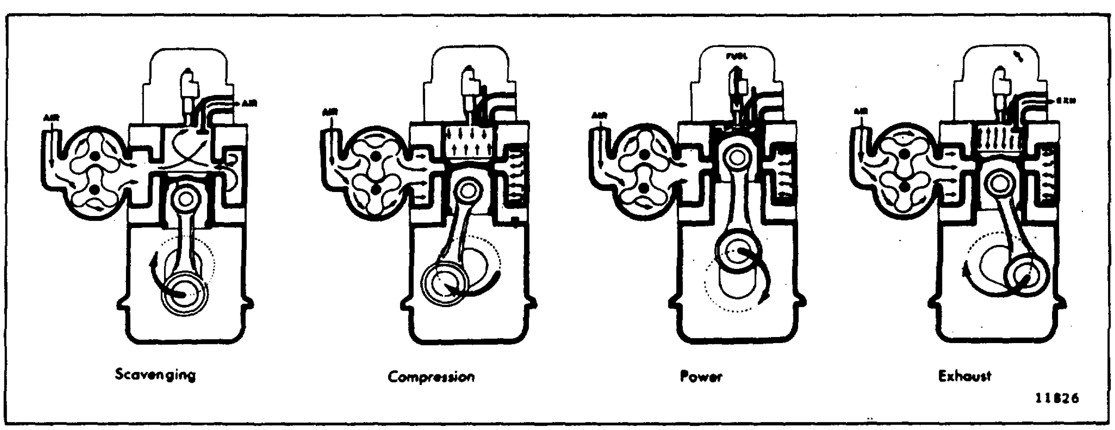


Figure 1-3. Two-Stroke Cycle Operation

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression (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 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion 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 halfway down, allowing the burned gases to escape into the exhaust manifold (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".

The two-cycle engines covered in this manual are produced in three, four and six-cylinder models having the same bore and stroke and many of 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 which can be located on either side of the engine, regardless of the direction of rotation. Further flexibility in meeting installation requirements can be had by placing the exhaust manifold and the water outlet manifold on either side of the engine (Fig. 1-4). This flexibility in the arrangement of parts is obtained by having both the cylinder block and the cylinder head symmetrical at both ends and with respect to each other.

The meaning of each digit in the model numbering system is shown in Fig. 1-4. The letter L or R indicates left or right-hand engine rotation as viewed from the front of the engine. The letter A, B, C or D designates the blower and exhaust manifold location as viewed from the rear of the engine.

Each engine is equipped with an oil cooler, lubricating oil filter, fuel oil strainer, fuel oil filter, air cleaner, governor, fan and radiator, and starting motor.

Full pressure lubrication is supplied to all main, connecting rod and 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 where 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 heat exchanger or 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 a strainer by a gear-type fuel pump. It is then forced through a filter and into the fuel inlet gallery in the cylinder head and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet gallery 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 or silencer.

Engine starting is provided by an electric 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 type engine governor.

GENERAL SPECIFICATIONS

	4-71
Type	2 Cycle
Number of Cylinders	4
Bore (inches)	4.25
Bore (mm)	108
Stroke (inches)	5
Stroke (mm)	127
Compression Ratio (Nominal) ("N" Engines)	18.7 to 1
Total Displacement - cubic inches	284
Total Displacement · litres	4.66
Firing Order - R.H. Rotation	1-3-4-2
Number of Main Bearings	5

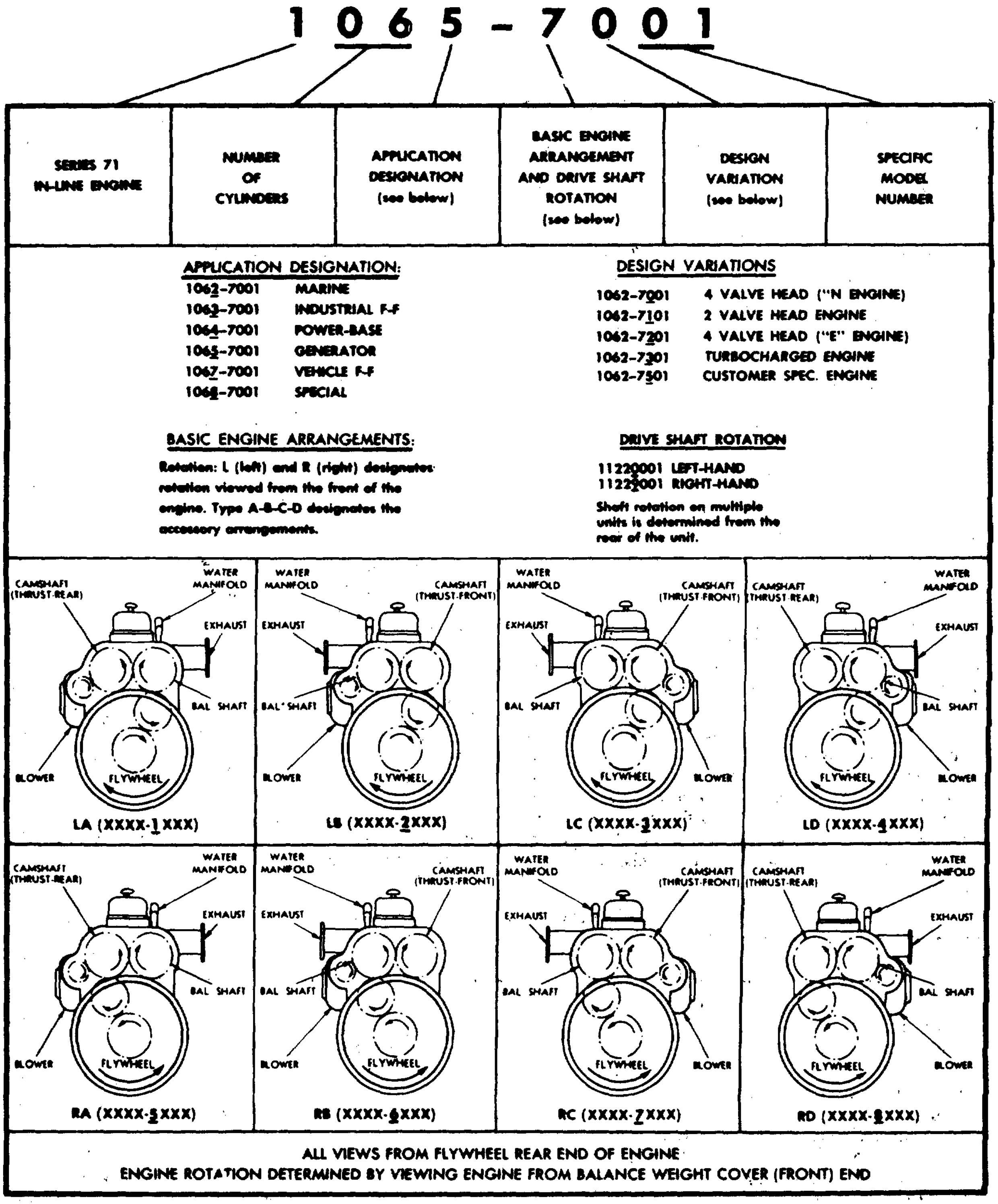


Figure 1-4. Model Number Coding

Diesel Engine Model and Serial Numbers

On all current Series 71 engines, the engine serial number and the engine model number are stamped on the cylinder block (Figs. 1-4 and 1-5). The engine serial number and model number are also stamped on the Option Plate (when used) attached to the valve rocker cover.

Diesel Engine Serial Number

The engine serial number is prefixed by numerals indicating the number of cylinders and the letter "A" which designates a Series 71 engine.

Diesel Engine Model Number

Current Series 71 engines are identified by an eight digit model number (Fig. 1-4). The engine model number 1065-7001 illustrated is interpreted as follows: Series 71 In-line engine (1), six-cylinder (06), generator set (5), right-hand rotation with "C" accessory arrangement (7), four-valve head "N" engine (0) and specific model variation No. 1 (01).

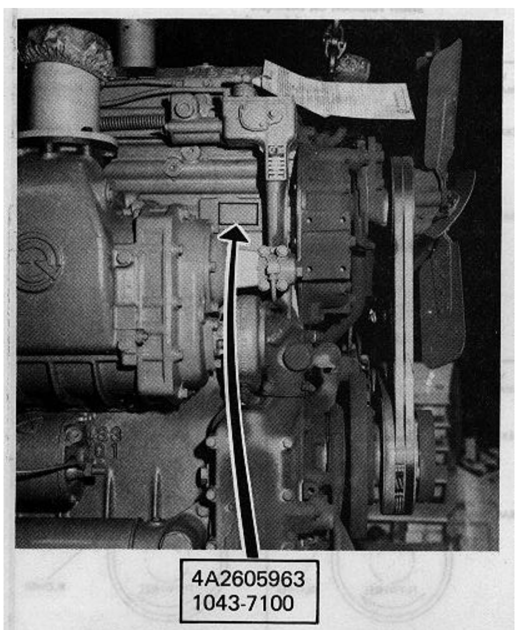


Figure 1-5. Typical Engine Serial Number and Model Number as Stamped on Cylinder Block Option Plate

An option plate, attached to the valve rocker cover (only one valve rocker cover of a multiple engine unit), is stamped with the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 1-6).

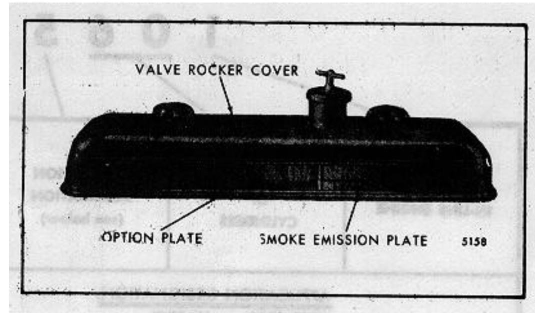


Figure 1-6. Option Plate

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.

Built-in Parts Book

The *Built -In Parts Book* is a photoetched aluminum plate (Option Plate) that fit into a holding channel on the engine valve rocker cover and contains the necessary Information required when ordering parts. It is recommended that the engine user read the section on the *Built -In Parts Book* in order to take full advantage of the information provided on the engine option plate.

Numerous exploded view type illustrations are included to assist the user in identifying and ordering service parts.

Pump Engine

Pump engines are of the four cycle type, in which each of the four operations of suction, compression, expansion and exhaust requires a complete stroke. This gives one power stroke per cylinder for each two revolutions of the crankshaft.

Cooling

Cooling is accomplished by a flow of air, circulated over the cylinders and heads of the engine, by a combination fan-flywheel encased in a sheet metal shroud. The air is divided and directed by ducts and baffle plates to insure uniform cooling of all parts.

Never operate an engine with any part of the shrouding removed- this will retard air cooling.

Keep the cylinder and head fins free from dirt and chaff. Improper circulation of cooling air will cause engine to overheat.

Carburetor
The proper combustible mixture of gasoline and air is furnished by a balanced carburetor, giving correct fuel to air ratios for all speeds and loads.

Ignition System The spark for ignition of the fuel mixture is furnished by a high tension magneto driven off the timing gears at crankshaft speed. The magneto distributor rotor turns at half-engine speed. The magneto is fitted with an impulse coupling, which makes possible a powerful spark for easy starting. Also, the impulse coupling automatically retards the spark for starting, thus eliminating possible kick back from engine while cranking.

Lubrication System
A gear type pump supplies oil to four nozzles which direct oil streams against fins on the connecting rod caps. Part of the oil enters the rod bearing through holes in the rods, and the balance of the oil forms a spray or mist which lubricates the cylinder walls and other internal parts of the engine. An external oil line from the oil header tube in the crankcase lubricates the governor and gear train.

Governor
A governor of the centrifugal flyweight type maintains the engine speed by varying the throttle opening to suit the load imposed upon the engine. These engines are equipped with a variable speed control to regulate the governed speed of the engine.

Rotation
The rotation of the crankshaft is clockwise when viewing the flywheel or cranking end of the engine. This gives counter-clockwise rotation when viewing the power takeoff end of the crankshaft. The flywheel end of the engine is designated the front end, and the power take-off end, the rear end of the engine.

Horsepower
Horsepower specified in the accompanying chart is for an atmospheric temperature of 60° Fahrenheit at sea level and at a Barometric pressure of 29.92 inches of mercury.

For each inch lower the Barometric pressure drops, there will be a loss in horsepower of 3 1/2%.

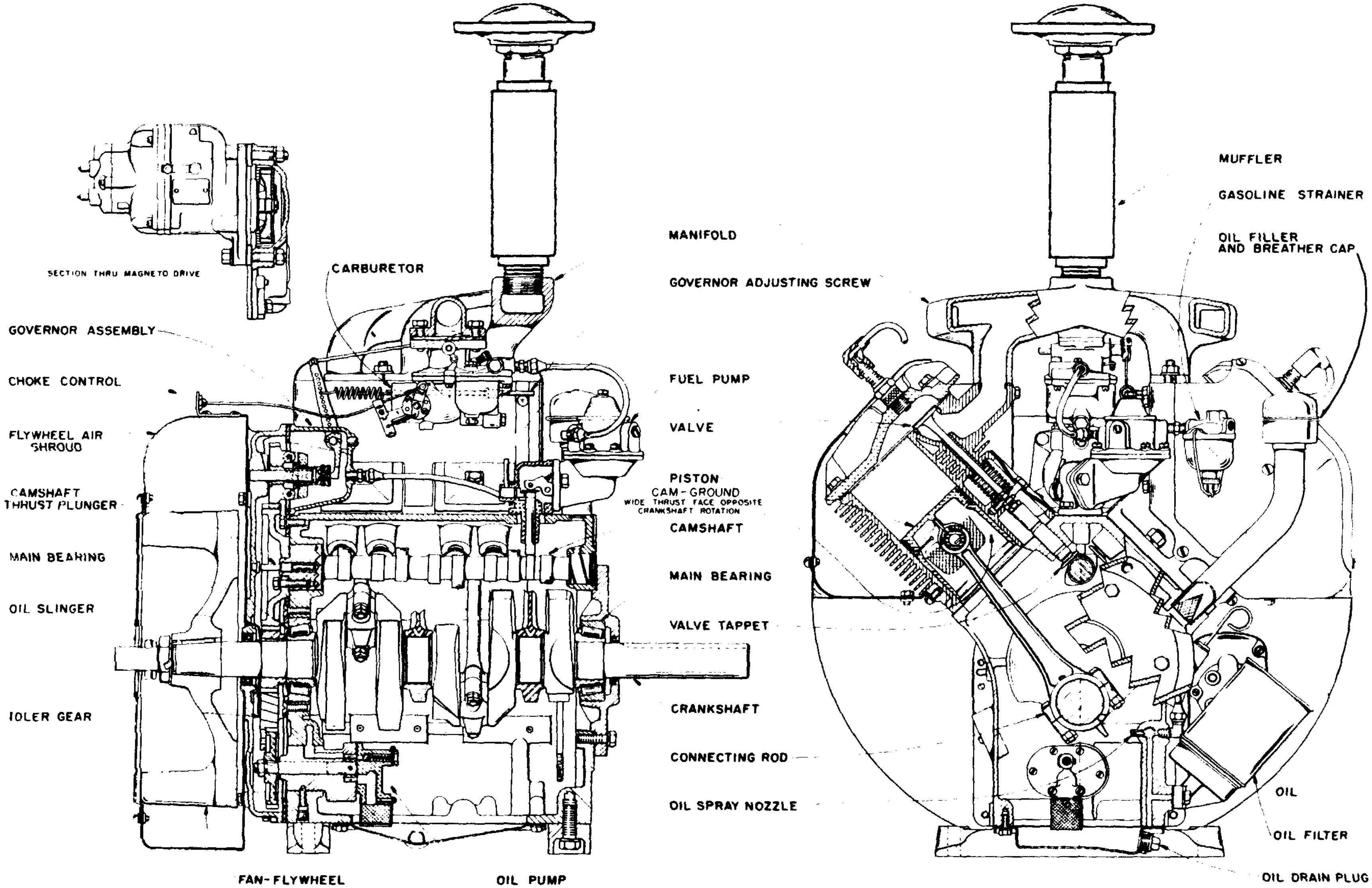
For each 10° temperature rise there will be a reduction in horsepower of 1%.

For each 1000 ft. altitude above sea level there will be a reduction in horsepower of 3 1/2%.

The friction in new engines cannot be reduced to the ultimate minimum during the regular block test, but engines are guaranteed to develop at least 85 per cent of maximum power when shipped from the factory. The power will increase as friction is reduced during the first few days of operation. The engine will develop at least 95% of maximum horsepower when friction is reduced to a minimum.

For continuous operation, allow 20% of horsepower shown as a safety factor.

R.P.M.	HORSEPOWER
1400	17.2
1600	20.0
1800	22.5
2000	24.7
2200	26.5
2400	28.0
2600	29.2
2800	30.0



CROSS SECTION OF ENGINE MODEL VH4D

Shipping and Lifting
Normally machines leaving the factory, shipping domestic, are shipped as much assembled as possible except for the miscellaneous equipment. Machines shipping export will usually have the rotor and hood assembly removed from the machine and crated separately.

Machines may be lifted utilizing a four point suspension using the two lifting eyes to the rear of the machine. The front may be lifted at the front side with chain hooks. Use a spreader bar approximately 45 inches long to keep from damaging the engine housing. Lift machine in a horizontal plane.

Diesel Engine

Remove the filler cap and fill the cooling system with clean, soft water or a protective solution consisting of high boiling point type antifreeze, if the engine will be exposed to freezing temperatures (refer to *Engine* Coolant). Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

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 of 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 under *Lubricating Oil Specifications*. 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. fill the crankcase to the proper level with *heavy-duty* lubricating oil as specified under *Lubricating Oil Specifications*. Then pre-lubricate 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.

Fill the tank with the fuel specified under *Diesel Fuel Oil Specifications*.

Be sure the tank fuel valve is open.

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 filter between the fuel pump and the injectors. The filter may be primed by removing the plug in the top of the 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.

Check the batteries. The tops 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: Check the batteries with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

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.

Adjust all drive belts as recommended under *Lubrication and Preventive Maintenance*.

Pump Engine Lubrication
Before starting a new engine, fill the oil base with good "gasoline engine" oil, as specified in the "Grade of Oil" chart. Fill through the breather tube with 4 quarts of oil.

For run-in of new engines, use same oil as recommended in Grade of Oil Chart.

After the engine has been run for a short time, the oil lines and oil filter will have been filled with oil. Shut off the engine and check the oil level by means of dip stick (oil gauge saber). If necessary, add enough oil to bring level up to the full mark. The dip stick location is below the oil filler-breather tube.

Use only high-grade highly refined oils, corresponding in body to the S. A. E. (Society of Automotive Engineers) Viscosity Numbers listed in Grade of Oil Chart.

GRADE OF OIL

SEASON OR TEMPERATURE		GRADE OF OIL
Spring, Summer or Fall + 120°F to + 40°F		SAE 30
Winter + 40°F to + 15°F + 15°F to 0°F Below Zero		SAE 20-20W SAE 10W SAE 5W-20
Use oils classified as Service MS, SD or SE		
Crankcase Capacity	New engine	4 Qts.
	Oil and filter change	4 Qts.
	Less – filter or filter change	3½ Qts.

Service Classification of Oil

In addition to the S.A.E. Viscosity grades, oils are also classified according to severity of engine service. Use oils classified by the American Petroleum Institute as Service MS, SD or SE. These types of oil are for engines performing under unfavorable or severe operating conditions such as: high speeds, constant starting and stopping, operating in extreme high or low temperatures and excessive idling.

Fill the air cleaner bowl to level mark with the same grade of oil used in the crankcase.

The fuel tank should be filled with a good quality gasoline free from dirt and water. The capacity of the tank is approximately 13 gallons.

The gasoline should have an octane rating of at least 90. Low octane gasoline will cause the engine to detonate, or knock, and if operation is continued under this condition, cylinders will score, valves will burn, pistons and bearings will be damaged, etc.

Be sure that air vent in tank cap is not plugged with dirt, as this would prevent fuel from flowing to the carburetor.

Preparation and Assembly of Miscellaneous Equipment

Make a good visual inspection and check of the machine. Refer to the engine manuals or manual included in the miscellaneous equipment. Also refer to the lubrication chart in this manual for oils and grease and points of lubrication.

One set of extra shear pins and tines are included in the miscellaneous equipment for spares.

Remove protective tape from gauges and instruction plates.

Install operator's platform seat.

Install exhaust extension on exhaust pipe and air cleaner extension on air cleaner.

Check steering gear housing and hydraulic brake master cylinder reservoirs. Lift access door on operator's platform.

Assemble "skis" to hood bottom. The hood must be raised to do this. Refer to "operating instructions". The skis consist of two right and left side pieces. The rear ski pins slip into slots in the hood base, then push or pound ski forward to lock. Secure to hood with the bolts provided. Fit and bolt front ski in place (Fig. 1-7). Lower hood.

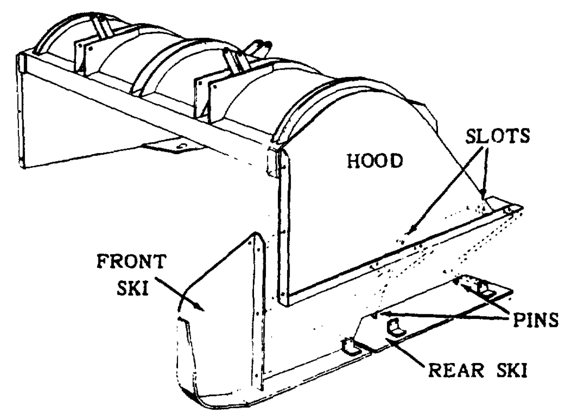


Figure 1-7. Hood Assembly

Connect intake hose to pump inlet. Install hose boom in boom support at the right front of the mixer frame. Hose is supported by means of a loop and spring. Thread hose thru spring loop and attach end of spring to boom hook.

Caution: Do not operate pump without liquid in the pump body or damage to the pump seal will result. (Refer to
liquid handling system before starting.)

Operation

Prior to starting the Pulvi-Mixer, the operator should familiarize himself with all machine controls and engine equipment. Control levers are identified on instruction plates attached to the hood top.

REFERENCE FOR FIGURE 1-8

1. GALLONS PER MINUTE GAUGE (VPI)
2. FEET PER MINUTE GAUGE (VPI)
3. PROPORTIONING GAUGE (VPI)
4. GALLONS PER SQUARE YD. GAUGE (VPI)
5. HOOD AND ROTOR LIFT LEVER
6. TAILBOARD LEVER
7. SPRAY BAR LEVER
8. METERING VALVE LEVER
9. HIGH-LOW ROTOR DRIVE LEVER
10. ROTOR DRIVE CLUTCH PEDAL
11. HIGH-LOW TRACTION DRIVE LEVER
12. FORWARD-REVERSE LEVER
13. THROTTLE LEVER (ENGINE)
14. LOCKOUT KNOB LEVER (REVERSE)
15. HYD. BRAKES, RIGHT AND LEFT
16. APPLICATION CHART
17. DIESEL ENGINE START BUTTON
18. SHUT-DOWN LEVER
19. EMERGENCY PULL STOP
20. IGNITION KEY
21. PUMP ENGINE IGNITION KEY
22. PUMP ENGINE START BUTTON
23. PUMP ENGINE CHOKE LEVER
24. PUMP ENGINE THROTTLE
25. BRAKE LOCK LEVER
26. SERIAL NO. PLATE
27. LIGHTING SWITCH
28. INSTRUMENT PANEL LIGHTS
29. DIESEL ENGINE TEMPERATURE GAUGE
30. DIESEL ENGINE AMMETER
31. DIESEL ENGINE OIL PRESSURE GAUGE
32. DIESEL ENGINE TACHOMETER
33. PUMP ENGINE HOUR METER
34. PUMP ENGINE TACHOMETER
35. PUMP ENGINE OIL PRESSURE GAUGE
36. HYDRAULIC SYSTEM OIL TEMPERATURE GAUGE

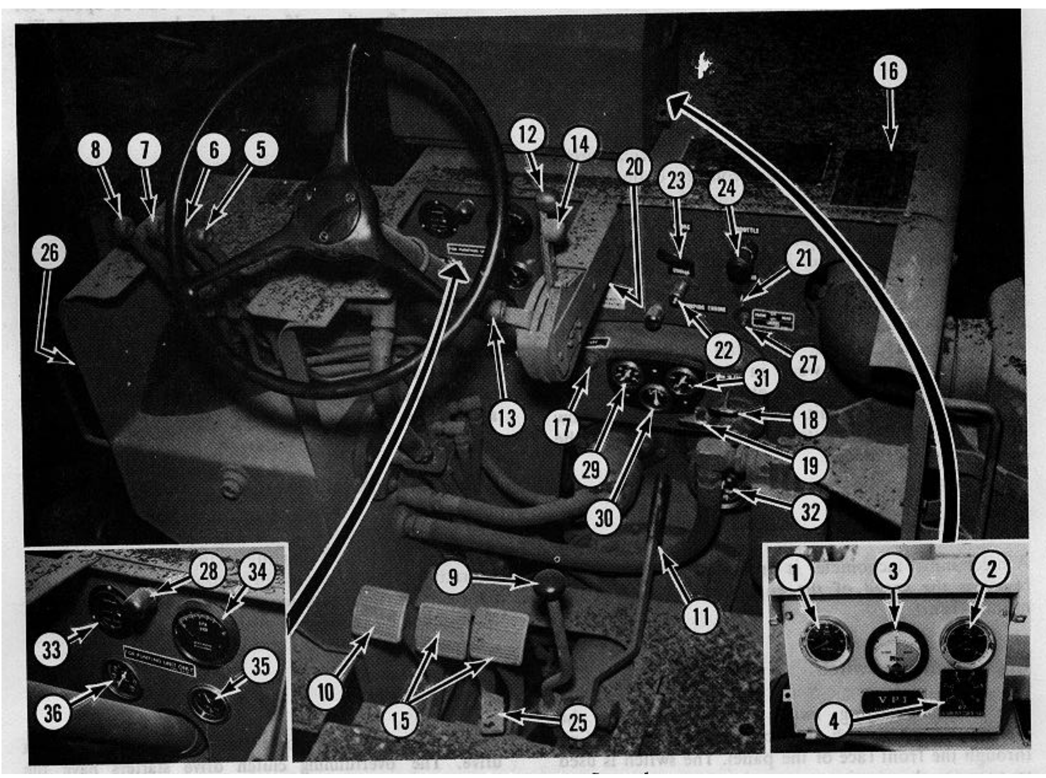


Figure 1-8. Operating Controls

Diesel Engine
The instruments generally required in the operation of a diesel engine consist of an oil pressure gage, a water temperature gage, an ammeter and a mechanical tachometer.

Also, closely related and usually installed in the general vicinity of these instruments are certain controls consisting of an engine starting switch, an engine shut-down lever, an emergency pull stop and the engine hand throttle. (Fig. 1-8)

Oil Pressure Gage
The oil pressure gage registers the pressure of the lubricating oil in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure listed under Running in the Engine Operating Instructions, the engine should be stopped and the cause of low oil pressure determined and corrected before the engine is started again.

Water Temperature Gage
The engine coolant temperature is registered on the water temperature gage.

Ammeter
An ammeter is incorporated into the electrical circuit to show the current flow to and from the battery. After starting the engine. the ammeter should register a high charge rate at rated engine speed. This is the rate of charge received by the battery to replenish the current used to start the engine. As the engine continues to operate. the ammeter should show a decline in charge rate to the hatter)'. The ammeter will not show zero charge rate since the regulator voltage is set higher than the battery voltage. The small current registered prevents rapid brush wear in the battery-charging generator. If lights or other electrical equipment are connected into the circuit. then the ammeter will show discharge when these items are operating and the engine speed is reduced.

Tachometer
A mechanical tachometer is driven by the engine and registers the speed of the engine in revolutions per minute (rpm).

Engine Starting Switch
The engine starting switch is mounted on the instrument panel with the contact button extending through the front face of the panel. The switch is used to energize the starting motor. As soon as the engine starts. release the switch.

Shut-Down Lever
A shut-down lever is used to shut the engine down. When stopping an engine, the speed should be reduced to idle and the engine allowed to operate at idle for a few minutes to permit the coolant to reduce the temperature of the engine's moving parts. Then the shut-down lever should be pushed in and held in until the engine stops. Pushing in the shut-down lever manually places the injector racks in the "no-fuel" position. The shut-down lever should be returned to it's original position after the engine stops.

Emergency Pull Stop
In an emergency or if after pushing in the shut-down lever the engine continues to operate, the emergency Pull Stop may be pulled to stop the engine. The emergency Pull Stop will trip the air shut-off valve located between the air inlet housing and the blower and shut off the air supply to the engine. Lack of air will prevent further combustion of the fuel and stop the engine.

The emergency Pull Stop must be pushed back in after the engine stops, so the air shut-off valve can be opened for restarting after the malfunction has been corrected. The air shut-off valve located on the blower air inlet housing must be reset by hand, by pushing handle in until it is latched, CAUTION The emergency Pull Stop should only be used to stop the engine in an emergency, as damage to the blower seals may result.

The manually operated shutdown device is operated by the Pull Stop, located on the instrument panel, which is connected to the valve shaft lever by a control wire.

Throttle Control
The engine throttle is connected to the governor speed control shaft through linkage. Movement of the speed control shaft changes the speed setting of the governor and thus the engine speed.

Electrical Starting System
The electrical system on an engine generally consists of a starting motor, starting switch, battery-charging alternator, voltage regulator, storage hatters and the necessary wiring. Additional electrical equipment may he installed on the engine at the option of the owner.

Starting Motor
The electric starting motor has an overrunning clutch drive. The overrunning clutch drive starters have the solenoid mounted on the starter and have a totally enclosed shifting mechanism.

Starter Switch
To start the engine, a switch is used to energize the motor. Release tie switch immediately after tile engine starts.

Battery-Charging Alternator
A battery-charging alternator is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

Alternator Precautions
Precautions must be taken when working on or around an alternator. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding the output wires or the field wires between the alternator and the regulator. run an alternator on an open circuit.

Grounding an alternator's output wire or terminals, which are always hot regardless whether or not the engine is running. and accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme caution be used.

Accidentally reversing the battery connections must be avoided.

Never disconnect the batteries while an alternator is in operation. Disconnecting the batteries will result in damage to the diodes, due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

If a booster battery is to be used, the batteries must be connected correctly (negative to negative and positive to positive).

Never use a fast charger with the batteries connected, or as a booster for battery output.

Never attempt to polarize an alternator. Polarization is not necessary and is harmful.

The alternator diodes are also sensitive to heat, and care must be exercised to prevent damage to them from soldering irons, etc.

if faulty operation of an alternator occurs on an engine equipped with an insulated starting motor. check to be sure that a ground strap is present and is correctly installed.

Regulator
A regulator is incorporated in the electrical system to regulate the voltage and current output of the battery charging alternator and to help maintain fully charged storage batteries.

Storage Batteries
Two 6-volt lead acid storage batteries are used and connected in series which provide 12 volt power for the electrical system.

The lead-acid storage battery is an electrochemical device for converting chemical energy into electrical energy.

The battery has three major functions:

1. It provides a source of electrical power for starting the engine.

2. It acts as a stabilizer to the voltage in the electrical system.

3. It can. for a limited time, furnish current when the electrical demands of the unit exceed the output of the alternator.

The battery is a perishable item which requires periodic servicing. A properly cared for battery will give long and trouble-free service.

1. Check the level of the electrolyte regularly. Add water if necessary. but do not overfill. Overfilling can cause poor performance or early failure.

2. Keep the top of the batteries clean. When necessary, wash with a baking soda solution and rinse with fresh water. Do not allow the soda solution to enter the cells.

3. Inspect the cables, clamps and hold-down bracket regularly. Clean and re-apply a light coating of grease when needed. Replace corroded, damaged parts.

4. Use the standard, quick in-the-unit battery test as the regular service test to check battery condition.

5. Check the electrical system if the batteries become discharged repeatedly.

WARNING: Explosive gas may remain in or around the batteries for several hours after they have been charged. Sparks or flame can ignite this gas causing

an explosion which could shatter the batteries. Flying pieces of the battery structure and splash of electrolyte can cause personal injury.

If the engine is to be stored for more than 30 days, remove the batteries. The batteries should be stored in a cool, dry place. Keep the batteries fully charged and check the level of the electrolyte regularly.

The *Lubrication and Preventive Maintenance* section of this manual covers the servicing of the starting motor and alternator.

Forward and Reverse Travel

1. Place the rotor drive shift lever in neutral position. The clutch pedal must be depressed when shifting.

2. The forward-reverse hand control lever (traction drive), must be in neutral, (vertical position), and pulled back against the stop. This is the longer of the two levers to the right of the steering wheel.

3. Place the traction drive (high-low) lever in neutral when starting. The lever may then be shifted to high or low range.

CAUTION: Before starting an engine for the first time, carefully read and follow the instructions listed previously and in the Engine Tune-Up Procedure.

Attempting to run the engine before studying these instructions may result in serious damage to the engine.

Be sure the emergency Pull Stop lever (19) is pushed in before starting the engine. The blower will be seriously damaged if operated with the air shut-off valve in the closed position.

To start the engine.

4. The shut-down lever must be pulled out.

5. Advance the throttle lever a slight amount.

6. Turn ignition key to "on," and depress starter button. DO NOT START ENGINE BY TOWING. If engine fails to start within 30 seconds, release starter button and allow the starting motor to cool a few minutes before trying again. If engine fails to start after four attempts, an inspection should be made to determine the cause.

CAUTION:

To prevent serious damage to the starter, if the engine does not start, do not press the

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. The normal and minimum oil pressures are shown in Table 1-1.

Warm-Up

Run the engine at part throttle and no-load for approximately five minutes, allowing it to warm-up before applying the load.

OIL PRESSURE

Engine Speed (rpm)	4, 71 psi	4, 71 kPa	71N psi	71N kPa
1200				
Normal	30-60	207-414	30-60	207-414
Minimum	18	124	18	124
1500				
Normal	–	–	–	–
Minimum	–	–	–	–
1800				
Normal	38-60	262-414	38-60	262-414
Minimum	27	186	27	186
2000				
Normal	–	–	–	–
Minimum	–	–	–	–
2100				
Normal	40-60	276-414	40-60	276-414
Minimum	30	207	30	207
2300				
Normal	40-60	276-414	–	–
Minimum	30	207	–	–

TABLE 1-1. Oil Pressures For Various Engine Speeds

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°-F (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 20 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* lubricating oil specified under *Lubricating Oil Specifications*.

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 high boiling point type antifreeze.

To move machine forward.

7. The rotor must be in the raised position (off the ground). Pull the hood and rotor lift lever back until rotor and hood clear the ground, then release lever to neutral.

8. Place the high-low traction drive lever in either the working range (low) or traveling range (high).

9. Advance throttle lever so the engine speed is approximately 2000 rpm.

10. Move the forward-reverse lever forward a slight amount until the machine begins to move forward. The further forward the lever is moved, the faster the machine will travel. Hydrodynamic braking will be experienced as the lever is returned to neutral. In high range, some noise may be experienced during acceleration or deceleration or on a hard pull. This is merely high pressure relief valves bypassing as is their function. After momentum is obtained, the noise will cease. If the grade or rolling resistance is too great, shift to low range.

To move the machine backward.

11. Bring the machine to a stop by moving the forward-reverse lever back against the stop and use foot brakes if required.

12. Lift the lock-out pin knob and move the forward-reverse lever backward until the machine begins to move in reverse. The further the lever is pulled backward the faster the machine will travel.

The machine has an engine governed speed of 2000 rpm. The speed of the Pulvi-Mixer is infinitely variable in forward or reverse between the limits of 0 to 2-lh mph in working range (low) and 0 to 15-,1 mph in traveling range (high). The machine must be stopped before shifting the traction drive lever into the working or traveling range.

Caution must be exercised during this familiarization period as the controls may seem quite different from conventional machines. The foot operated clutch has no control over forward or reverse movement.

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.

To stop the engine.

13. Move the forward-reverse lever to neutral position.

Move throttle lever to idle. Let engine idle a few minutes to lower engine temperature. Lower rotor and hood assembly by pushing hood and rotor lift lever until rotor and hood rests on the ground. Stop the engine by pushing the shut-down lever "in." Turn ignition key to "off." Depress brake pedal and depress brake pedal lock.

Emergency Stopping
In an emergency or if after pushing the shut-down lever "in," the engine continues to operate, the emergency pull stop may be pulled to stop the engine. This control cuts off the air to the engine. Do not try to restart again until the cause for the malfunction has been found and corrected. The air shut-off valve located on the blower air inlet housing must be reset by hand, by pushing handle "in" until it is latched.

CAUTION: The emergency pull stop should only be used to stop the engine in an emergency as damage to the blower seals may result.

Rotor Depth Control Adjustment (Figure 1-9)
All rotor depth adjustments should be made with the machine setting on a hard, level surface.

It is presumed that the operator is familiar with the controls and the hood skis are attached.

1. Lower crane until the crane lifting ram is completely collapsed and the crane will then be in a horizontal position.

2. Adjust depth control caps (one each side) to the desired depth (D). (D) would be from the bottom of the depth control cap to the top of the rib of the hood.

3. Position the rotor depth cap so the distance between the bottom of the cap and top of the traction spring is equivalent to the rotor depth (D).

4. Adjust hood lift cap to top of bar for material mixing. (Adjust lift cap down as required when aerating or working on rotor.)

5. Adjust the hood tilt adjusting bolts (each side) so the skies have approximately 2" clearance from the surface to the front of the ski surface where shown.

The results of the above adjustments should give the depth desired. The depth should be checked by actual measurement of the cut when the machine has processed 10 to 20 feet of material. Check as follows:

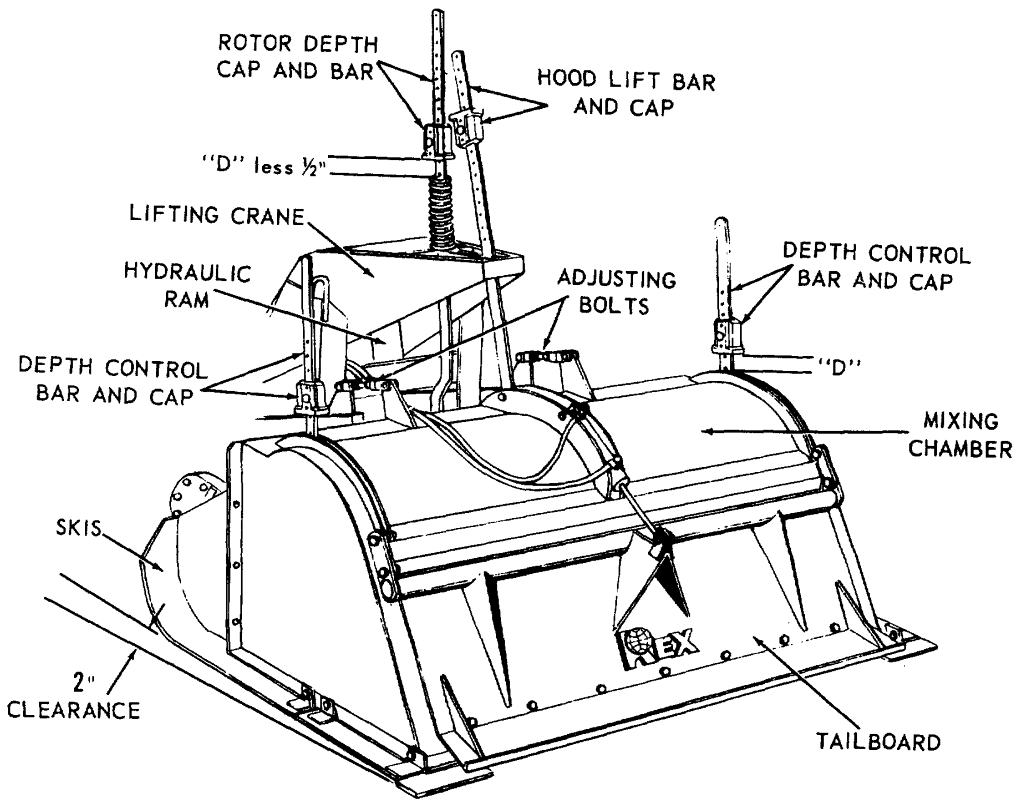


Figure 1-9. Hood and Rotor Assembly Nomenclature

a. Bring the machine to a stop by placing the forward-reverse lever in neutral, allowing rotor to continue to turn.

b. Raise hood and rotor assembly by means of the control lever so both hood and rotor clear the ground.

c. Move entire machine forward to uncover the cut.

d. Measure depth of cut and if necessary make final corrections to the depth control caps and rotor depth cap as required. After this procedure is followed, return Pulvi-Mixer a few feet behind cut and continue.

Material Processing

When processing materials, the operator will have to keep in mind the forward speed, positioning of the tailboard, depth of cut plus the type of material being processed, blended or pulverized.

CAUTION: Never attempt to engage rotor clutch to drive rotor when rotor is down on surface or in material. Severe torsional loads imposed will damage driveline components. Always have rotor raised and spinning before lowering into material for mixing. Lower rotor slowly into material.

With the engine started, proceed as follows to assure proper mixing, blending and/ or pulverization.

1. Make sure the rotor is in the raised position pull rotor and hood lift lever back until rotor and hood clear the surface.

2. Place traction drive lever in working range (low).

3. With clutch disengaged, place rotor drive lever in either low or high range depending on the material.

NOTE: Use high range only for light or finish mixing.

4. Engage clutch to start rotor turning.

5. Advance throttle lever so that the engine speed is approximately 2000 rpm.

6. Lower hood and rotor gradually into material. This can be done either when the machine is stationary or as the machine moves forward.

7. Move the forward-reverse lever smoothly forward until a point is reached where proper processing is accomplished at maximum forward speed. As soil conditions change, the

forward speed should vary accordingly. The rotor depth control caps should always ride tight on top of the hood reinforcing ribs.

8. By using the tailboard lever, adjust tailboard opening so that an even flow of material results. The proper retention of material in the mixing chamber controls the buildup and spill-over. This affects the extent of mixing, blending and pulverization.

To further simplify on the preceding procedure and to add to the mixing operation the following information is detailed:

a. At the job site, the material for mixing should be either scarified (loosened), bladed or in windrows, where applicable.

b. Drive onto the lane to be mixed with the hood and rotor assembly raised. When in position to start mixing operation with engine at 2000 rpm and at normal operating temperatures, rotor at low speed, slowly move forward-reverse lever forward, increasing speed. As machine moves forward, lower the rotor and hood assembly to full adjusted mixing depth. Travel and mix as outlined in steps 5 thru 8.

c. To finish a run where the end joins a previous section, operate the mixer right up to the section end, decrease speed, depress rotor clutch, raise rotor and hood assembly. This procedure will leave a pile of material at the end. This pile can be carried back by straddling it on the return trip. Work it back or feather it out. Following this procedure will prevent the movement of materials away from the end or joint. Avoid successive starts on the same spot without having first deposited a spill-over pile from the previous run. (Too much material moved from one spot, will of course, change the grade and also result in a "leaning out" of the mixture by constantly exposing new base material.) In the event that the mixing unit is raised too rapidly and a ridge is left, raise rotor, back up and lower the mixing unit onto this ridge and work the mixer through it and then proceed to "feather out" again. Then the mixer unit can be raised all the way and the machine moved to the next location.

NOTE: One of the most important functions contributing to the efficiency of the mixing characteristics of the mixer is the "spill-over" mentioned in the previous paragraph. This "spill-over" material will show up at the end of a section when the mixer is stopped and the mixing unit is raised for a turn-around. These steps should be followed to achieve the smooth finish results possible. (Fig. 1-10) d. Work mixer right up to the end of the section and stop the unit abruptly. Raise rotor into hood with the hood remaining on the ground. Slowly move the machine forward, thereby dragging the spill-over material into the trench left by the rotor. Stop working and turn around. The mixer is then worked back into the section and the material "feathered out" as described earlier.

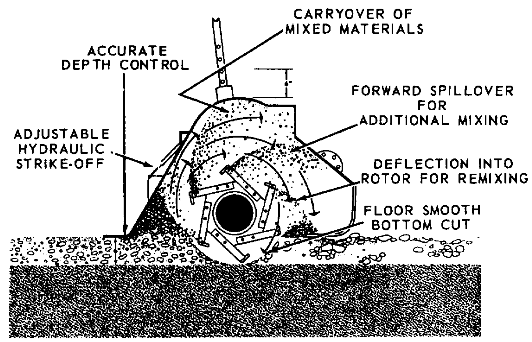


Figure 1-10. Rotor Operation

e. This procedure will leave a finished surface that will roll out smooth and level. A very important function of the machine known as the diagonal cross mix can be effectively incorporated into the process after the admixture pass. This "cross-blending" action serves to mix the materials and to blend out any variations in materials, minor grade and crown. Any road will normally require two cross mixing passes and then straight passes to cover the full width. The diagonal pass is accomplished by simply driving the machine in long, easy curves, crossing the work at a shallow angle of not more than 300 from straight ahead' position. DO NOT "swing" the machine too short and cause the rear unit to spread and overlap the outer edges. Long, easy turns work out the best, starting from the outer edge of the work.

f. Regulating the tailboard opening will control the spill-over (or the amount of material carried forward within the hood for remixing). The tighter the tailboard opening, the better the mixing and blending; however, the forward mixing speed, depth of cut, type of material and engine power are all factors that dictate how tight the tailboard should be. This must be determined for each individual job.

g. On "slippery" or "tender" material where traction can become a problem and wheel slippage occurs, the crane should be raised slightly compressing the traction spring, thereby effecting a weight transfer to the rear drive axle and increasing tractive effort. As long as the rotor depth control caps remain resting on the hood reinforcing ribs, the depth of the cut will not be affected.

h. When processing rocky or "bony" material where severe shock can be transmitted to the machine, reduce the engine rpm to 1200-1400 rpm. This reduces the rotor rpm, proportionally and makes for a much smoother operation without sacrificing any mixing ability.

There are three alternatives available to the operator when depth is not being maintained. Also if the depth should vary, then the structural design criterion will also vary. Therefore, these corrective actions should be taken in preferred order.

1. Reduce forward travel speed until desired depth* is obtained.

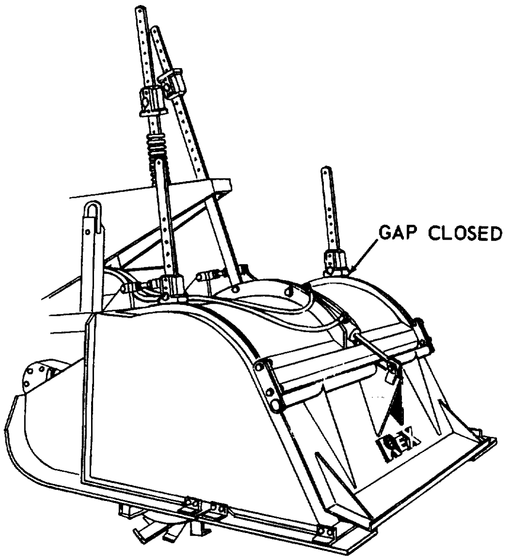


Figure 1-11. Instant Depth Check

2. Open tailboard to release unnecessary build-up of material in the mixing chamber.

3. Replace the tines, if they are badly worn.

* Desired depth (Fig. 11) Instant check on controlled depth can be made by merely looking to see if the gap between the bottom of the depth control cap and the top of the rib reinforcing is closed.

Shear Coupling (Fig. 1-12)
A shear coupling is provided in the rotor driveline. Its purpose is to provide a protection to the power unit and rotor two speed transmission that in the event the rotor strikes an object it cannot move or climb over, the pins will shear or break.

An extra set of pins are provided in the miscellaneous equipment.

Do not use cap screws or bolts in the coupling as a substitute for the pins.

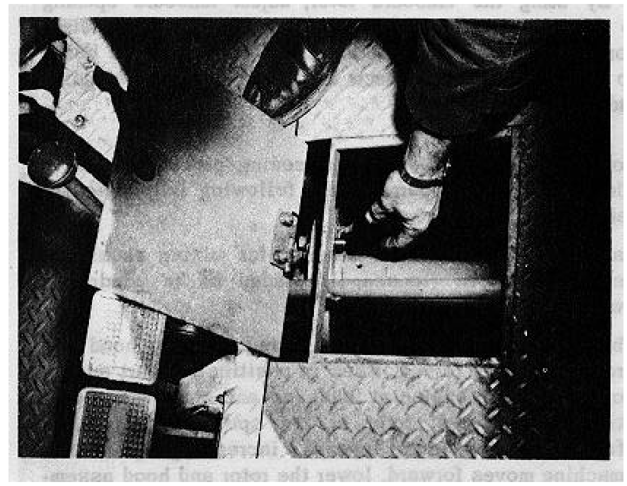


Figure 1-12. Shear Coupling

V.P.I. Fluid Handling System
The V.P.I. is an electrically instrumented system provisioned with gauges and a liquid control to visually indicate to the operator the performance of the fluid handling system.

It operates on an electrical balance principle that integrates the fluid rate of flow with the stabilizer travel speed, fulfilling the need for more accurate control and faster dispersion of liquid, (emulsified asphalt, water or asphalt cutbacks).

Volumes of liquid up to 500 gallons per minute (refer to recapitulation chart, Table 1-2) can be obtained and controlled with extreme accuracy. This system minimizes the number of re-mix passes, advances the travel speeds, which also benefits the tank trucks resulting in fewer problems that otherwise might be encountered at slower travel speeds.

CAUTION: The V.P.I. fluid handling system for handling emulsified asphalt is designed to handle this liquid at temperatures not to exceed 1500F and for asphalt cutbacks not to exceed 2500F.

Whenever a new fluid meter assembly is installed in the V.P.I. system, the V.P.I. panel must be recalibrated with the meter. Refer to calibration instructions pages thru

	HDS-E	
	Main Asphalt Emulsion	Aux. Water System w / or w/o Pump
Line Size	4"	2½"
Recommended Fluids	** Asphalt Emulsions Water Other Aqueous Solutions	Water
Normal Pumping Temperatures	Asphalt Emulsions 80^{0}-120^{0}F.	Water- Ambient
** Maximum Temperature of Fluid	** 150^{0}F.	150^{0}F.
Approximate Viscosity Range for Asphalts - (Saybolt-Furol)	25-50	–
Spread Range Dial (Gals. per square yard)	0-7	–
Pump Volume Range* (Gals. per minute)	Asphalt Emulsions 100-420 Water 100-520	– 150 – G.P.M.
(Feet per minute) Working Speed Range (Std.) High Speed Gearing (Opt.)	0-220 0-430	0-220 0-430

*These values may vary slightly due to extraneous factors, as bulker supply, line size, grade of asphalt and temperature, and viscosity of the asphalt.

****WARNING: Under no circumstances should the liquid being pumped exceed 150° F. If this temperature is exceeded, damage to the non-metallic parts may result with the entire liquid system including possible hose failure under pressure.**

The V.P.I. instruments are mounted on the engine hood, Fig. 1-9, in full view of the operator and indicates thru gauges the gallons per minute *(1) of liquid passing through the meter; the machine travel speed in feet per minute *(2); a proportioning gauge (3) and a manual dial control for setting the number of gallons of liquid per square yard (4) required.

*Multiply needle reading times ten.

An application reference chart, Table 1-3 is affixed to the right top side of the engine hood opposite the operating control instruction plate and is used to initially determine the liquid and travel equivalents.

1. Operating Description, See Paragraph 2 for Operation. The metering valve control lever when actuated, opens and closes a metering valve by means of a hydraulic cylinder. A quadrant, scaled from 1 to 10, is located next to the metering valve hydraulic cylinder. As the valve is opened, the pointer which is attached to the rod end of the cylinder will indicate, when compared to the application reference chart, the number of gallons of liquid flowing thru the metering valve.

Example: V.P.I. system only. Supposing the job specifications call for five gallons of liquid per square yard for the soil to be stabilized. Turn knob on gal./sq. yd. gauge to five gallons per square yard. The job conditions will determine optimum forward travel speed. For example, select a speed of 112 feet per minute. This would indicate from the application chart, Table 1-3, a quadrant setting for the metering valve of seven for water or eight for emulsified asphalt at 112 fpm. The flow rate as indicated on the application chart will be 400 gallons per minute which will be read on the gal./min. gauge. The gallons per lineal foot will be 3.57 as indicated in column six. With the figure of 3.57 gallons per lineal foot and knowing the tank truck capacity, it can be determined how many lineal feet will be covered with the capacity of the tank truck. A 5,000 gallon tank truck will cover approximately 1,400 lineal feet of soil to be processed.

The proportioning gauge will indicate whether or not the liquid being pumped is in relationship to the feet per minute travel speed. When the needle varies to the left, "lean," this indicates an adjustment of more liquid is needed and the metering valve must be opened by actuating the metering valve control lever.

A needle variance to the right, "rich," indicates too much liquid is passing in relationship to the feet per minute travel speed and a closing adjustment to the metering valve must be made.

It is always better to vary the liquid volume so that a constant forward speed may be maintained by the tank truck Pulvi-Mixer train.

2. Operation (Fig. 1-9)
The following V.P.I. fluid handling suggested instructions are to be used with the preceding instructions on "Forward and Reverse Travel" and the "Material Processing" instructions.

Attach suction hose to the liquid pump intake.

Swing the boom around to the front of the machine and thread hose through the spring loop and attach end of spring to the boom hook.

CAUTION: Do not operate pump without liquid in the pump body as operating pump dry will result in damage to the seal.

The liquid pump must be primed before starting operations.

Remove priming plug from the pump and use liquid from the tank truck to fill pump body. Replace plug. (CAUTION: DO NOT ATTEMPT TO FILL THE PUMP BODY WITH THE PUMP ENGINE RUNNING.) The pump is now ready for operation. The liquid used to prime the pump should be as free of solids as possible.

If the pump has been pumping liquid containing a considerable amount of solids, it is advisable to flush the solids out of the body before refilling with liquid. In freezing weather, the pump should be primed with warm water if possible. Always drain pump after it has been operating in freezing temperatures.

Attach suction hose to the tank truck. Suction hose connections must be tight with no leaks. Air being drawn into the suction line affects the pumping capacity. Make sure outlet valve on tank truck is open after connecting the hose.

Start machine engine and run at 2,000 rpm when processing the soil.

Using the application chart, Table 1-3, as an initial start (per example in paragraph 2) turn knob on gallons per square yard gauge to desired setting.

Open metering valve by actuating the metering valve control lever to indicated setting on application chart.

Start pump engine and run at governed engine rpm.

GALS. PER SQUARE YARD	FLOW RATE (GPM)	APPROX. INITIAL QUADRANT SETTING		TRAVEL SPEED (FPM)	GALS. PER LINEAL FOOT
		EMUL. ASPHALT	WATER		
2	200	4	3	140	1.43
	250	5	4	175	
3	200	4	3	94	2.14
	250	5	4	117	
	300	6	5	140	
	350	7	6	164	
	400	8	7	187	
4	200	4	3	70	2.85
	250	5	4	88	
	300	6	5	105	
	350	7	6	123	
	400	8	7	140	
	450	10	9	158	
	500	–	10	175	
5	200	4	3	56	3.57
	250	5	4	70	
	300	6	5	84	
	350	7	6	98	
	400	8	7	112	
	450	10	9	126	
	500	–	10	140	
6	250	5	4	58	4.28
	300	6	5	70	
	350	7	6	82	
	400	8	7	94	
	450	10	9	105	
	500	–	10	117	
7	300	6	5	60	5.00
	350	7	6	70	
	400	8	7	80	
	450	10	9	90	
	500	–	10	100	

Table 1-3. Pulvi-Mixer Reference Application Chart.

Pump Starting Procedure 1. Check crankcase oil level and gasoline supply. Open shut-off valve in fuel strainer.

2. Set throttle 1 open.

3. Turn ignition key ON.

4. Close carburetor choke by pulling choke lever to extreme out position.

5. Depress starter button.

6. After engine starts, push choke in gradually as required for smooth running. Choke must be completely open (lever in) when engine is warmed up.

If flooding should occur, open choke fully by pushing choke lever in and continue cranking. Less choking is necessary in warm weather or when engine is warm, than when cold.

If all conditions are right, engine will start promptly after one or two attempts. Allow engine to warm up a few minutes before applying load, as prescribed in "Warm-Up Period" paragraphs.

New engines should be "run-in" gradually to insure trouble-free service.

Warm-Up Period
The engine should be allowed to warm up to operating temperature before load is applied. This requires only a few minutes of running at moderate speed. Racing an engine or gunning if, to hurry the warm-up period, is very destructive to the polished wearing surfaces on pistons, rings, cylinders, bearings, etc., as the proper oil film on these various surfaces cannot be established until the oil has warmed up and become sufficiently fluid, This is especially important on new engines and in cool weather.

Racing an engine by disconnecting the governor, or by doing anything to interfere with the governor controlled engine speed, is extremely dangerous. The governor is provided as a means for controlling the engine speed to suit the load applied, and also as a safety measure to guard against excessive speeds, which not only overstrain all working parts, but which might cause wrecking of the engine and possible injury to bystanders.

All parts of the engine are designed to safely withstand any speeds which might normally be required, but it must be remembered that the stresses set up in rotating parts, increase with the square of the speed. That means that if the speed is doubled the stresses will be quadrupled; and if the speeds are trebled, the stresses will be nine times as great.

Strict adherence to the above instructions cannot be too strongly urged, and greatly increased engine life will result as a reward for these easily applied recommendations.

Engage rotor and lower hood and rotor into material and throttle up to the required feet per minute, simultaneously opening spray bar by actuating the spray bar control lever which will automatically lower the fifth wheel to obtain the feet per minute reading on the ft./min. gauge.

As material is processed, pay particular attention to the needle on proportioning gauge. Should the needle vary off center, control liquid as required by actuating the metering valve control lever increasing or decreasing the liquid flow.

At the end of a mixing pass, first shut off spray bar by actuating the spray bar lever. This will automatically retract the fifth wheel as the flow of liquid is stopped.

Stop forward travel of the machine by actuating the forward-reverse travel lever to neutral. Raise the rotor into the hood as described in paragraph 8d in "Material Processing" instructions then feather out the cut by moving the machine forward far enough to pull the material in the hood into the cavity left by the rotor. Stop machine forward travel and disengage rotor.

Raise hood and rotor to clear the surface. Disconnect the suction hose and place in bracket provided on the machine.

Machine is now ready to attach to another tank truck and continue introducing the liquid blender. For re-mixing passes when an additive is not being introduced, it is recommended that the spray bar be retracted from the hood using the tail board spray bar jack provided and the cover plate for the nozzle holes be slipped into position.

IMPORTANT: After completing the day's operation, the liquid system must be cleaned.

Stopping Pump Engine
If the engine has been running hard and is hot, do not stop it abruptly from full load, but remove the load and allow engine to run idle at 1000 to 1200 R.P.M. for three to five minutes. This will reduce the internal temperature of the engine much faster, minimize valve warping, and of course the external temperature, including the manifold and carburetor will also reduce faster, due to air circulation from the flywheel.

Two main troubles resulting from abruptly shutting off a hot engine are vapor lock and dieseling. Vapor lock will prevent the flow of fuel in the fuel lines and carburetor passages, which will result in hard starting. This can be overcome by choking the engine when cranking or waiting until the engine has cooled off sufficiently to overcome the vapor lock.

Dieseling, is caused by the carbon and lead deposits in the cylinder head being heated up to such an extent that they continue to fire the engine and keep it running after the ignition has been shut off. By idling the engine, as previously mentioned, the carbon and lead deposits cool off, break up and will blow out thru the exhaust, If engine has a tendency to diesel, by suddenly setting the throttle wide open and at the same time shutting off the ignition, the engine will stop.

Turn ignition key (22) off after engine cooling period.

Operating Only A Portion Of The Spray Bar Nozzles (Fig. 1-13)
The spray bar nozzle assembly is equipped with two /2" "gas" cocks. The upper "gas" cock being linked to the connecting bar with a valve lever. The lower "gas" cock may be closed with a wrench, thus shutting off the liquid flow thru that particular nozzle.

When flushing out the liquid system at the end of operation, all nozzles must be flushed out by opening the "gas" cocks previously closed.

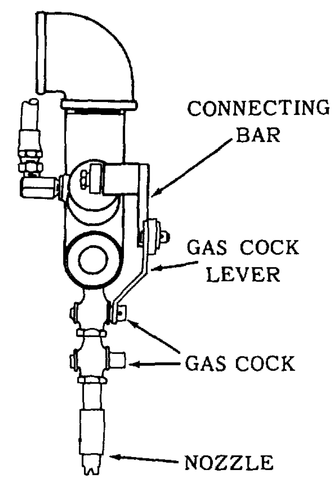


Figure 1-13. Spray bar Nozzle Assembly

Cleaning Asphalt And Emulsion Fluid System (Fig. 1-14)
The system must be thoroughly flushed clean using fuel oil. A fuel oil tanker can be hooked up to the liquid pump in a similar manner as for processing soil.

If pump body is not full, it must be primed with fuel oil first. Run pump engine at approximately half throttle. All spray nozzles must be open. Open tailboard to its extent. Raise hood and rotor to their extent. Lower nozzles into hood. Rotate rotor in high. Centrifugal force of the rotor plus the fuel oil will clean the rotor.

CAUTION: MAKE SURE NO PERSONNEL ARE BEHIND THE MACHINE AS THEY MAY BE HIT WITH FLYING MATERIAL.

Flush system until clean oil appears at the nozzles.

The system is equipped with a strainer at the intake side of the pump to retain any solids from entering the fluid system which could cause damage and possible failure of the meter or pump.

Frequent inspection and cleaning of the strainer must be made using fuel oil or solvent, SD-2.

WARNING
Solvent SD-2 is potentially dangerous. Do not use near open flame or heat.

The fuel oil may be drained from the fluid system by opening the pump drain (A) and line drain (B). It is recommended that fuel oil be left in the system until the following day's operation.

Each line is equipped with a line fill plug (C) that may be removed and fuel oil added to the lower line system as a protection to the meter in case of an emergency.

When the fluid system is not going to be used for some time, remove the suction line and cap the pump intake. Fill entire system with fuel oil.

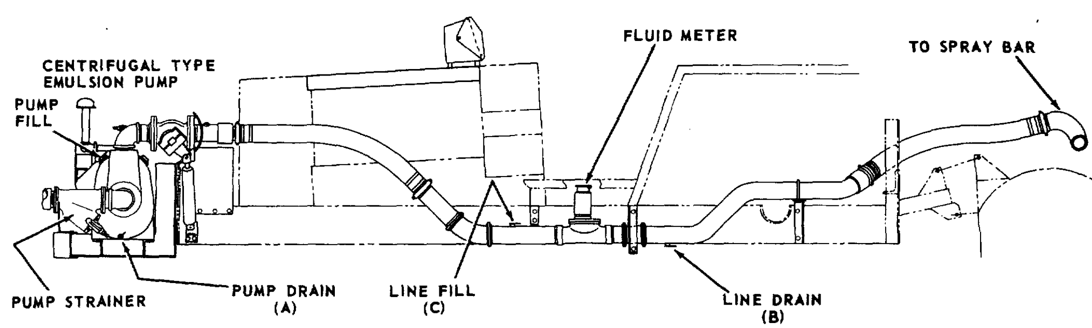


Figure 1-14. Emulsion Fluid System

Wash Down System (Fig. 1-15)

The wash down system is used with the asphalt emulsion system to clean the rotor hood and adjacent areas of accumulated asphalt or emulsion.

Diesel fuel, drawn from the engine fuel tank, is used as the cleaning agent. Do not run pump dry for more than 30 seconds as lack of liquid will burn the impeller. The pump's impeller is designed for temperatures between 45°F and 160°F.

The system's pump is operated by means of a "startstop" switch at the instrument panel. A liquid by-pass is designed into the system that returns fuel to the tank when the pump is started and the nozzle is closed.

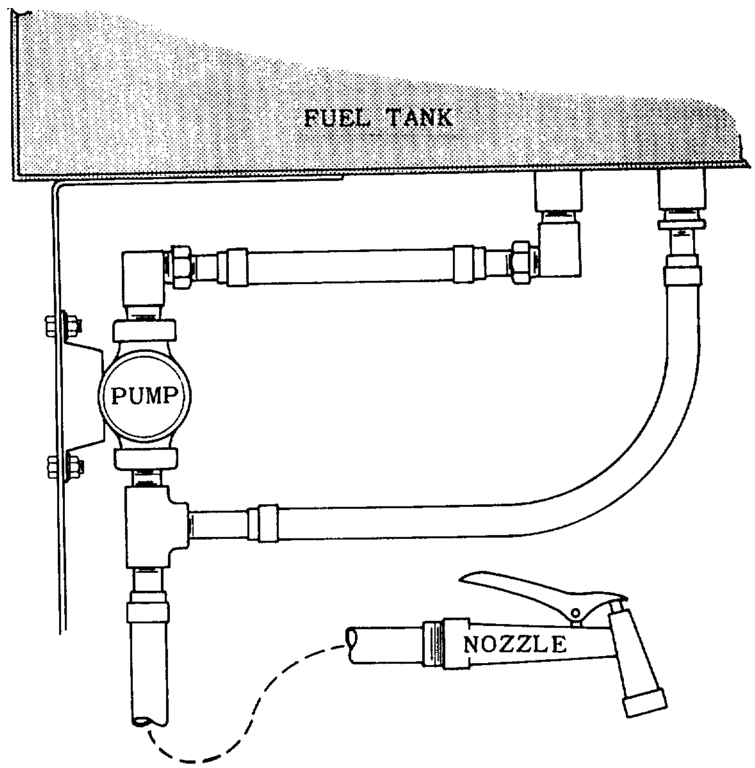


Figure 1-15. Wash Down System

Tines

Figure 1-16 illustrates the standard "103¼" bevel edge tine furnished with the "tube" rotor.

This tine is used for maximum pulverization due to the close tolerance between tines and extreme right angle of the tine. All material in the required depth is completely picked up, mixed and consistently spilled over to assure maximum pulverization and blending.

Also used where positive depth control is essential in a single pass, a level cut plane at the depth desired will result.

Where aggregates of 2" or less are encountered, maximum mixing and blending will result.

The "103 1/2" bevel tine is used for maximum aeration since aeration is facilitated by particle size or air contact, it is essential that all material be broken down into the smallest possible particles and then dispersed to get maximum air contact.

Rotors

Figure 1-17 illustrates the STANDARD type rotor made up of a 10" diameter tube to which are welded 14 tine plates, including one right hand and one left hand end tine plate. Each plate has provision to mount 6 tines, three right hand and three left hand.

The standard "103'2" tine mounts to overlap the tine plate.

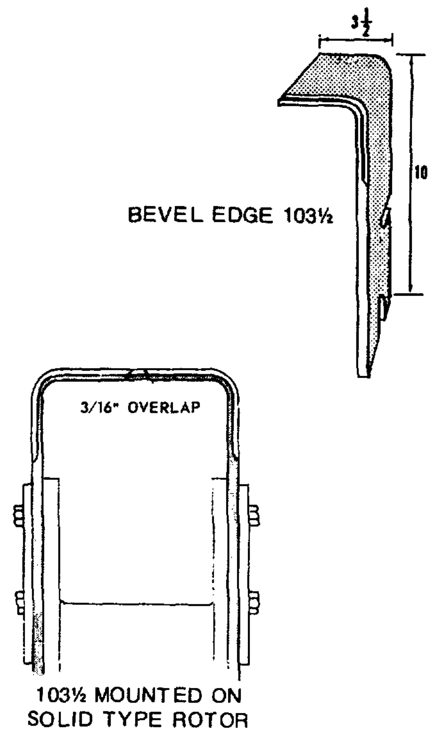


Figure 1-16. 103 1/2 Bevel Edge Tine

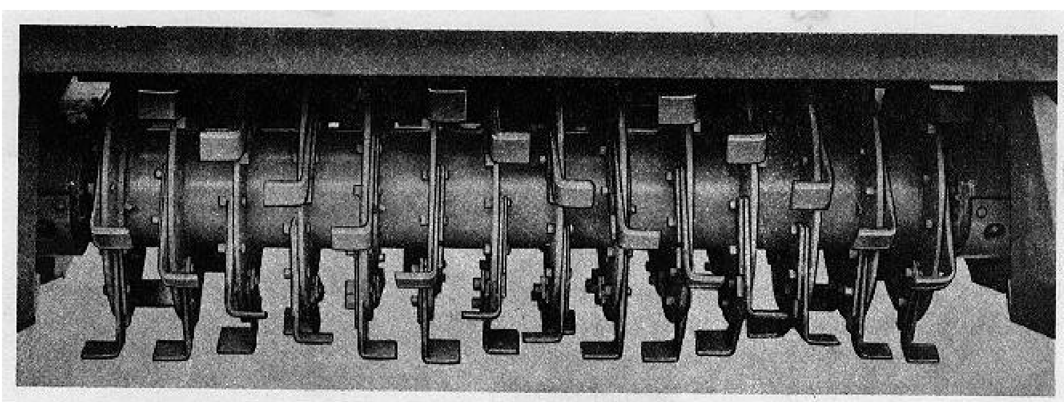
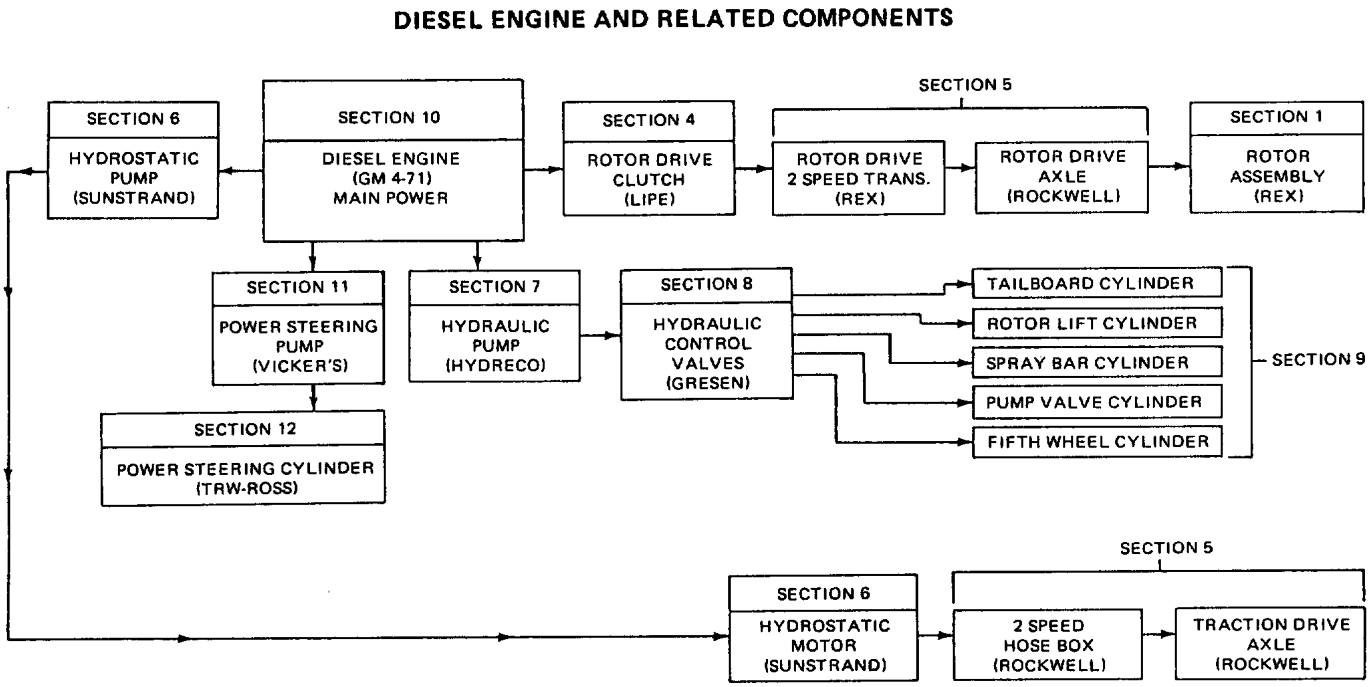
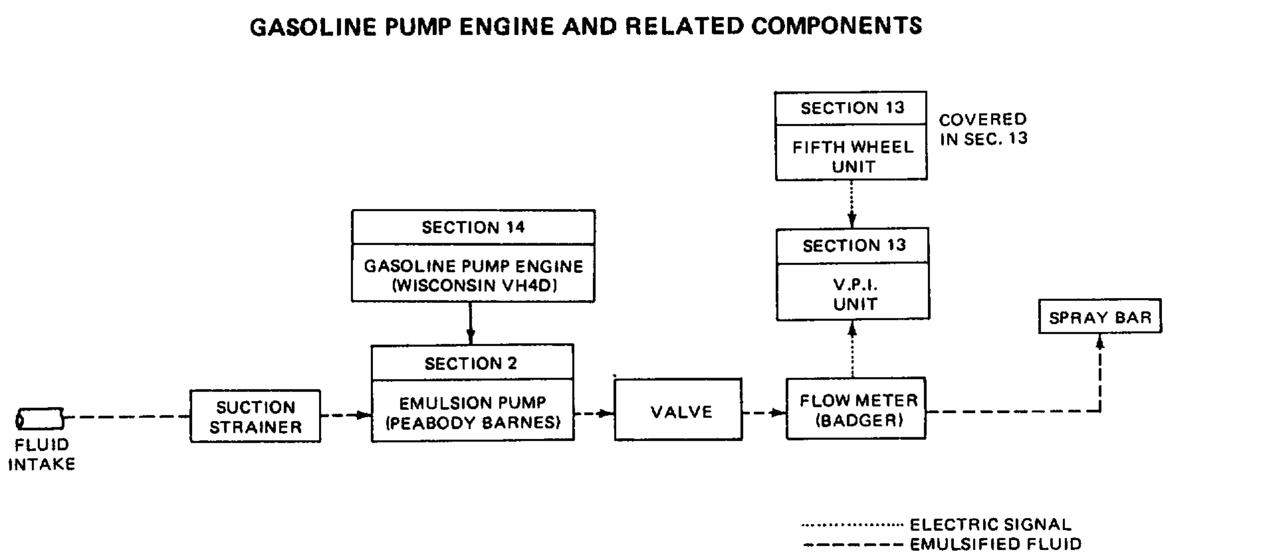
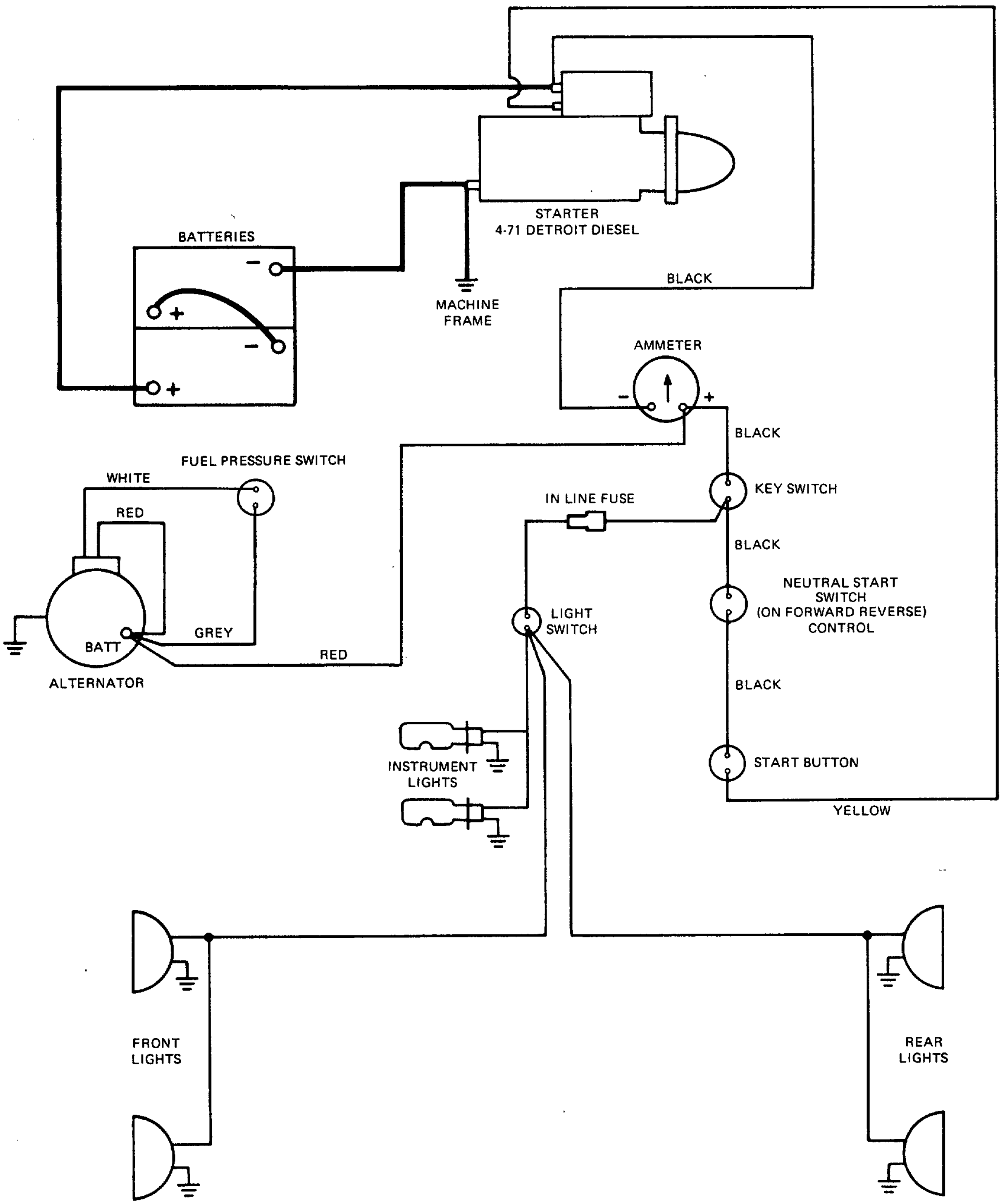


Figure 1-17. Standard Rotor

VEHICLE SYSTEMS AND RELATED MAINTENANCE SECTION SCHEMATIC







MAIN VEHICLE WIRING DIAGRAM

SECTION 2 - MAINTENANCE

SUBSECTION 1 HOOD, ROTOR ASSEMBLY AND CHAIN END DRIVE

HOOD REMOVAL FOR REPAIR OR REPLACEMENT (Fig. 1)

1. Locate machine in a suitable working area, preferably on a firm level surface.

2. Start engine and hydraulically collapse the hydraulic ram, lowering the crane.

3. Disconnect fluid line at hose coupling and disconnect the hydraulic lines at the spray bar hydraulic ram. Mark lines for correct replacement.

4. Disconnect the two hydraulic hoses from the tailboard hydraulic ram.

CAUTION

Make certain all hydraulic ram ports and hydraulic hose ends are plugged or protected to keep out foreign materials. Bring hydraulic line ends back and tie to machine. Again mark lines for correct replacement.

5. Remove the depth control bar caps. Remove rotor lift bar cap. Reposition the hood lift bar cap as far down as possible. Hydraulically raise the hood as far as possible and hold. Rotor depth bars will fall thru slots in hood. Remove the rotor depth control bars at the pin connection on the end drive case assembly.

6. Place blocking forward and rearward below skis. Blocks should be large enough to support hood above the rotor. Lower hood slightly so blocking takes the load.

7. Disconnect the hood lift bar from hood and remove bar. Disconnect the two hood adjusting bolts at the hood end. Disconnect the two hood arms from the hood at the hood bracket pin connection.

8. Machine may now be driven away from hood.

9. Reassemble hood in reverse of above procedure.

FIGURE 1.

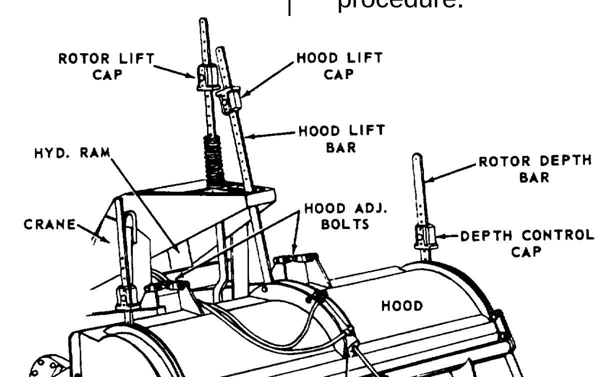
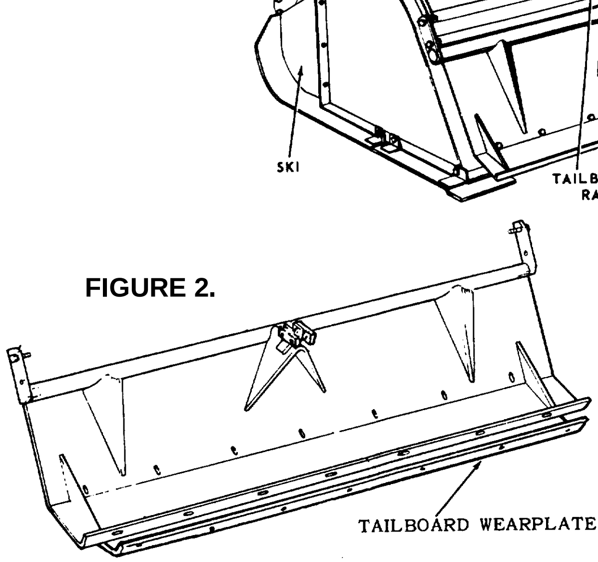


FIGURE 2.



TAILBOARD WEARPLATE (Fig. 2)

The tailboard has a bolted on replaceable wearplate. Periodic inspection of the wearplate should be made and replaced before wear extends into the tailboard itself.

ROTOR TINE REPLACEMENT

REMOVAL

1. Loosen tine clamp nuts (V) to allow tine clamp (W) clearance from rotor tube.

2. Remove by pulling tine (X) away from rotor tube.

INSTALL

1. Position bevel edge of tine (X) opposite of stop lock and insert tine between clamp (W) and rotor tube. Be sure slots in tine are fully seated over tine bolts (Y).

2. Tighten clamp nuts (V).

END DRIVE CHAIN CASES

REMOVAL OF ROTOR FROM END DRIVE CHAIN CASES (Fig. 3, View 4)

The machine should be setting on a hard level surface. Raise the hood to its fullest extent and block crane in this position as a safety precaution. Place blocking under each end case to retain cases from falling after rotor is removed.

1. Remove twelve 5/8" x 1 3/4 cap screws (A), (six each side), holding rotor end shaft (B) to the outer tine plates (BB) and (CC).

2. Move rotor back, away from mixer.

NOTE.

If cap screws (A) need to be replaced, these cap screws are Nyloc 3/8" x 1 3/4" H. C. -H. T. (U. N. C.). Do not use ordinary cap screws.

DISASSEMBLY AND ASSEMBLY OF THE END DRIVE CHAIN CASE (Fig. 3)

The machine should be brought into a shop with adequate working facilities and tools. The following instructions are offered as a guide in making the end drive repairs.

1. Raise hood to its fullest extent and block crane in this position as a safety precaution.

2. Place blocking under the rotor drive differential so when the rotor is removed, the end cases will not fall.

3. Remove six cap screws (A) each side, holding end shaft (B) to rotor end plates. Roll rotor away from end cases.

4. Remove covers (C), (D) and (E) from case being careful not to damage gaskets. This will expose portions of the chain (F) and drive sprocket (G).

5. Turn the universal rotor drive shaft manually until the chain connecting links are exposed thru opening at cover position (C). Drive out connecting link pins. Remove chain from rear sprocket.

6. Before removing bearing housing (H), match mark housing with end case so when the bearing housing is reassembled to the chain case, it will go on in the same position. Remove cap screws (J) from housing (H).

NOTE:

Bearing housing (H) has an eccentric set of holes. This permits tightening of the chain after chain is reinstalled by rotating housing and before securing housing to the end case. Pull entire end shaft assembly from end case.

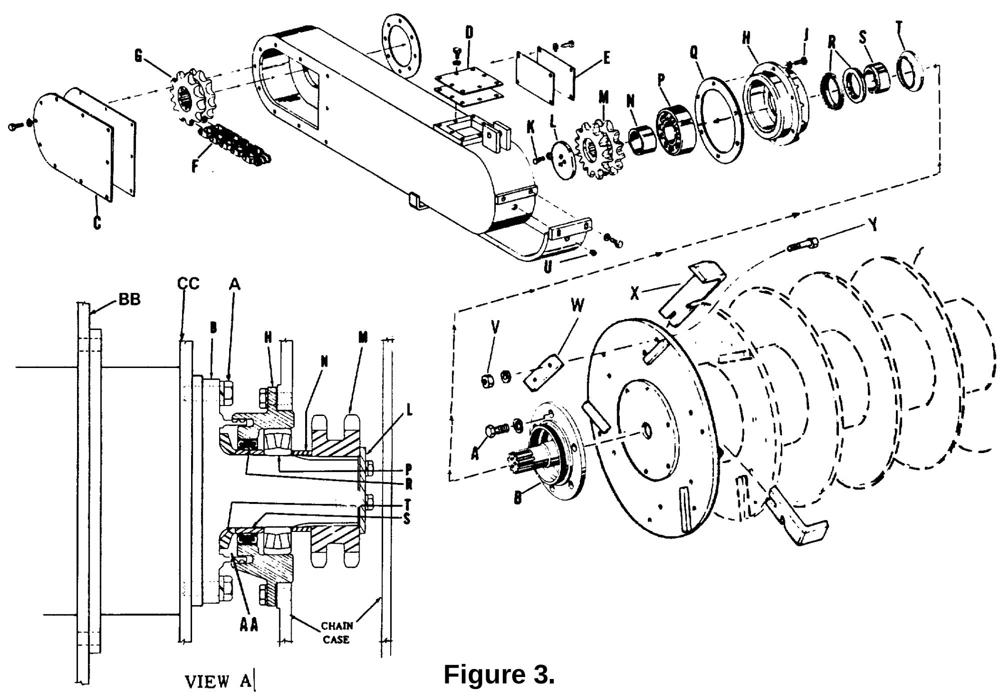


Figure 3.

7. Disassembly of bearing housing assembly Remove lock plate (L) by removing three cap screws (K). Pull sprocket (M) off end shaft. Remove spacer (N). Pull housing (H) with bearing (P) and oil seals (R) off end shaft (B). Remove spacers (S) and (T). Seals (R) and bearing (P) may now be removed from housing. Note that the seal lips face opposite each other. Inspect and replace worn or damaged parts. Soak new seals in oil before assembly.

8. Assembly of bearing housing material Place end shaft (B) on bench with shaft end up. See view "A" of figure 3. Slip spacer (T) on shaft and follow with spacer (S) with chamfer of spacer facing splines. Before proceeding, hand pack cavity "AA" with chassis, grease to prevent dirt from entering this area which may cause seal and/or bearing failure. Press seals (R) into housing (H) with the seal lips facing opposite each other, then assemble housing on end shaft being careful not to rupture seals on the spacer. Follow with bearing (P), spacer (N), sprocket (M) with lock plate and cap screws. Thread wire thru cap screw holes and tie.

NOTE:

Use Permatex on gaskets in reassembly.

9. Using a new gasket (Q) install the end shaft material assembly to the chain case locating the eccentric set of holes in such a manner that when the chain is connected, the chain will be loose. Using two of cap screws (J), opposite each other, temporarily bolt housing to case. Reconnect the chain. Remove the two bolts, rotate housing to tighten chain and to match marks previously made. Refer to following paragraph "Chain Adjustment" if chain is to be tightened.

10. Replace chain case side covers. Remove oil level plug (U). Fill case to this level with

HD80-90 -30°F

HD140 +30°F

Replace plug and top cover.

11. Reinstall rotor to the rotor end shafts. Torque cap screws (A) to 100 ft. lbs. (approx.).

CHAIN ADJUSTMENT, END DRIVE CASE (Fig. 3)

Periodic inspection for chain tightness should be made to retain the chain at the correct tightness. Inspection can be made by removing side cover (C). A certain amount of oil will be lost by removing the cover. Each drive chain must be tightened a like amount and to have a droop of 2/2" on the slack side. Do not overtighten as this will excessively preload the bearings. Bearing housing (H) is made with an eccentric set of holes, that by rotating the bearing housing (clockwise, L. H. side) and (counterclockwise R. H. side) standing at the outside of the end case, the chain may be tightened. Loosen bolts (J) until they are free from the end case. Rotate bearing housing (H), as described above, one hole or more if required to tighten chain. Retighten bolts (J). Replace cover (C), add oil to level plug (U) and replace top cover.

ROTOR AND JACK AXLE REMOVAL

1. Follow steps for Hood Removal and remove hood.

2. Place blocking under the jack axle differential case to retain case from falling. Remove the rotor lift bar from the differential case.

3. Remove four bolts holding the driveline flange to the differential case.

4. Remove eight bolts(4 each side)holding rotor arms to the jack axle.

5. Machine may now be driven away from rotor.

ROTOR DRIVE PROPELLER SHAFTS REPLACEMENT
FRONT SHAFT REPLACEMENT

1. Remove the two U-bolts that attach the front of shaft to the end yoke of rotor drive transmission.

2. Remove the two U-bolts that attach the rear of shaft to end yoke of intermediate shaft.

3. Remove shaft by sliding slip yoke and pulling shaft down. Installation is the reverse procedure.

REAR SHAFT REPLACEMENT

1. Remove the two U-bolts that attach the front of shaft to the end yoke of the intermediate shaft.

2. Remove the two U-bolts that attach the rear of shaft to the end yoke of the traction drive axle.

3. Remove shaft by sliding slip yoke and pulling shaft down. Installation is the reverse procedure.

INTERMEDIATE SHAFT REPLACEMENT

1. Disconnect the front and rear propeller shafts by removing the U-bolts from both ends of the intermediate shaft.

2. Place a support under the pillow block bearing assemblies.

3. Remove the four bolts and nuts that attach the pillow block assemblies to the frame.

4. Remove support and shaft assembly installation is the reverse procedure.

PILLOW BLOCK BEARING REPLACEMENT

After the intermediate shaft has been removed from vehicle, the pillow block bearing assemblies can be removed.

1. Remove the locking bolt from the end yoke of either end of the intermediate shaft.

2. Pull the end yoke off the splines of the shaft.

3. Loosen the two set screws on the pillow block and turn locking collar until pillow block is free to slide off of shaft.

NOTE:

Pillow block locking collar will turn in one direction only. Installation is the reverse procedure.

SHEAR COUPLING REPAIR (Fig. 4)
Disassembly

1. The coupling should be removed from the driveline for bench work. Disconnect coupling from the 2-speed case at flange yoke (A) and pull coupling free from slip joint (B).

2. Flip spring clip (C) back and remove shear pin (D). If flange (A) is removed from coupling half (E), pin may be removed from either side, if not, pin must be removed in direction of arrow.

3. Back out the two set screws (F), opposite each other in tube (G). The set screws are a "lock-in" for the coupling half (E). Coupling half (E) with bearings (H) and (J) may now be pulled free from tube (G), or removed by inserting longer. same thread, screws and use screws to jack out coupling half (E) with bearings.

4. Remove retainer ring (K) and bearing (H) from shaft of coupling half. Pull bearing (J) off shaft and spacer (L).

5. Clean and inspect all parts. If the shear pin (D) fits loose in the coupling halves, bushings (M) need to be replaced. Drive out bushings from the inside out. If spring clip (C) needs replacement, remove machine screw and break tack weld holding clip, or remove two machine screws. Replace with new. Tack weld spring clip slightly. Too much weld will remove spring temper, or replace the two machine screws.

Assembly

6. Slip spacer (L) on shaft of coupling half (E). Press bearing () on shaft and follow with bearing (H). Install retainer ring(K). Slip this assembly into tube (G) and tap slightly to fully seat bearings against shoulders in tube. Tighten down set screws (F). Tap assembly again then back off on set screws just far enough so screws do not touch bearing. Install flange yoke (if removed). Yokes must be in line as shown.

7. Insert shear pin and "lock-in" with spring clip (C). Reinstall coupling in driveline.

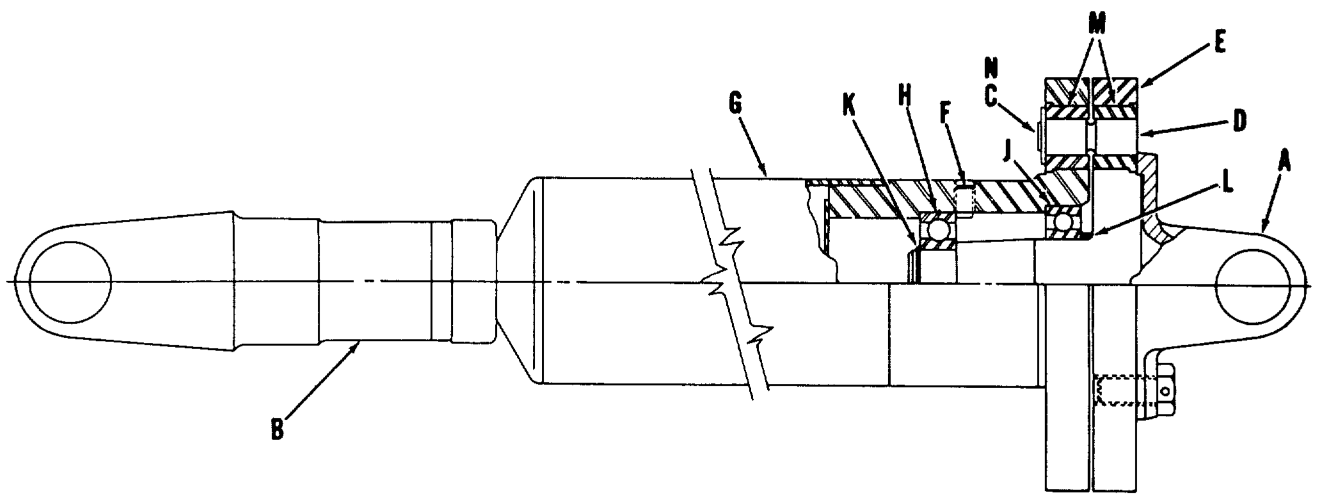


Figure 4

SUBSECTION 2 EMULSION PUMP AND WASH DOWN PUMP

PUMPING UNIT REMOVAL AND INSTALLATION

1. Disconnect valve cylinder from pump output valve.
2. Disconnect pump outlet hose where it joins the steel elbow on the mixer frame.
3. Disconnect pump engine throttle and choke cables.
4. Disconnect cable from starter.
5. Disconnect and label the wire from the oil pressure sensor.
6. Disconnect and label the wire from the magneto.
7. Attach a hoist to the pumping unit frame.
8. Remove the six (6) nuts and cap screws that attach the pumping unit to the main mixer frame.
9. Hoist the pumping unit off the main mixer frame and place in a suitable work area.
10. Installation is the reverse procedure.

REPAIR OF EMULSION PUMP (Refer to Fig. 1)

Check Valve Unscrew suction flange nuts (A) and take off suction flange (B). It may be necessary to jar this loose with a rubber hammer. (Do not pry with sharp instrument as it may damage gasket.) This will expose suction flange gasket (Cc) to which are attached weights (Cb) and (Cd). Inspect and replace parts which show excessive wear and reassemble. Make sure that the larger weight (Cd) is on the pump side of the gasket and that the long lip of the suction flange is installed downward.

Impeller and/or Seal Unbolt pump from base and intermediate coupling to body nuts (D). Remove pump body (E). This will expose body gaskets (F) and impeller (G). Using a wood block and hammer, loosen impeller (G). The impeller thread is right hand and to loosen, turn counterclockwise. Remove impeller (G). Impeller shims (H) and (J), seal spring (Kc) and rotating seal ring (Kb) can then be removed. Remove cap screws (L) and intermediate coupling(M)from engine. Remove stationary seal ring (Ka) from intermediate coupling (M), remove sleeve (N) from engine shaft if used. Clean seal and shaft sleeve. If any part of seal assembly is found to be damaged, replace entire seal. If shaft sleeve shows any sign of grooving it should be replaced. The pump can then be reassembled. Secure intermediate coupling (M) to engine. Insert stationary seal ring (Ka) over shaft sleeve into intermediate coupling.

CAUTION:
Be sure seal face is absolutely clean.

Oil rubber part of seal ring before insertion. Slide rotating seal ring (Kb) over shaft or shaft sleeve until it contacts stationary seal ring in the intermediate coupling. Be sure to clean and oil rubber section that contacts shaft or sleeve. Then place seal spring (Kc) in place and screw on the impeller (G).

Impeller Adjustment In reassembling the impeller and pump, particular care should be taken to see that the impeller is properly spaced with sufficient clearance between the impeller and the pump body. Failure to adjust clearance as closely as possible will result in lowered capacity of the pump. On the other hand if the impeller is adjusted with tolerance so close that friction results, it will excessively load the engine, reduce its speed and lower the capacity and head of the pump. Use a combination of impeller shims (J) and (H) and body gaskets (F) to result in an impeller clearance of approximately 1/64". Failure to adjust clearance as closely as possible will result in lowering the capacity of the pump. If the impeller is worn so that proper clearance cannot be made, it should be replaced.

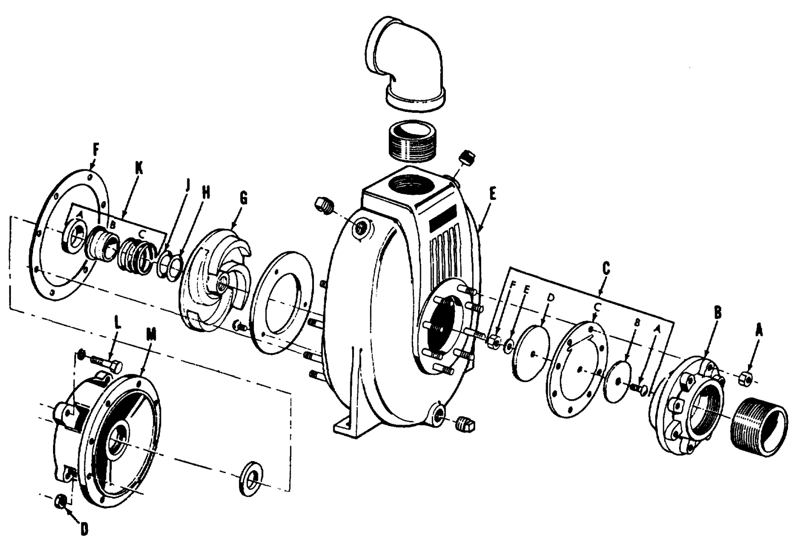


Figure 1.

Troubleshooting

POSSIBLE CAUSE	REMEDY
	1) ENGINE WILL NOT TURN OVER.
Frozen or corroded impeller.	Clean or replace if required.
Clogged or jammed impeller.	Remove pump body and clean out as required.
	2) PUMP DOES NOT PRIME.
Pump body not filled with liquid.	Fill pump body with liquid.
Leak in suction system.	Tighten all suction system connections and check hose or pipe for leaks.
Suction strainer or line clogged.	Clean out strainer and suction line.
	3) PUMP RUNS AT LESS THAN CAPACITY.
Engine speed low.	Check and adjust governor. (Refer to Engine Section.)
Suction lift too high.	Relocate pump closer to liquid supply.
Clogged suction system.	Clean strainer, check valve and suction line.
Leak in suction system.	Tighten all suction system connections and check hose or pipe for leaks.
Suction end out of liquid.	Submerge suction end below surface of liquid so no air is drawn through suction line.
Impeller clogged.	Remove pump body and clean out impeller.

SUBSECTION 2 EMULSION PUMP AND WASH DOWN PUMP

CAUTION:
Before performing service on wash down pump disconnect in-line fuse on orange wire from pump. Fig. 2

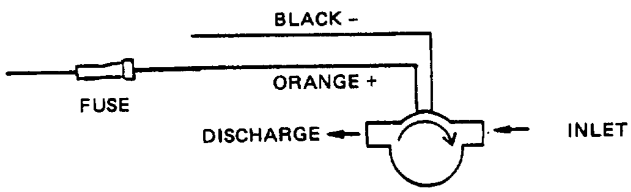


Figure 2.

SERVICE INSTRUCTIONS FOR WASH DOWN PUMP (Fig. 3)

1. Disassembly

a. Remove screws (A), cover (B) and gasket (C).

b. Withdraw impeller (D).

c. Loosen and remove two slotted screws (H) holding pump body (G) to motor (K).

d. Tap pump body lightly between ports and remove body from motor.

e. Deform seal (E) and remove from body cavity. Do not tamper with or disassemble motor.

2. Assembly

a. Lubricate seal (E). Deform seal and install in cavity with open side of seal facing impeller.

b. Lubricate motor shaft and install pump body on motor.

c. Lubricate impeller bore. Align "flat" in impeller bore with "flat" on impeller shaft, install impeller.

d. Install gasket, end cover and screws.

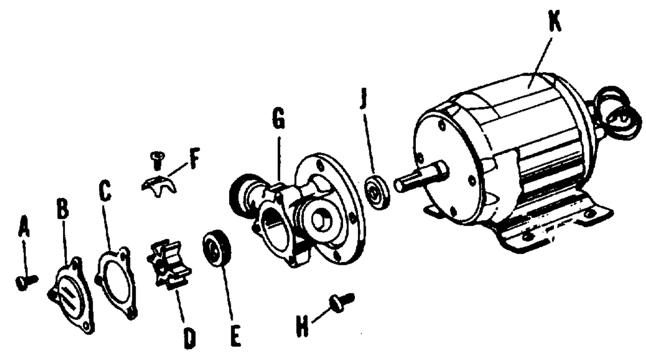


Figure 3.

SUBSECTION 3 BRAKES
GENERAL DESCRIPTION

The Hydraulic Brake commonly referred to as the plain "H" is a light duty, two shoe type brake, mounted on a backing plate which also serves as a dust shield. Adjustable anchor pins provide a means of centering the brake shoe are in relation to the drum, and secondary or minor adjustments are made by rotating the eccentric cam which bears on the brake shoe web or pin in the shoe web.

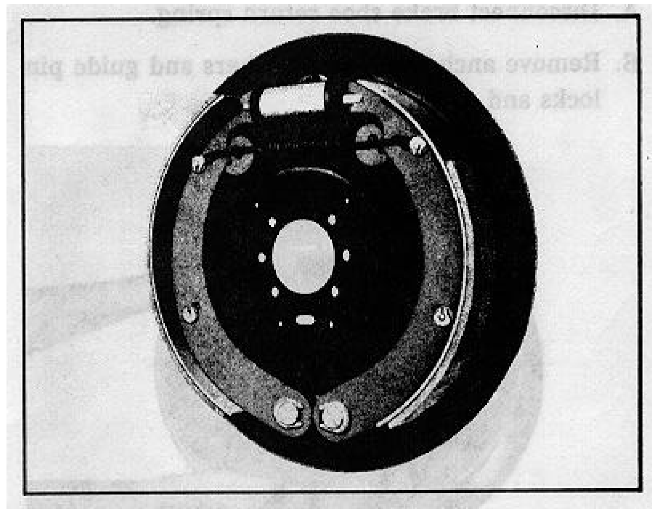


Figure 1.

HYDRAULIC BRAKE LAYOUT

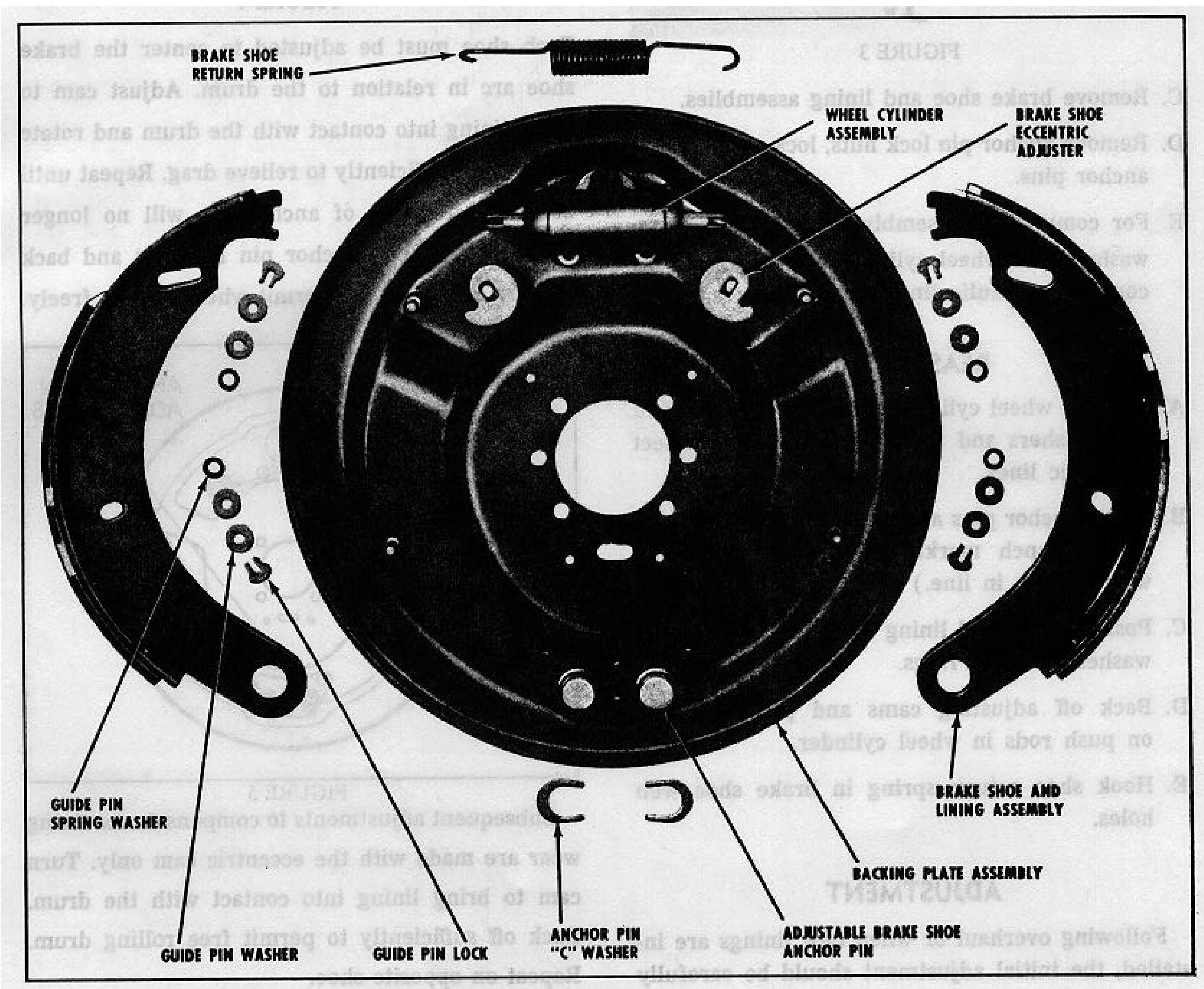


Figure 2.

DISASSEMBLY

A. Disconnect brake shoe return spring.

B. Remove anchor pin "C" washers and guide pin locks and washers.

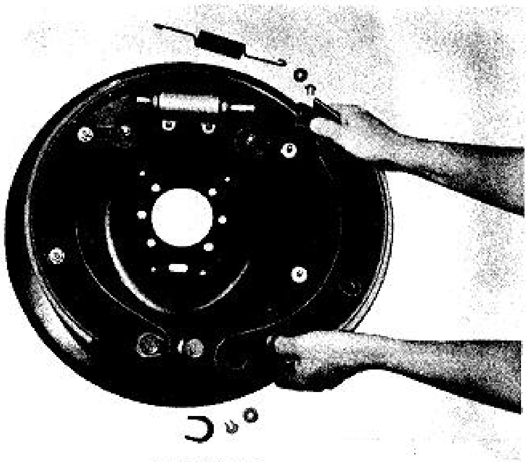


FIGURE 3 .

C. Remove brake shoe and lining assemblies.

D. Remove anchor pin lock nuts, lock washers and anchor pins.

E. For complete disassembly remove cap screws, washers and wheel cylinder assembly and disconnect hydraulic lines.

REASSEMBLY

A. Position wheel cylinder, install cap screws and lock washers and tighten securely. Re-connect hydraulic lines.

B. Insert anchor pins and install washers and lock nuts. (Punch marks must be together and wrench flats in line.)

C. Position shoe and lining assemblies and install washers and lock rings.

D. Back off adjusting cams and position shoes on push rods in wheel cylinder.

E. Hook shoe return spring in brake shoe web holes.

ADJUSTMENT

Following overhaul or when new linings are installed, the initial adjustment should be carefully made to both properly locate the curvature of the lining to the drum and obtain the proper clearance.

Each shoe must be adjusted to center the brake shoe arc in relation to the drum. Adjust cam to bring lining into contact with the drum and rotate anchor pin sufficiently to relieve drag. Repeat until additional rotation of anchor pin will no longer relieve drag. Lock anchor pin lock nut and back off cam sufficiently to permit wheel to turn freely.

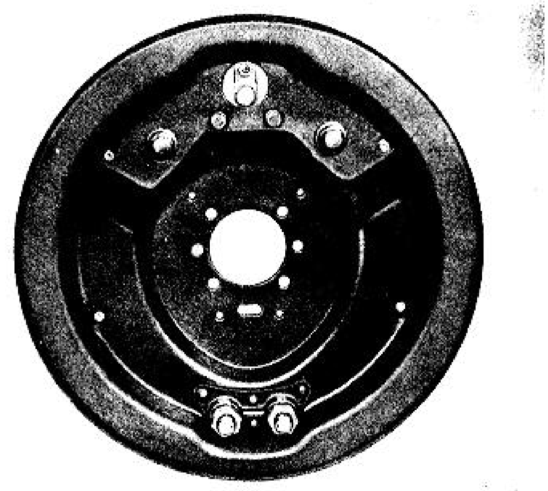


FIGURE 5.

Subsequent adjustments to compensate for lining wear are made with the eccentric cam only. Turn cam to bring lining into contact with the drum.

Back off sufficiently to permit free rolling drum.

Repeat on opposite shoe.

BRAKE MASTER CYLINDER

A brake master cylinder is used for each rear wheel brake cylinder. The master cylinder linked to the brake pedal provides hydraulic pressure to actuate the wheel cylinders to apply the brake assembly. The master cylinder casting combines the reservoir and master cylinder, cast integrally. It is the compensating type, providing a port and vent to permit fluid expansion with temperature changes.

a. To remove the master cylinder for either brake system, it is necessary to remove the service access cover on operator's platform, and by working through cover opening and from underneath the machine, the master cylinders can be removed. Two bolts and nuts are used to secure the master cylinders to mounting bracket. Disconnect the hydraulic lines and pedal linkage before removing cylinder mounting bolts. The installation is reverse of above. Bleed brake hydraulic system after reassembly.

b. The master cylinder can be repaired by replacement of internal parts and/or honing of cylinder bore. Whenever the master cylinder is defective and a disassembly is made for correction, the internal parts must be replaced.

To disassemble the cylinder, remove the link and boot from cylinder and remove snap ring (Items 1, 2, and 3, Figure 6). This will permit the removal of piston and all internal parts.

Inspect all parts and clean thoroughly in alcohol. Pitted cylinders which won't clean up with light honing should be replaced. Piston to bore fit must not exceed 0.003." clearance after honing.

Make sure compensating and secondary port and vent are open, not obstructed. Pre-lubricate all components with silicone brake fluid and reassemble.

Install valve seat washer. Install check valve assembly. Install spring and retainer. Install piston cup piston and secondary cup, stop plate and snap ring. Install boot and link. Install master cylinder.

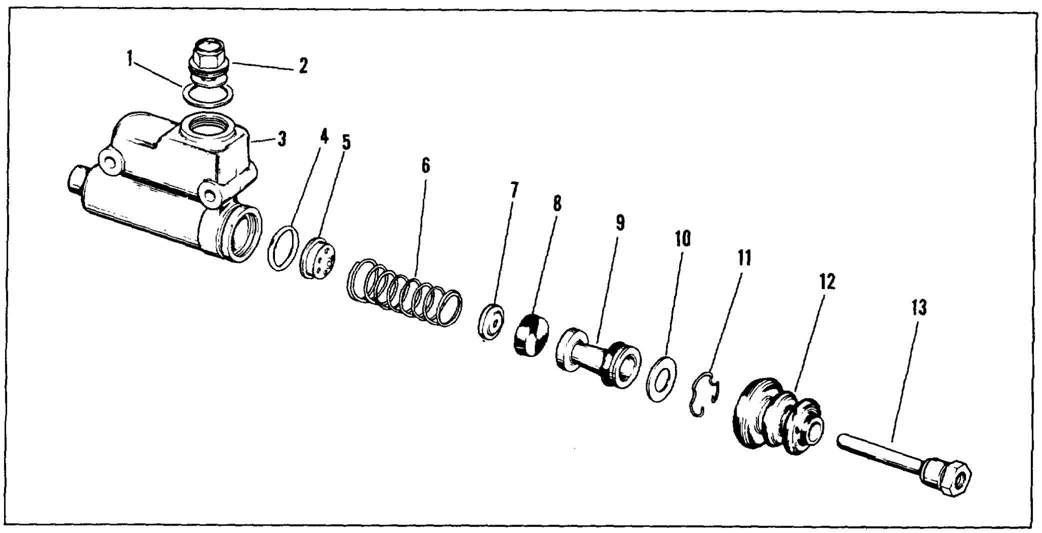
WHEEL CYLINDER

A single wheel cylinder is used at each rear wheel location, and is 1.5" in diameter. To remove the wheel cylinder, the wheel, hub and drum, and brake shoe lever assemblies have to be removed. Then the hydraulic line and two cap screws can be removed which will permit the wheel cylinder to be removed outboard.

Like the master brake cylinder, the wheel cylinder can be repaired by replacement of internal parts and/or light honing to remove a series of pits or scratches, providing a clearance of more than 0.003" is not existent between cylinder and pistons.

Parts should be thoroughly cleaned in alcohol and inspected before reassembly. Cups should always be replaced before reassembly. Install spring, cups, pistons and boots in this order. Parts should be pre-lubricated with silicone brake fluid before assembly.

Install cylinder. Fill master cylinder. Install hub and



1. Gasket
2. Vent and Filler Cap
3. Reservoir and Housing
4. Valve Seat
5. Check Valve Assembly
6. Piston Return Spring
7. Spring Seat
8. Piston Cup
9. Piston and Cup
10. Piston Stop Washer
11. Retainer Ring
12. Dust Boot
13. Link

Figure 6. Exploded View of Master Cylinder

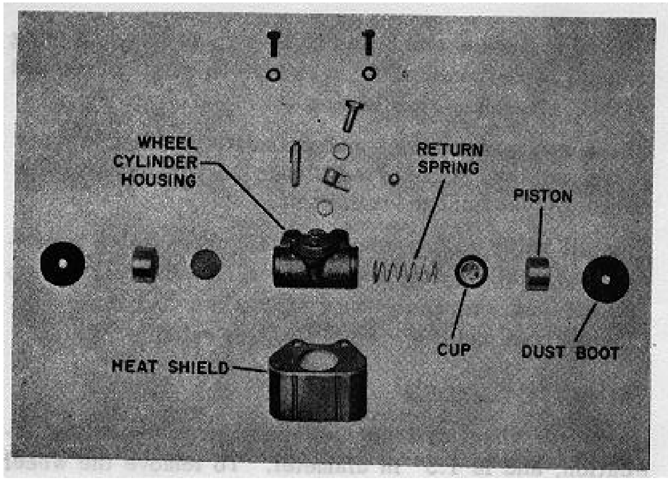


Figure 7. Wheel Cylinder Exploded View

drum assembly. Adjust brakes. Bleed brakes. Top off master cylinder.

BRAKE SYSTEM BLEEDING

The brake system requires a solid oil linkage for efficient operation. All air must be bled from the system.

Each wheel cylinder has a bleeder screw with a bulbous fitting to accommodate a piece of rubber hose for bleeding. The bulbous end of the bleeder screw is 0.308" diameter. It will fit a 9/32" I. D. hose.

A brake pressure "Bleeder" can be used or the master cylinder can be used for bleeding purposes. If the master cylinder is used, the oil reservoir in the cylinder must be kept filled at all times during bleeding.

a. Bleeding procedure with pressure "Bleeder".

1. Fill pressure "Bleeder" with fluid and then charge to proper pressure with air.
2. Fill brake master cylinder and attach "Bleeder hose" to master cylinder.
3. Fill a bottle (clean) with hydraulic fluid to half-full point.
4. Attach bleeder hose 2-3' long to bleeder screw and insert hose to bottom of bottle half-filled with fluid.
5. Open valve on Bleeder to pressurize master cylinder and brake system.
6. Open bleed screw and observe discharge of air and fluid into bottle.
7. When bubbles stop flowing from the hose, turn bleeder screw to "off" (tight) position.

b. Bleeding procedure with helper operating brake pedal and master cylinder.

1. Fill master cylinder and attach bleeder hose to wheel cylinder bleeder screw.
2. Insert bleeder hose in a bottle half-filled with fluid.
3. Have helper slowly depress brake pedal, while you open bleeder screw. Observe bubbles at end of bleeder hose.
4. When bubbles cease flowing from hose, have helper stop the pedal depression.
5. Close the bleeder screw by tightening.

BRAKE PEDAL ADJUSTMENT

Two simple pedal adjustments are provided. One for pedal lash to insure the uncovering of the brake master cylinder compensating port and, one to level the brake pedals. The latter also acts as a pedal stop on pedal return spring action. Access for adjustments is through panel provided above master cylinders on operator's platform.

a. The pedal lash adjustment is made on the master cylinder to pedal linkage link adjacent to the link boot and clevis. Adjust for 3/8" pedal travel before master cylinder piston movement.

b. The pedal stop or leveling adjustments are on the cylinder mounting bracket above the pedal linkage. Adjust for pedal leveling.

SUBSECTION 4 - ROTOR DRIVE

CUTAWAY DETAIL - TYPICAL

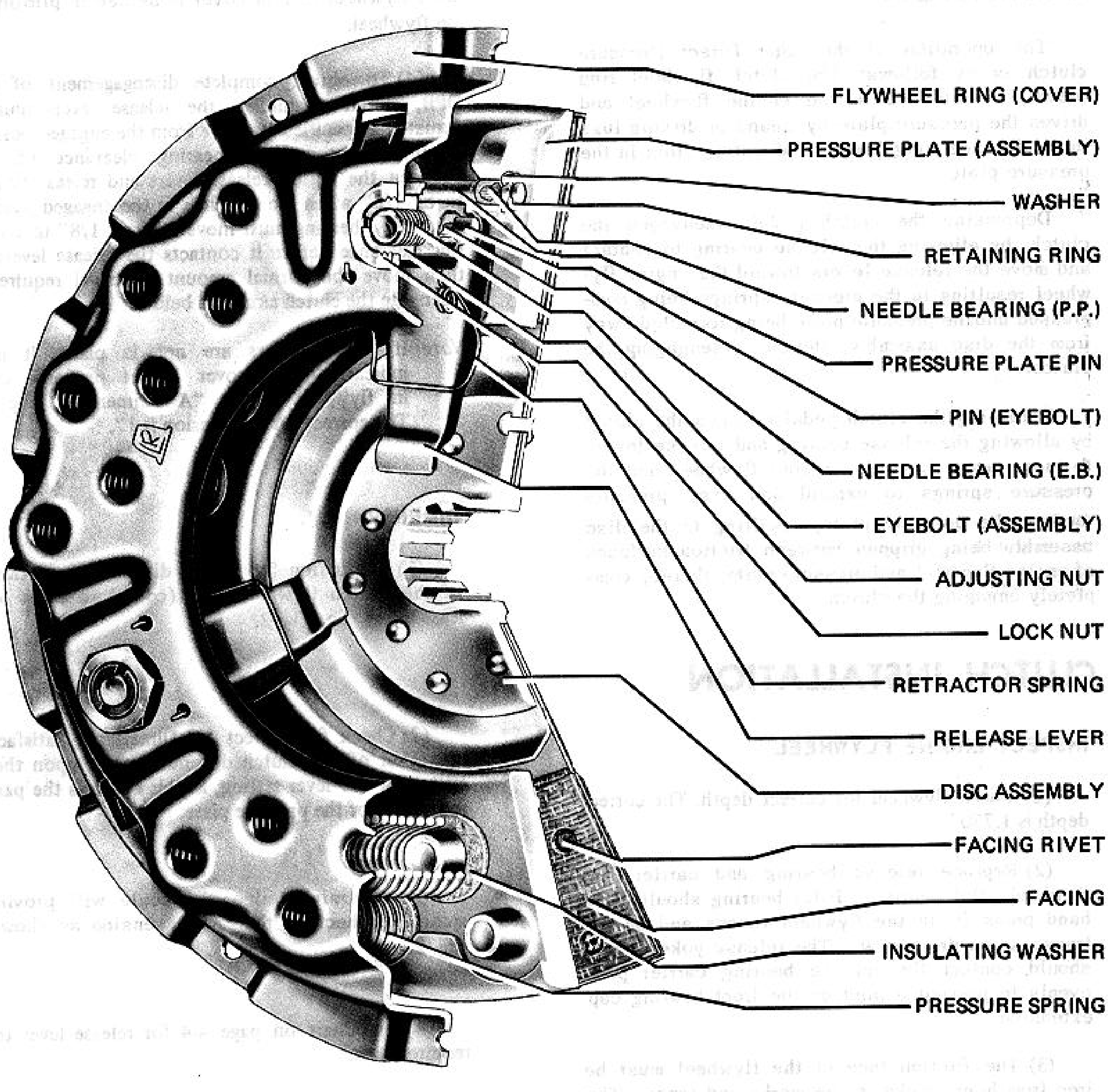


Figure 1. Sectional View of Type DPB Single Plate Clutch

GENERAL DESCRIPTION

The Rotor drive clutch is a Lipe type DPB direct pressure clutch. It is a precision heavy duty unit incorporating few parts. This clutch assembly requires no maintenance other than maintaining release bearing clearance which is accomplished by normal linkage adjustments.

OPERATION

The operation of the Lipe Direct Pressure clutch is as follows: The clutch flywheel ring (cover) is attached to the engine flywheel and drives the pressure plate by means of driving lugs in the flywheel ring (cover) and mating slots in the pressure plate.

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

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

CLUTCH INSTALLATION

INSPECT ENGINE FLYWHEEL

(1) Check flywheel for correct depth. The correct depth is 1.750".

(2) Replace release bearing and carrier, and flywheel pilot bearing. Pilot bearing should be a hand press fit in the flywheel recess and on the transmission drive gear. The release yoke or fork should contact the release bearing carrier pads evenly to prevent a bind on the front bearing cap extension.

(3) The friction face of the flywheel must be free from heat cracks, score marks and taper. The presence of any of these conditions will have an adverse effect on clutch function and life.

INSTALLING CLUTCH ASSEMBLY

(1) It is a good idea to try the cover assembly on the flywheel without the disc assembly to check fit where cover is piloted at O. D.

(2) Install driven disc, making sure that it is properly positioned and insert an aligning shaft. The long end of the driven disc hub extends toward the transmission. Make sure that the driven disc hub does not come within 5/32" of the pilot bearing.

(3) Bolt the cover assembly to the flywheel, tightening each SAE Grade 8 cap screw gradually until the cover is drawn up tight using 45 lbs./ft. of torque. Extreme care must be exercised to make sure flywheel ring or cover is seated in piloting rim on flywheel.

(4) To obtain complete disengagement of Type DPB, clutch assemblies, the release levers must be actuated a specified distance from the engaged position. Assuming the release bearing clearance (distance between the clutch release levers and release bearing) to be 1/8" when the clutch is in the engaged position, the release bearing must move forward 1/8" to take up this clearance before it contacts the release levers and then move the normal amount of travel required to disengage the clutch as shown below.

Note:
If release levers are not in plane, it is an indication that cover is not properly seated in flywheel. Check "A" dimension, Fig. 20. The correct "A" dimension is 1".

DIMENSION 'A'

(1) Dimension 'A' is the distance from the top of the clutch flywheel ring (cover) to ends of release levers. See Fig. 2.

(2) Check for correct 'A' Dimension. Satisfactory operation of the clutch depends greatly upon the accuracy of the lever setting, as this controls the parallel movement of the pressure plate.

(3) A straight edge and scale will provide a means of checking the 'A' Dimension as shown in Fig. 2.

(4) See Chart on page 4-4 for release lever travel requirements.

(5) New or genuine Lipe-Rollway exchange cover assemblies are pre-adjusted at the factory and the lever settings shall not be altered. If the 'A' dimension does not check out within 1/32" recheck the complete installation and, if necessary, remove the cover.

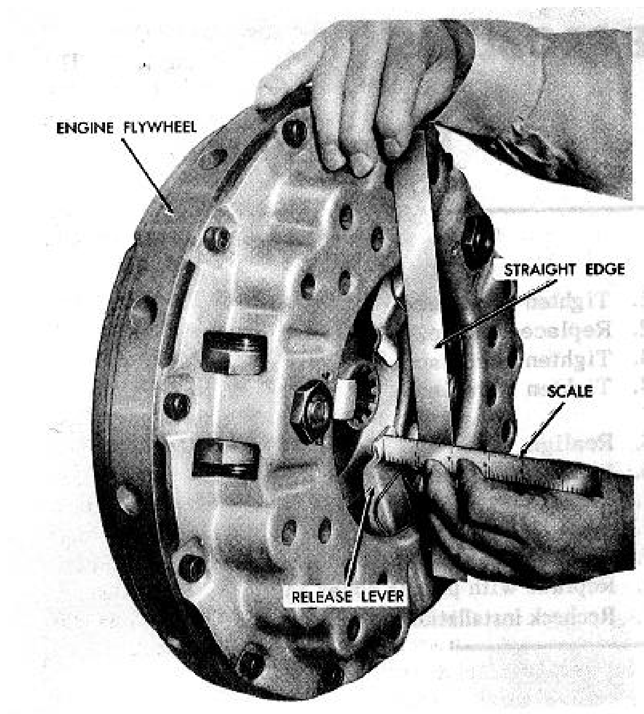


Figure 2. Checking Dimension 'A'

CLUTCH RELEASE TRAVEL CHART

Clutch Size & Clearance	Release Bearing Travel	Normal Release Bearing Required	Total Bearing Travel Type
15" Single Plate	1/8"	7/16"	9/16"

CLUTCH PEDAL ADJUSTMENT

Never wait for the clutch to slip before making a pedal adjustment.

(1) Keep the clutch pedal in proper adjustment by frequent inspection of the clutch pedal 'free travel' which is the first easy movement of the clutch pedal.

(2) Check clutch pedal 'free travel' with hand to be positive that 'free travel' is a result of actual release bearing clearance and not caused by worn linkage. Fig. 3.

(3) Proper clutch pedal 'free travel' is approximately 1/2". The gradual reduction from this amount is a normal condition caused by wearing of the facings.

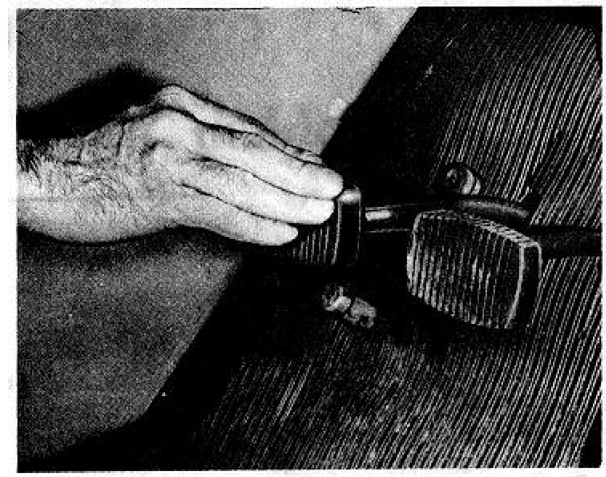


Figure 3. Checking Clutch Pedal 'Free Travel'

(4) If inspection indicates clutch pedal 'free travel' is less than 1/2", immediate adjustment of the clutch pedal linkage should be made to restore proper 1 1/2" 'free travel' Fig. 4. This 1" pedal 'free travel' normally results in 1/8" clearance between the clutch release levers and release bearing.

(5) If excessive free play is present in the clutch pedal linkage due to worn parts, the worn parts must be replaced. Excessive wear of the release linkage may give a false impression of the actual amount of release bearing clearance.

CAUTION:

Excessive clutch pedal 'free travel' may prevent complete clutch disengagement while insufficient clutch pedal 'free travel' will cause slippage, and short clutch life.

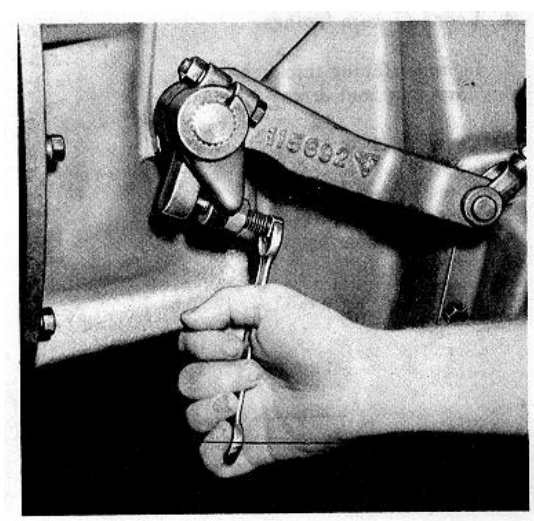


Figure 4. Adjusting Clutch Pedal Linkage

COMMON SERVICE PROBLEMS

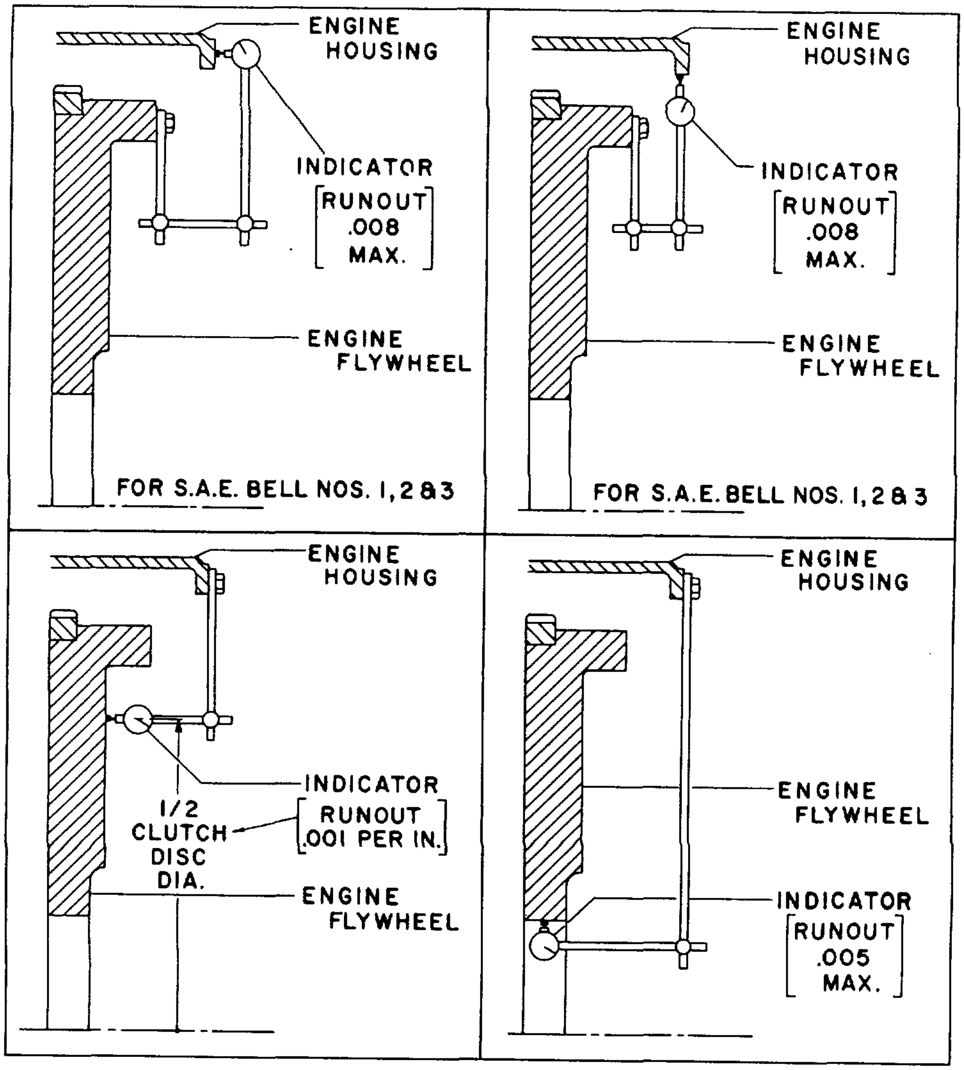
Problem	Remedy
CHATTER	
1. Loose, broken or worn engine mounts.	1. Tighten or replace.
2. Pedal linkage worn.	2. Replace linkage.
3. Loose or cracked clutch housing.	3. Tighten or replace.
4. Spring shackles and mountings loose, worn or broken.	4. Tighten or replace.
5. Misalignment.	5. Realign. See page 37.
6. Oil or grease on facings.	6. Install new facings or disc ass'y.
7. Warped or bent driven disc ass'y.	7. Install driven disc ass'y.
8. Improper disc facing thickness.	8. Install proper disc ass'y.
9. Worn pilot bearing.	9. Replace.
10. Wrong spring pressure in cover assay.	10. Replace with proper cover ass'y.
11. Release levers not parallel.	11. Recheck installation.
AGGRESSIVE	
1. Worn or loose pedal linkage.	1. Replace or tighten.
2. Excessive backlash in power train.	2. Adjust or replace worn parts.
3. Warped driven disc.	3. Install new disc ass'y.
4. Worn hub splines.	4. Install new disc ass'y.
5. Worn splines on splined shaft.	5. Replace shaft or install Lipe Spline-Saver disc kit.
6. Improper facing material	6. Install proper driven disc ass'y.
INSUFFICIENT RELEASE	
1. Broken or loose motor mounts.	1. Replace or tighten.
2. Worn or loose pedal linkage.	2. Replace or tighten.
3. Excessive idling speed.	3. Adjust to factory specs.
4. Loose or worn facings.	4. Replace facings or install new driven disc ass'y.
5. Improper facing thickness.	5. Install proper driven disc ass'y.
6. Warped or bent driven disc ass'y.	6. Install recommended driven disc ass'y properly.
7. Lever settings wrong.	7. Refer to "A" dimension and recheck installation.
8. Worn splines.	8. Replace with new driven disc ass'y.
9. Worn or rusty splines on splined shaft.	9. Repair or replace or install Lipe Spline-Saver disc kit.
10. Worn pilot bearing.	10. Replace.

COMMON SERVICE PROBLEMS (Cont.)

Problem	Remedy
HARD PEDAL	
1. Worn pedal linkage.	1. Replace with new linkage.
2. Binding in pedal linkage.	2. lubricate and adjust.
3. Excessive spring pressure in cover ass'y,	3. Install proper cover ass'y.
4. Contact pad of release bearing carrier worn bv shifter yoke.	4. Replace carrier and shifter yoke. Also check for proper hook-up to provide best linkage operating positions.
SLIPPAGE	
1. Oil or grease on facing.	1. Replace facing or install new driven disc ass'y. and correct oil leak.
2. Loose or worn facings.	2. Replace facings or install new driven disc ass'y.
3. Flywheel burned, checked or cracked,	3. Replace or regrind.
4. Insufficient plate pressure.	4. Install new cover assembly.
5. Binding in pedal linkage.	5. Lubricate and adjust.
6. Improper facing material.	6. Use correct facing or replace disc ass'y.
VIBRATION	
1. All or part of power train out of balance.	1. Check each unit individually and recheck as a complete ass'y.
2. One or more units in power train out of alignment.	2. Check and align (replace faulty component).
3. Worn splined shaft.	3. Replace.
4. Worn crankshaft bearings.	4. Replace.
5. Worn or loose engine mounts.	5. Replace or tighten.
6. Loose or out of balance universal joint.	6. Tighten or replace - check for balance.
7. Clutch out of balance	7. Install balance unit.
8. Worn disc splines.	8. Replace disc.

SUMMARY OF PROBLEMS AND SOLUTIONS - *Generally if the flywheel, engine mounts, transmission shaft, and power train are all installed properly: and operating correctly, then the correct clutch, properly installed, until do the job in the vehicle.*

CHECKING FOR MISALIGNMENT



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

TWO SPEED ROTOR DRIVE TRANSMISSION

1. GENERAL. A "REX WORKS" two-speed transmission is used to transmit two speeds of drive to the rotor gear assembly, direct and one reduction ratio 1.63: 1. The model and serial number plate (item 17 on Fig. 8) is attached to the upper left section of the transmission housing. (Refer to this, when ordering parts).

2. TRANSMISSION REMOVAL. The transmission is removed most readily from beneath the machine as an assembly, including the clutch housing.

a. Remove transmission end of universal joint assembly and clutch control lever. Drain oil from transmission. Remove gear shift lever (item 31).

b. Remove the 12 cap screws (item 5) attaching clutch housing to the flywheel housing.

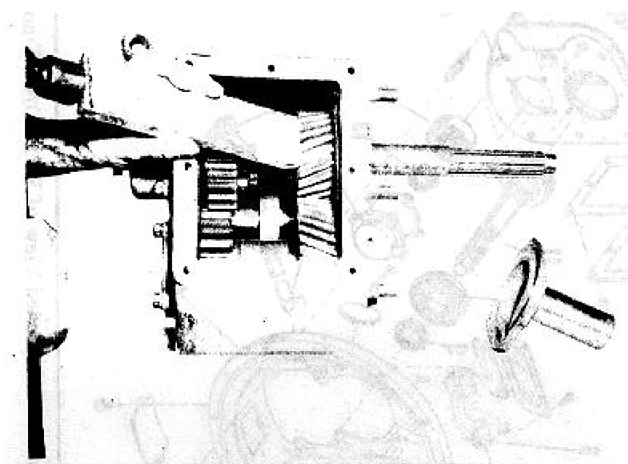


Figure 5. Knocking Out Drive Gear Assembly

c. The transmission can now be pulled backward and downward pulling main drive gear shaft (item 11) through the clutch assembly.

d. A suitable hoist or floor jack should be used as the unit weighs approximately 152 lbs. Oil capacity is 4 qts.

e. Remove clutch throw-out bearing lubricating hose (item 2) and throw-out bearing (item 1). Remove clutch throw-out bearing fork (item 6) and actuating shaft (item 7).

f. Remove clutch housing (item 4) from transmission case (item 16).

g. Clean transmission externally and place on suitable bench for repair.

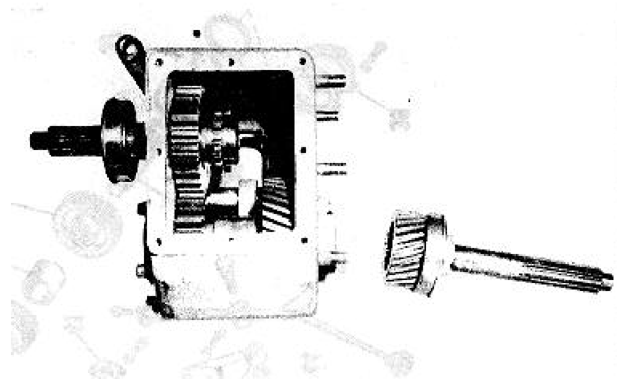


Figure 6. Removing Main Shaft and Bearing Assy

h. Transmission disassembly.

(1) Remove drive shaft flange.

(2) Remove drive gear bearing retaining housing (item 3).

(3) Drive gear bearing is slide fit with light interference to transmission case.

(4) Remove transmission case cover (item 15).

(5) A soft drift punch, brass or aluminum, can be used against drive gear (item 11) to knock out drive gear assembly from case. (See Figure 5.) (6) Main shaft pilot bearing (item 22) may stay in rear section of drive gear or may remain on main shaft (item 26).

(7) Remove cover (item 21) from sliding yoke opening and cut safety wire on yoke at setscrew.

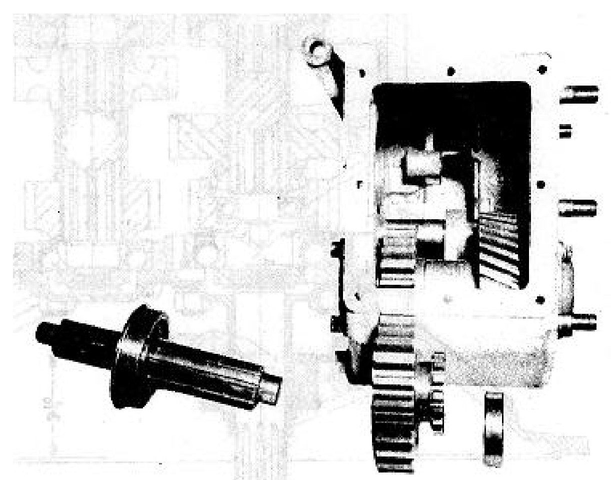


Figure 7. Main shaft, Bearing and Shaft Removed.

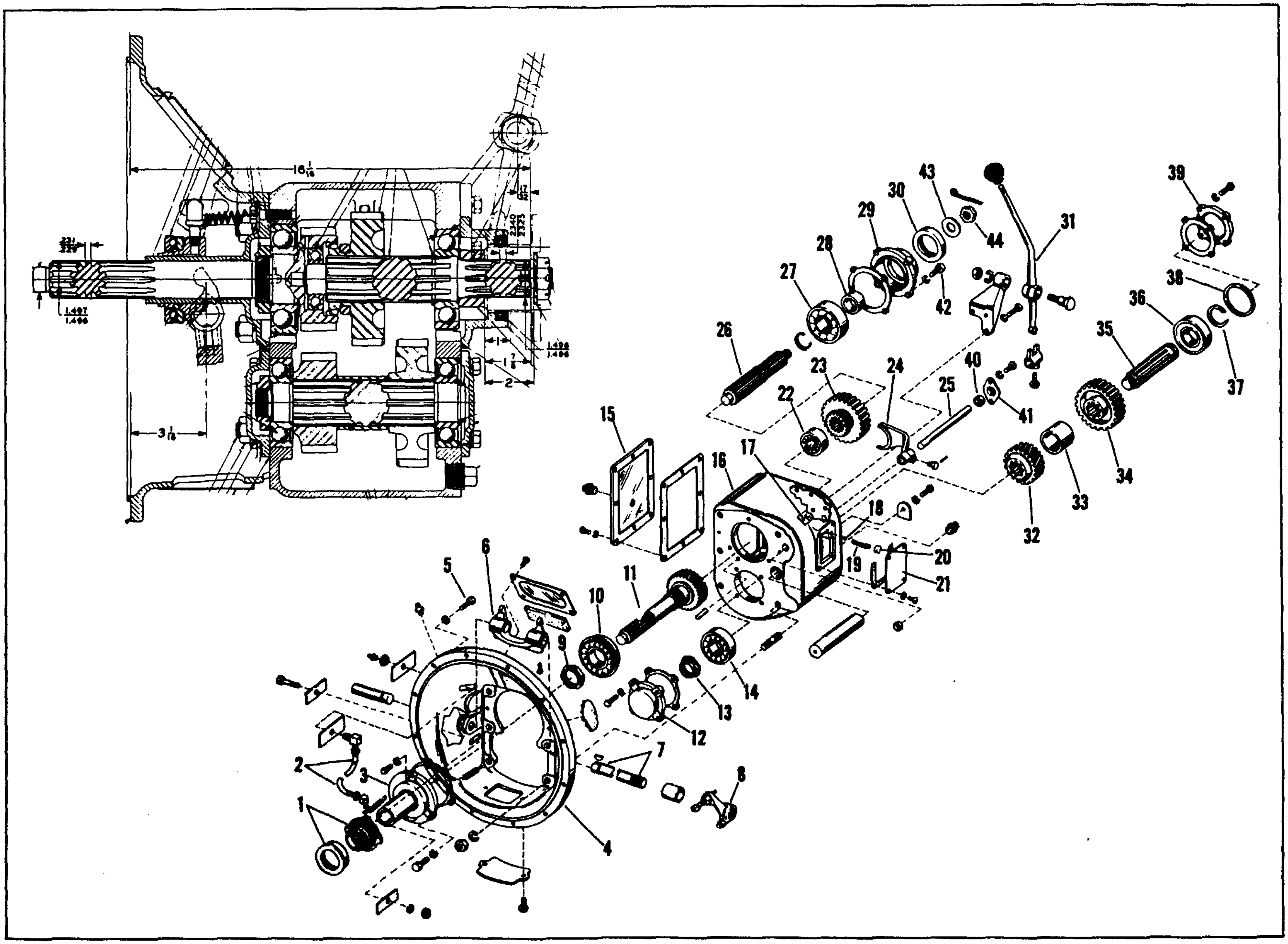


Figure 8. Sectional and Exploded View of Rotor Drive transmission

WARNING

Yoke bar detent spring (item 19) and spacer (item 20) will fly out, when cover is removed. Be alert to this and remove cover carefully. Remove detent ball (item 18), spring and spacer. Remove yoke bar (item 25) and yoke (item 24), bar seal (item 40) and retainer (item 41).

(8) Remove main shaft bearing cover bolts (item 42) at rear of transmission case and remove cover (item 29).

(9) Pull output shaft sharply to the rear knocking off pilot ball bearing and sliding gear (item 23).

(10) Remove sliding gear and pilot bearing from case.

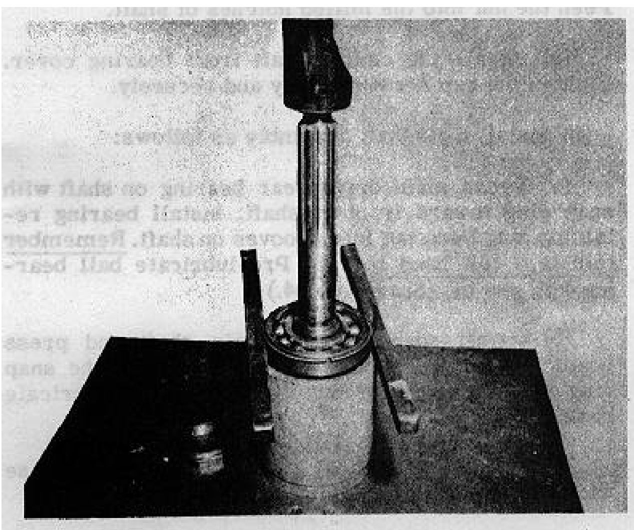


FIGURE 9. Removing Drive Gear Bearing

(11) Remove bearing covers (items 12 and 39) from front and rear counter shaft bearings (items 14 and 36).

(12) With a small cape chisel remove the stake metal from the nut on the front of countershaft (item 35), where it has been driven into groove of shaft. Hold or lock countershaft and remove this nut (item 13). Nut thread is right hand. Clockwise to tighten.

(13) With a soft punch or drift knock the countershaft rearward, through the gears and spacer.

(14) Remove the gears (item 32 and 34) and spacer (item 33) from the transmission case.

(15) Place the main drive gear (item 11) in a soft jawed vice and remove bearing retaining nut (item 9).

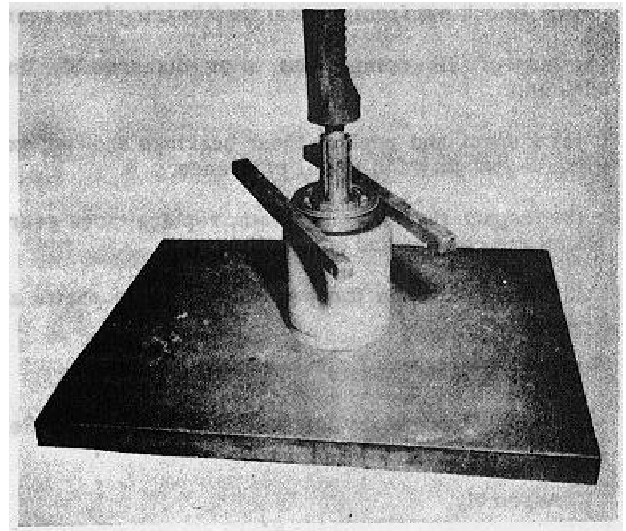


FIGURE 10. Removing Rear Main Shaft Bearing

NOTE

The drive gear bearing retaining nut is a left hand thread. Turn clockwise to remove, counterclockwise to tighten.

(16) Press off the bearing from drive gear, if replacement is contemplated. (See Figure 9.)

(17) Press rear main shaft bearing off of shaft. This bearing need not be removed, unless replacement is desired. (See Figure 10.)

(18) If replacement of countershaft rear bearing is required, remove snap ring (item 37) from rear of shaft and press off bearing. (See Figure 11.)

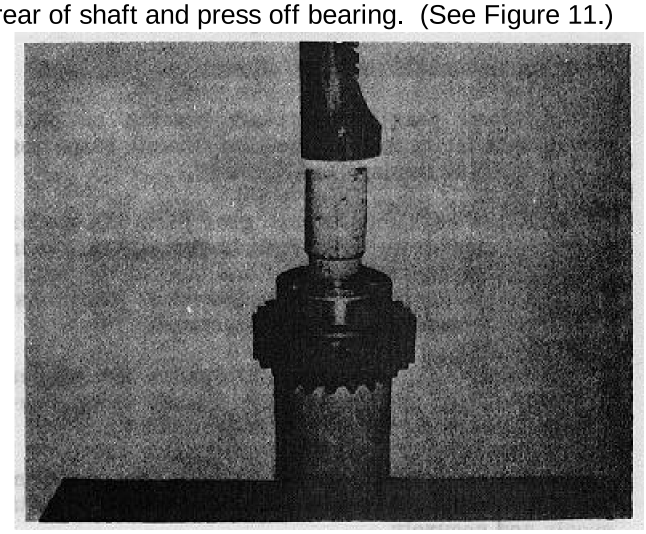


FIGURE 11. Removing Countershaft Rear Bearing

(19) Knock out front countershaft bearing from rear.

h. Inspect all components after disassembly and cleaning.

(1) Inspect and replace those bearings showing excessive end play and radial clearance.

(2) Inspect the engaging teeth, replace those gears which are chipped and snubbed.

(3) Check splines for wear and replace shafts as required.

(4) Install new gaskets.

(5) Inspect oil seals for hardness and cracks. Replace where required.

i. Assembly.

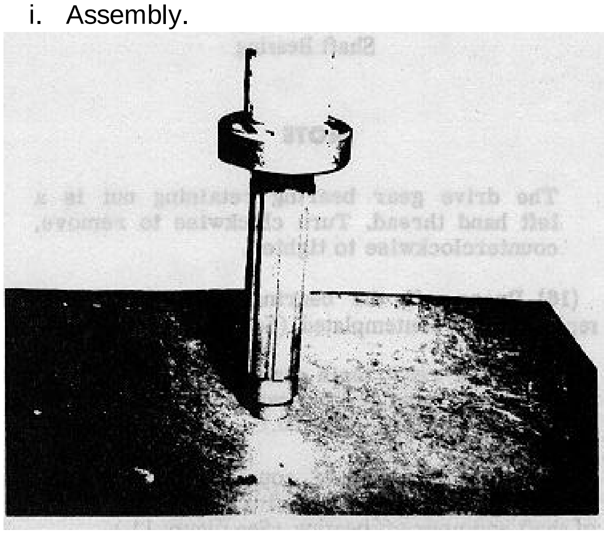


FIGURE 12. Pressing on Countershaft Rear Bearing

(1) Install countershaft as follows:

(a) Press rear countershaft bearing on shaft with shield facing splined section. Install snap ring in groove behind bearing. (See Figure 12.)

(b) Place rear countershaft gear (item 34), spacer (item 33) and front countershaft gear (item 32) in case with the longer hub sections toward the front. The duck-bill grind of rear countershaft gear must face sliding gear for ease of engagement.

(c) Slide countershaft through gears and spacer and knock shaft and bearing into place in case. Prelubricate bearing and gears with gear oil.

(d) Install rear countershaft bearing spacer (item 38) and bearing cover assembly. Tighten cover bolts evenly and securely.

(e) Drive front countershaft bearing into place in case with shield to the rear.

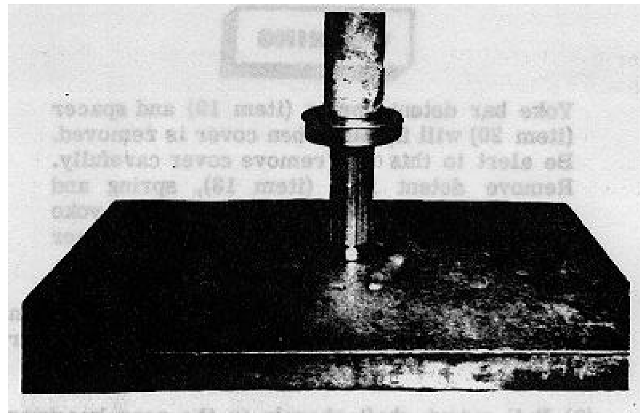


FIGURE 13. Main Shaft Bearing Being Pressed On

(f) Hold the countershaft from turning and install front countershaft retaining nut and tighten securely. Peen the nut into the milled notches of shaft.

(g) Install the countershaft front bearing cover. Tighten the cap screws evenly and securely.

(2) Install mainshaft assembly as follows:

(a) Press main drive gear bearing on shaft with snap ring toward front of shaft. Install bearing retaining nut. Peen nut into grooves on shaft. Remember this is a left hand thread. Pre-lubricate ball bearing with gear oil. (See Figure 14.)

(b) Install snap ring on main shaft and press bearing on rear section of shaft against the snap ring with bearing snap ring to the rear. Pre-lubricate bearing.

(c) Place the sliding gear (item 23) into case with yoke collar groove forward.

(d) Slide main shaft through rear bearing bore

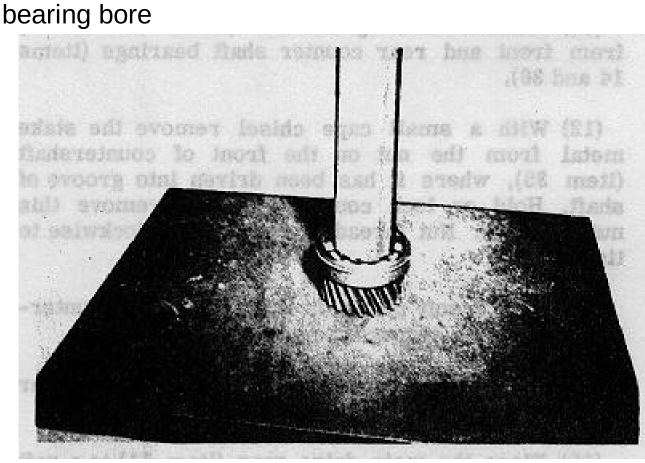


Figure 14. Installing Drive Gear Shaft Bearing

hole-and through sliding gear. Drive rear section of shaft and bearing into case bearing bore.

(e) Install rear bearing cover oil seal (item 30) and mount bearing cover (item 29) on case, tightening cap screws (item 42) evenly and securely.

(f) Drive pilot bearing (item 22) on end of front section of main shaft. Pre-lubricate bearing.

(g) Drive main drive gear assembly (item 11) into case from front.

(h) Install shifting yoke (item 24) and yoke bar (item 25).

(i) Install shifting yoke lock screw and safety wire.

(j) Install poppet ball (item 18), tension spring (item 19) and tension spring spacer (item 20).

(k) Install flat cover (item 21).

(l) Install yoke bar seal (item 40) and retainer (item 41).

(m) Install case cover (item 15) and tighten screws evenly, and securely.

(n) Install mainshaft spacer (item 28), universal joint flange, washer (item 43) and nut (item 44). Cotter key nut, after tightening.

CAUTION

The mainshaft is held in its proper place by the companion flange. The omission of parts between flange and bearing or failure to pull flange tightly into place will allow mainshaft to move endwise with resultant damage to pilot bearing, main drive gear, and rear bearing cover.

ROTOR DRIVE AXLE

GENERAL

The Rockwell-Standard Company Unit-Type Housing Drive Unit is a single-reduction drive of hypoid design. The differential and gear assembly is mounted on tapered roller bearings with the cups assembled in the case and cover halves of the housing. The straddle mounted pinion has two tapered roller bearings located forward of the pinion teeth and a radial bearing at the inner end.

The pinion shaft is splined to accommodate the flange and the bearing pre-load controlled by hardened and ground spacers of the correct thickness between the bearings. Bearings are retained in position by the companion flange nut.

DISASSEMBLE AXLE

A. Before disassembling, place length of pipe or suitable support, slightly smaller than axle shaft splines, approximately two-thirds through axle from the case side to prevent dropping the differential assembly.

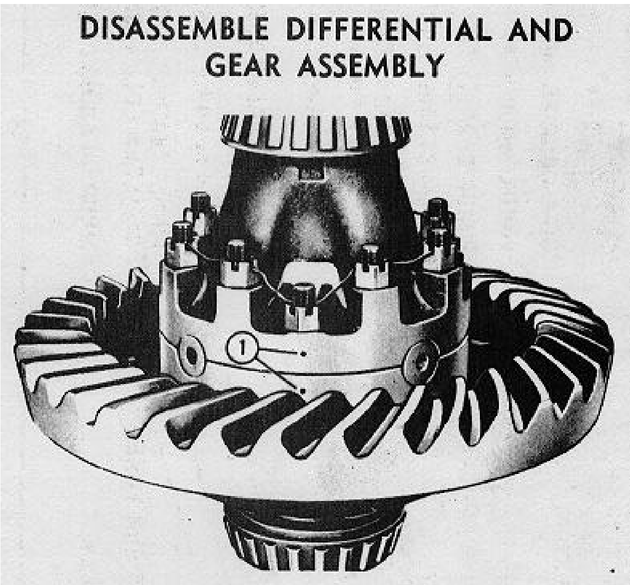
B. Remove bolts, nuts and washers from case and cover and remove cover half.

C. Remove differential and gear assembly.

D. Remove pipe.

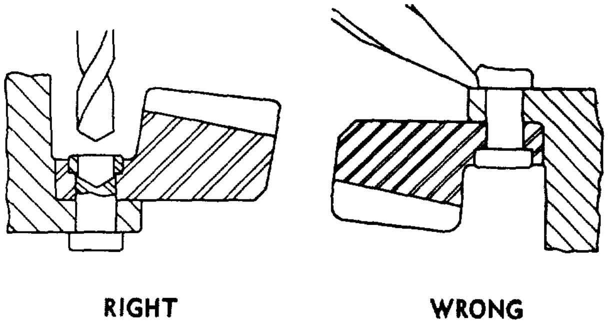
DISASSEMBLE DRIVE UNIT

DISASSEMBLE DIFFERENTIAL AND GEAR ASSEMBLY

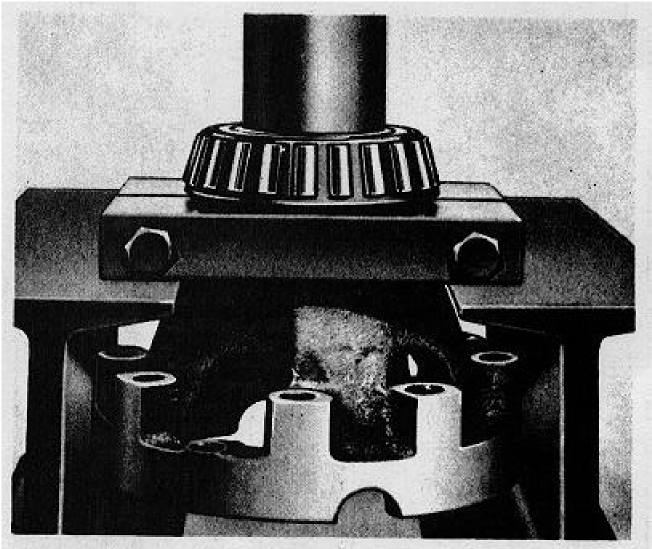


A. If original identification marks are not clear, mark differential case halves with a punch or chisel (as shown in photograph above) before disassembling, for correct alignment when reassembling.
B. Cut lock wire, remove bolts or cap screws and separate case halves.
C. Remove spider, pinions, side gears and thrust washers.
D. Remove rivets and separate gear and case if required.

REMOVE GEAR RIVETS



1. Carefully centerpunch rivets in center of head.
2. Use drill 1/32" smaller than body of rivet to drill through head.
3. Press out rivets.



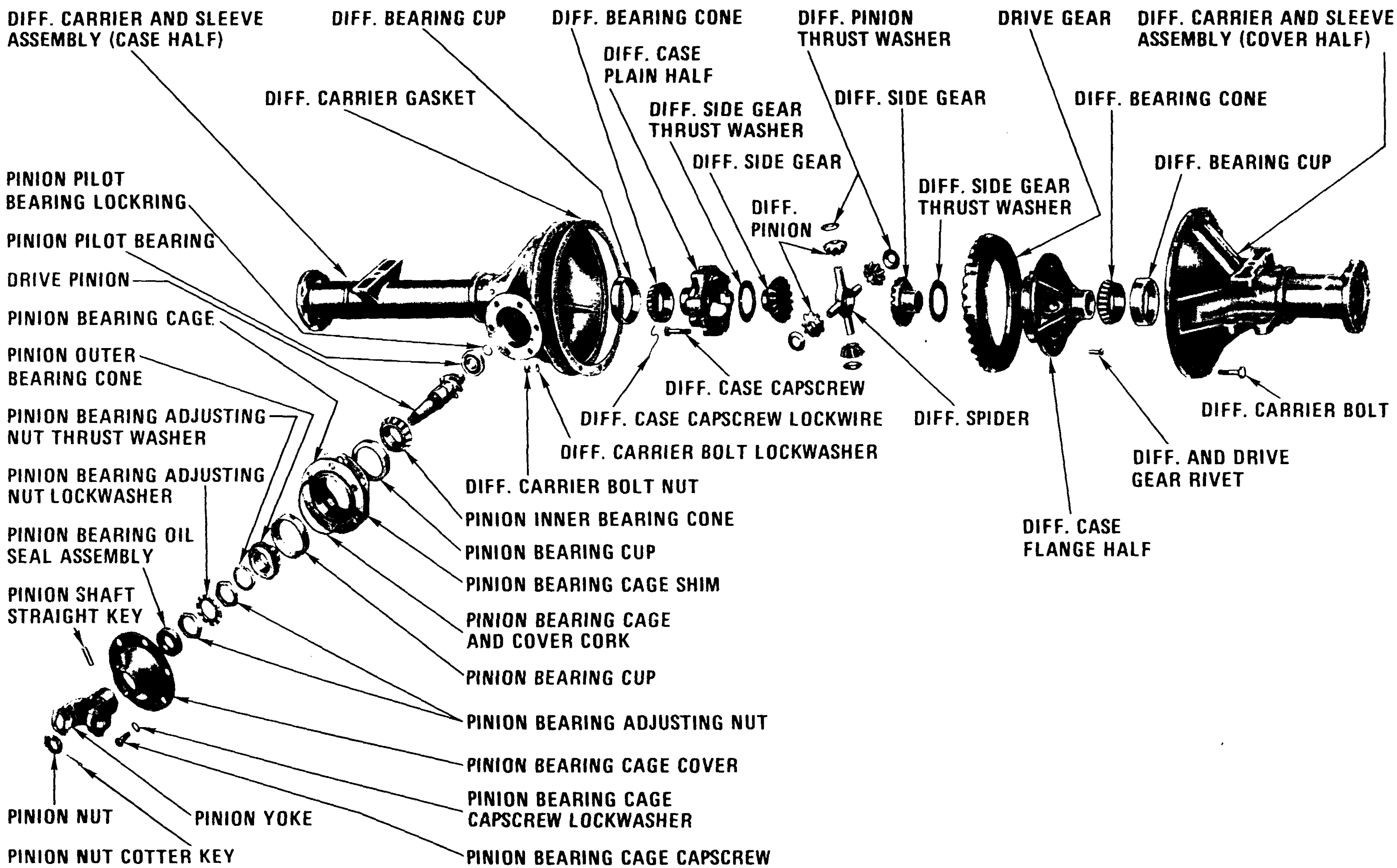
E. Remove differential bearings with bearing puller if necessary to replace.

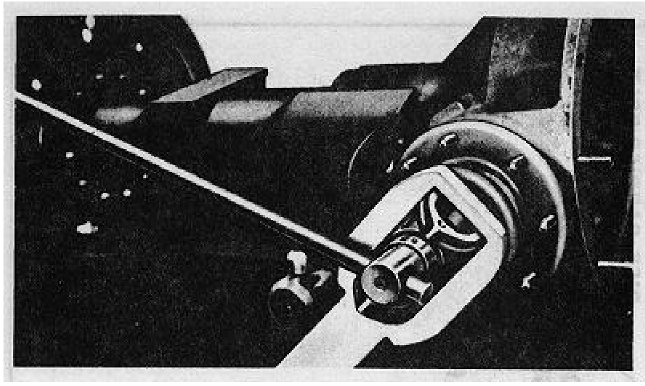
REMOVE PINION AND CAGE ASSEMBLY

The differential and gear assembly must be removed before the pinion and cage assembly can be disassembled.

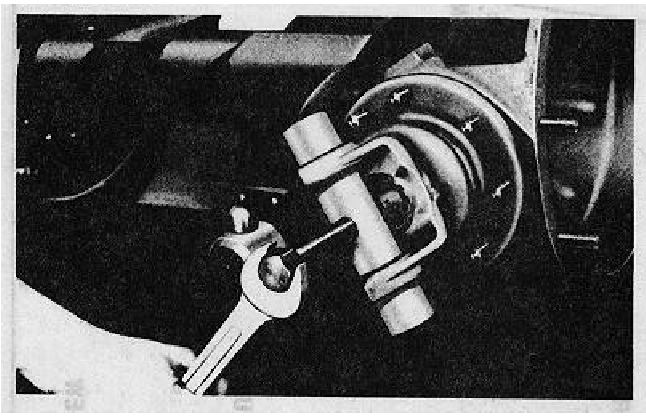
EXPLOSION VIEW OF UNIT TYPE HOUSING DRIVE AXLE

ROTOR DRIVE AXLE

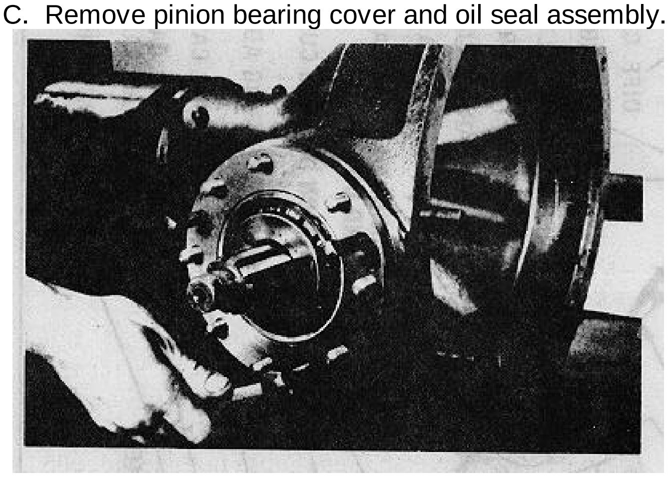




A. Secure yoke with holding tool and remove pinion shaft nut and washer.



B. Insert puller through yoke and remove.
C. Remove pinion bearing cover and oil seal assembly.

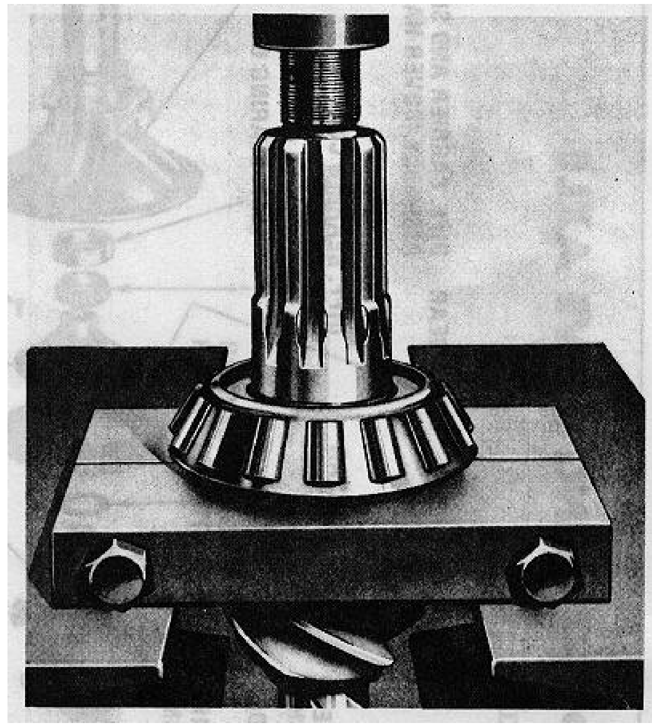


D. Remove pinion and cage assembly using puller screws in holes provided.

Driving pinion from inner end with a drift will damage the bearing lock ring groove.

DISASSEMBLE PINION AND CAGE ASSEMBLY

A. Tap shaft from cage with soft mallet or press shaft from cage.
B. Remove outer bearing from cage.
C. Remove spacer or spacer combination from pinion shaft.



D. Remove rear thrust bearing and radial bearing with bearing puller if necessary to replace.
E. Remove oil seal assembly from bearing cover.
F. IF NECESSARY TO REMOVE DIFFERENTIAL BEARING CUPS, WIRE THE SELECTIVE SPACERS WHICH ARE BEHIND THE CUPS TO THEIR RESPECTIVE AXLE HALVES.

PREPARE FOR REASSEMBLY

CLEAN

Parts having ground and polished surfaces such as gears, bearings, shafts and collars, should be cleaned in a suitable solvent such as SD-2 kerosene or diesel fuel oil.

GASOLINE SHOULD BE AVOIDED.

WARNING

Potentially dangerous. Do not use near open flame or heat. *Do NOT clean these parts in a hot solution tank or with water and alkaline solutions such as sodium hydroxide, orthosilicates or phosphates.* We do NOT recommend steam cleaning assembled drive units after they have been removed from the housing. When this method of cleaning

is used, water is trapped in the cored passage of the castings and in the close clearances between parts as well as on the parts. This can lead to corrosion (rust) of critical parts of the assembly and the possibility of circulating rust particles in the lubricant. Premature failure of bearings, gears and other parts can be caused by this practice. Assembled drive units cannot be properly cleaned by steam cleaning, dipping or slushing. Complete drive unit disassembly is a necessary requisite to thorough cleaning.

ROUGH PARTS

Rough parts such as differential carrier castings, cast brackets may be cleaned in hot solution tanks with mild alkali solutions providing these parts are not ground or polished. The parts should remain in the tank long enough to be thoroughly cleaned and heated through. This will aid the evaporation of the rinse water. The parts should be thoroughly rinsed after cleaning to remove all traces of alkali.

WARNING

Exercise care to avoid skin rashes and inhalation of vapors when using alkali cleaners.

COMPLETE ASSEMBLIES

Completely assembled axles may be steam cleaned on the outside only, to facilitate initial removal and disassembly, providing all openings are closed. Breathers, vented shift units, and all other openings should be tightly covered or closed to prevent the possibility of water entering the assembly.

DRYING

Parts should be thoroughly dried immediately after cleaning. Use soft, clean, lintless absorbent paper towels or wiping rags free of abrasive material, such as lapping compound, metal filings or contaminated oil. Bearings should never be dried by spinning with compressed air.

CORROSION PREVENTION

Parts that have been cleaned, dried, inspected and are to be immediately reassembled should be coated with light oil to prevent corrosion. If these parts are to be stored for any length of time, they should be treated with a good RUST PREVENTIVE and wrapped in special paper or other material designed to prevent corrosion.

INSPECT

It is impossible to overstress the importance of careful and thorough inspection of drive unit parts prior to reassembly. Thorough visual inspection for indications of wear or stress, and the replacement of such parts as are necessary will eliminate costly and avoidable drive unit failure.

A. Inspect all bearings, cups and cones, including those not removed from parts of the drive unit and replace if rollers or cups are pitted or damaged in any way. Remove parts needing replacement with a suitable puller or in a press with sleeves.
   Avoid the use of drifts and hammers. They may easily mutilate or distort component parts.

B. Inspect first reduction bevel or hypoid and second reduction spur gears for wear or damage. Gears which are pitted, galled or worn or broken through case hardening should be replaced.
   When necessary to replace the pinion or gear of a gear set, the entire gear set should be replaced. We assume no responsibility for gears of these types when replaced in any other manner.

C. Inspect the differential assembly for the following:
   1. Pitted, scored or worn thrust surfaces of differential case halves, thrust washers, spider trunnions and differential gears.
      Thrust washers must be replaced in sets. The use of a combination of old and new washers will result in premature failure.
   2. Wear or damage to the differential pinion and side gear teeth.

      Always replace differential pinions and side gears in sets.

D. Spur pinions for wear or damage to teeth.

E. Check end of pinion for indications of brinelling caused by worn splines. Replace the parts if the splines of the pinion and/or thru-shaft are worn, permitting movement of the pinion on the thru-shaft.

F. Axle shafts for indications of torsional fractures and runout. Axle shafts should be inspected between centers to ascertain the amount of runout of the ground surfaces. Runout at the shaft flange and splines should not exceed .005" total indicator reading.

REPAIR

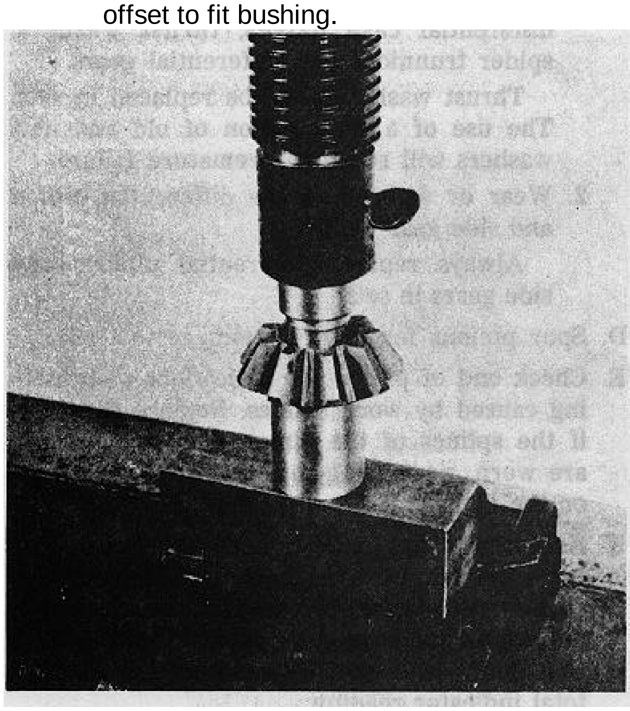
A. Replace all worn or damaged parts. Hex nuts with rounded corners, all lock washers, oil seals and gaskets should be replaced at the time of overhaul.
   Use only genuine Rockwell-Standard parts for satisfactory service. For example, using gaskets of foreign material generally leads to mechanical

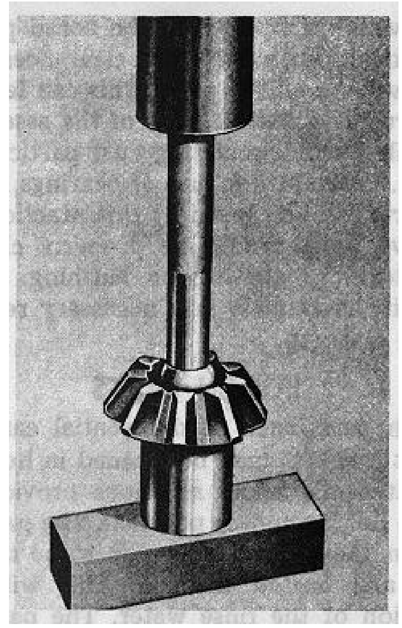
trouble due to variations in thickness and the inability of certain materials to withstand compression, oil, etc.

B. Remove nicks, mars and burrs from machined or ground surfaces. Threads must be clean and free to obtain accurate adjustment and correct torque. A fine mill file or India stone is suitable for this purpose. Studs must be tight prior to reassembling the parts.

C. If necessary, install new differential pinion bushings where used as follows:

1. Remove worn bushing. The bushing may be split with a hacksaw and the halves easily removed.
2. Remove burrs or sharp corner from inner edge of pinion bore to prevent shearing or buckling of bushing on installation.
3. Place pinion on anvil. Position bushing in inner end of pinion bore and press squarely into position. Use adapter with correct size offset to fit bushing.

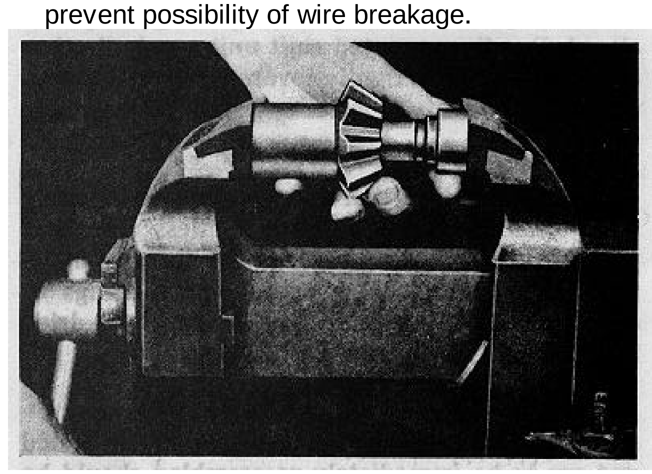




4. Use bar to press burnishing ball through bushing.
   If desired, the bar may be shortened to permit the use of a bench vise to install and burnish bushing.

D. When assembling component parts use a press where necessary. Avoid hammering.

E. Tighten all nuts to specified torque. See torque limits following service instructions.
   Lock wire must not be brittle; use soft iron wire to prevent possibility of wire breakage.

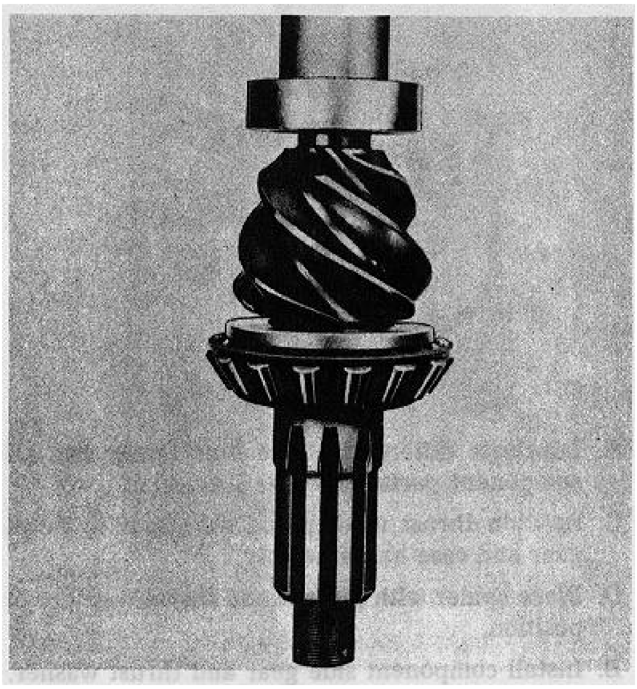


REASSEMBLE AXLE

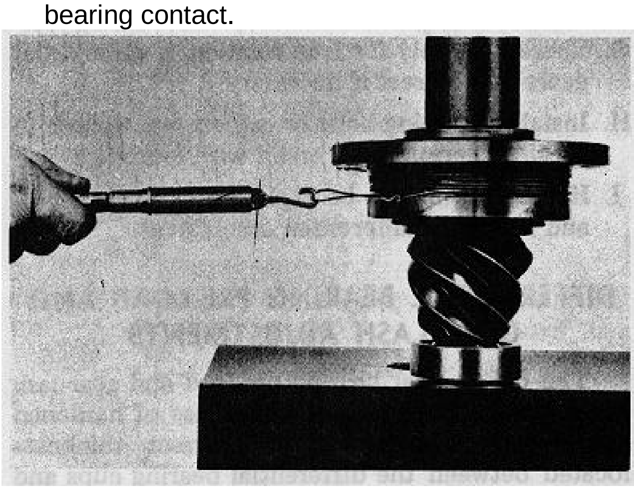
REASSEMBLE PINION AND CAGE ASSEMBLY

When a new pinion cage is required, the bearing and cage assembly furnished for service purposes should be used. This includes the cage with bearing cups assembled, bearing cones and the selective spacer required to obtain the correct bearing pre-load.

The used bearing cones should be removed from the pinion shaft and the new bearings and spacer used in the assembly.



A. Press rear thrust and radial bearings firmly against the pinion shoulders with a suitable sleeve.
B. Install radial bearing lock ring and squeeze ring into pinion shaft groove with pliers.
C. If new cups are to be installed, press firmly against pinion bearing cage shoulders.
D. Lubricate bearings and cups with light machine oil.
E. Insert pinion and bearing assembly in pinion cage and position spacer or spacer combination over pinion shaft.
F. Press front bearing firmly against spacer.
G. Rotate cage several revolutions to assure normal bearing contact.

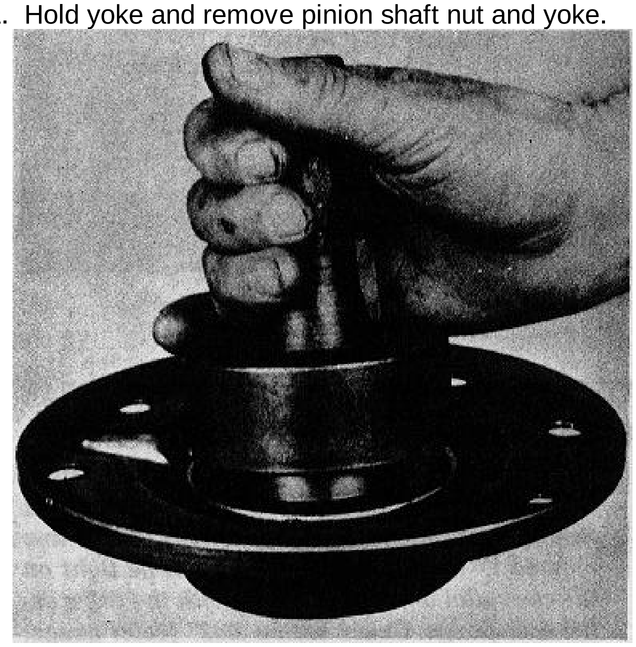


H. While in press at 25,000 pounds pressure, check bearing pre-load torque. Wrap soft wire around cage and pull on horizontal line with pound scale. If a press is not available, the yoke may be installed and the pinion nut tightened to specified torque for checking.

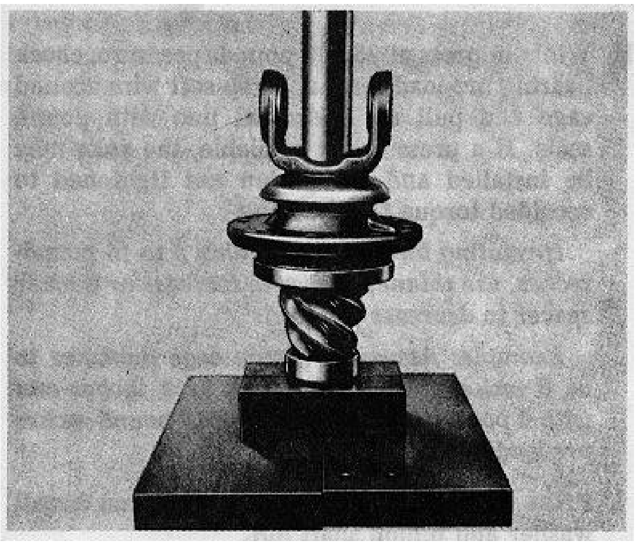
If rotating torque is not within 5 to 15 pound-inches, use thinner spacer to increase or thicker spacer to decrease pre-load.

Example: Assuming pinion cage diameter to be 6 inches the radius would be 3 inches and with 5 pounds pull would equal 15 pound-inches pre-load torque.

I. Press yoke against forward bearing and install washer and pinion shaft nut.
J. Place pinion and cage assembly over carrier studs, hold yoke and tighten pinion shaft nut to specified torque. The yoke must be held with a suitable tool or fixture to tighten nut.
K. Recheck pinion bearing pre-load torque. If rotating torque is not within 5 to 15 pound-inches, repeat the foregoing procedure.
L. Hold yoke and remove pinion shaft nut and yoke.

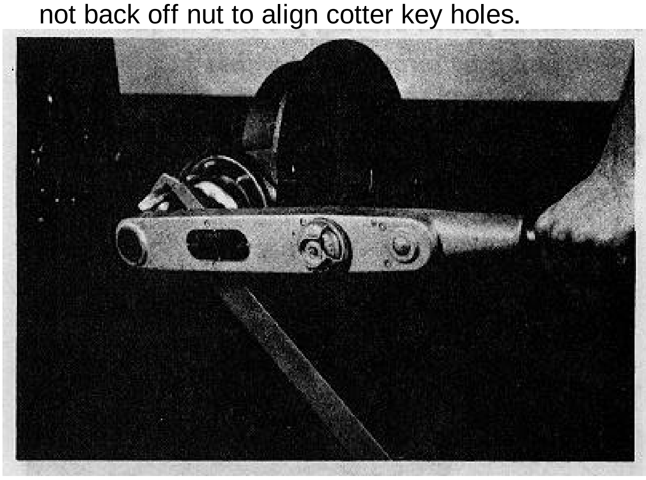


M. Lubricate pinion shaft oil seal and cover outer edge of seal body with a non-hardening sealing compound. Press seal against cover shoulder with seal driver.
N. Install new gasket and bearing cover.



O. Press yoke against forward bearing and install washer and pinion shaft nut.

P. Tighten to specified torque and install cotter key. Do not back off nut to align cotter key holes.



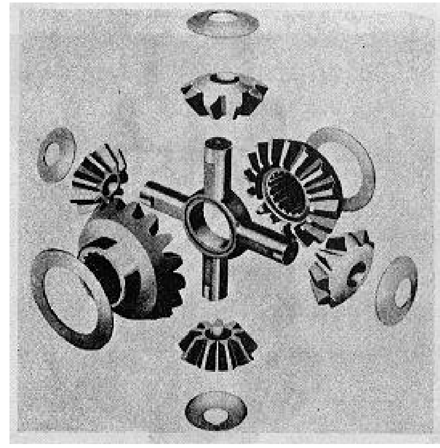
ASSEMBLE DIFFERENTIAL AND BEVEL GEAR

A. Rivet bevel gear to case half with new rivets.

If a new gear or differential case is to be used in the assembly, the rivet holes in the gear and case should be checked for alignment and line reamed if necessary. The gear must be tight on the case pilot and riveted flush with the differential case flange. Check with a .002" feeler gauge.

Rivets should not be heated, but should be up set cold. When the correct rivet and rivet set is used the head being formed will be at least As" larger in diameter than the rivet hole.

The head will then be approximately the same height as the preformed head. The formed head should not exceed /]6t" less than the preformed head as excessive pressure will cause distortion of the case holes and result in gear eccentricity.

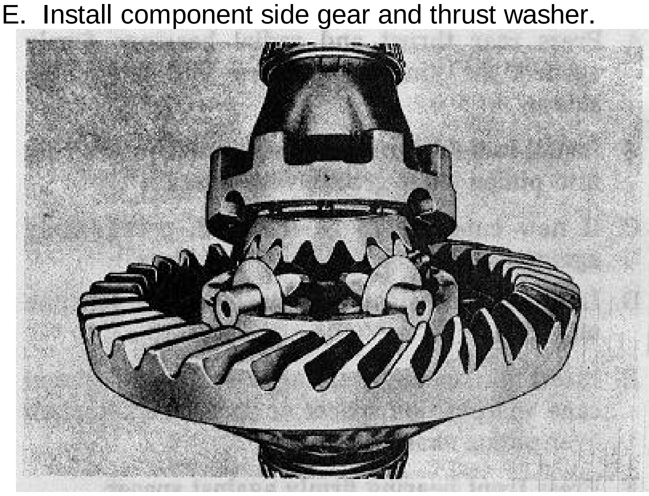


B. Lubricate differential case inner walls and all component parts with axle lubricant.

C. Position thrust washer and side gear in bevel gear and case half assembly.

D. Place spider with pinions and thrust washers in position.

E. Install component side gear and thrust washer.



F. Align mating marks, position component case half and draw assembly together with four bolts or cap screws equally spaced.

G. Check assembly for free rotation of differential gears and correct if necessary.

H. Install remaining bolts or cap screws, tighten to specified torque and thread with lock wire.

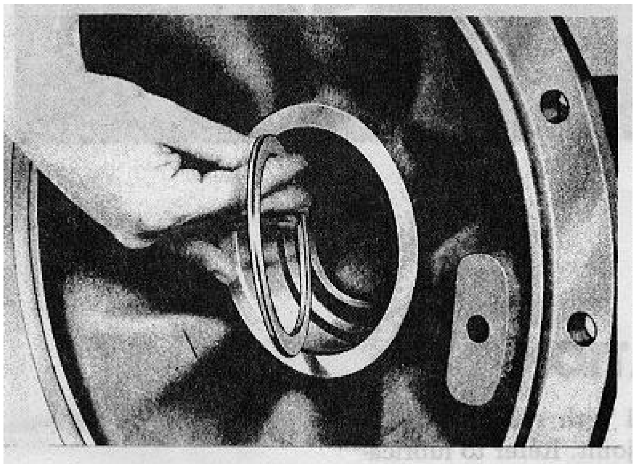
I. If bearings are to be replaced, press squarely and firmly on differential case halves.

DIFFERENTIAL BEARING PRE-LOAD AND GEAR LASH ADJUSTMENTS

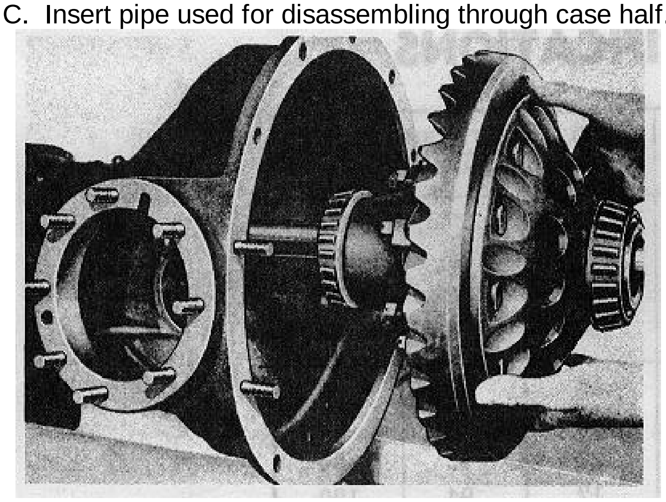
The differential bearing pre-load and gear-lash adjustments are obtained by the use of hardened and ground spacers of the correct thickness located between the differential bearing cups and the axle housing. On this type assembly, no shim pack is required between the pinion cage and axle housing.

ADJUST DIFFERENTIAL BEARING PRE-LOAD

A. Remove thrust block using drift to drive pin out of cover.
B. Install differential bearing spacers in the original positions if new bearing cups are installed.
SPACERS MUST BE INSTALLED WITH THE CHAMFERED EDGE TOWARD THE MACHINED SURFACES IN THE HOUSING.

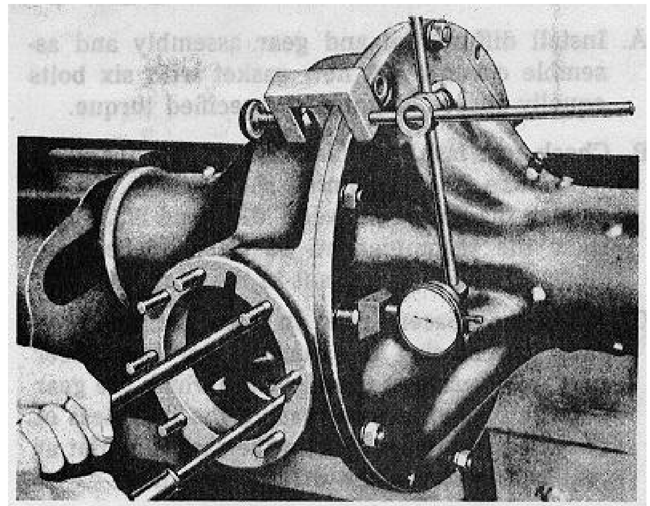


C. Insert pipe used for disassembling through case half.



D. Position differential and gear assembly over pipe with gear facing the case half and slide into position.
E. Install new gasket over case flange.
F. Position cover half over pipe and draw axle halves together with six bolts equally spaced.
G. Check differential and gear assembly end play with dial indicator through thrust block pin hole against gear.

Both the differential bearing pre-load and gear lash are controlled by selective spacers, available in increments of .003", which are installed between the differential bearing cups and the case and cover halves of the axle housing.



Bearing pre-load may be increased or decreased by using a thicker or thinner spacer respectively in the cover half of the assembly.

The gear may be moved toward the pinion, decreasing the gear lash, by decreasing the thickness of the spacer in the case half and increasing the thickness of the spacer by the same amount in the cover half. Reversing this transposition will move the gear away from the pinion and increase the gear lash.

The correct pre-load of .006" to .010" tight is obtained as follows:

1. Increase or decrease the thickness of the spacer used in the COVER HALF to obtain a freely rotating gear with from .000" to .005" end play.
2. Remove spacer in cover half and install a spacer ".006" plus the end play" thicker than the spacer used to obtain the adjustment in the above paragraph.
3. If a new gear or case has been installed, check runout at back face of gear. Correct and recheck if runout exceeds .005".
4. When adjustment is satisfactory, remove cover and move differential and gear out on support sufficient to permit installation of pinion and cage assembly.

H. Install thrust block and pin.

INSTALL PINION AND CAGE ASSEMBLY

A. Coat cage flange contact surface with non-hardening sealing compound. Position cage assembly over studs and tap into position with soft mallet.
B. Install lockwashers and stud nuts. Tighten to specified torque.

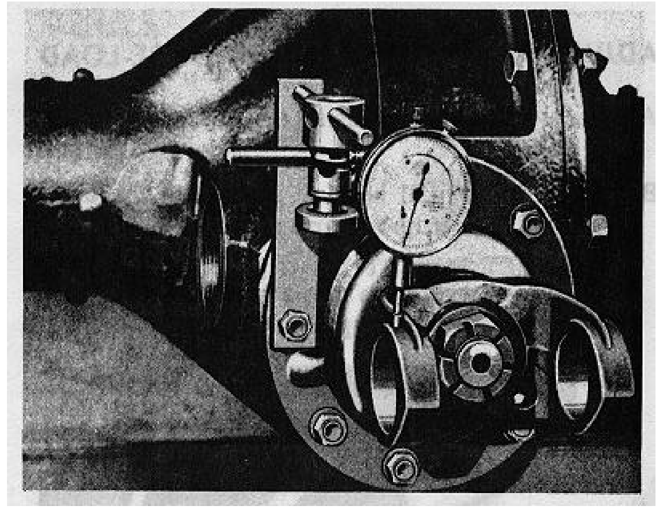
CHECK AND ADJUST GEAR LASH

A. Install differential and gear assembly and assemble cover using new gasket with six bolts equally spaced. Tighten to specified torque.

B. Check gear lash with dial indicator on universal joint yoke 2" from pinion shaft center. An indicator reading of between .013" and .033" will show the recommended backlash of between .006" and .012" is present in the gear set.

C. Transpose spacers used in both the case and cover, decreasing the thickness of the spacer used on the side in the direction which the gear is to be moved and increasing the thickness of the opposite spacer exactly the same amount as required to obtain the correct gear lash.

D. Install remaining bolts, washers and nuts in housing assembly and tighten all nuts in bolt circle to specified torque.



LUBRICATION

Fill axle to correct level with specified lubricant and lubricate universal joint. Refer to lubrication chart on page 15-1.

TORQUE SPECIFICATIONS

LOCATION	DIAMETER	NO. THREADS	TORQUE-LB. -- FT. Min.	Max.
Cover to case bolt nuts	3/8"	16	27	35
	3/8"	24	31	39
	7/16"	20	42	54
	1/2"	20	75	96
Pinion cage cap screws	3/8"	16	27	35
and stud nuts	3/8"	24	31	39
	7/16"	20	42	54
	9/16"	12	94	120
Differential case bolt nuts	3/8"	16	33	43
and cap screws	1/2"	13	81	104
	1/2"	20	92	118
Pinion shaft nuts	7/8"	20	175	200
	1"	20	300	400
Gear to case cap screws	3/8"	24	38	49

Torques given apply to parts coated with machine oil; for dry (or "as received") parts increase torques 10%; for parts coated with multi-purpose gear oil decrease torques 10%. Nuts on studs to use same torque as for driving the stud.

SUBSECTION 5 REAR AXLE ASSEMBLY AND FINAL DRIVE

GENERAL

The rear axle assembly is a single unit type, with attached two-speed nose box and planetary final wheel reduction drives. Tapered roll bearings are used at all bearing locations except drive pinion shaft end bearing and differential pinion gears. A straight roller bearing is used on the end of drive pinion shaft. A plain type bearing formed by spider and pinion surfaces is used on all differential pinions.

PREPARE FOR REMOVAL

Completely assembled axles may be steam cleaned on the outside only, to facilitate initial removal and disassembly, providing all openings are closed. Breathers, vented shift units, and all other openings should be tightly covered or closed to prevent the possibility of water entering the assembly.

REMOVAL

There are two types of repair procedures for rear axle unit assembly. One requires the complete removal of the rear axle from the machine, while the other only requires a removal of the cover half or left section of the unit. It is recommended that the easier of the two removals be attempted and after inspection of parts removed, the entire unit removal can be decided upon.

a. Complete Rear Axle Removal
   1. Raise and support the rear of machine with a dolly or a support under the rear section of machine frame so the tires clear the surface. Lower the hydraulic crane completely.
   2. Drain the lubricant from rear axle assembly including final drives.
   3. Remove the rear wheels and tires from machine.
   4. Remove the rear fenders.
   5. From above, remove the operator's platform and fuel tank tool box assembly.
   6. Remove hydrostatic motor from nose box.
   7. Disconnect the hydraulic brake lines at the wheel cylinders.
   8. Remove the four "U" bolts holding rear axle to machine frame. Disconnect shift linkage at the nose box. Also remove nose box hold-down bolts holding nose box to cross member.
   9. Attach an overhead crane with chain sling to rear axle assembly.
   10. With the use of a chain hoist, lift and manipulate axle from frame.
   11. The installation is the reverse of above procedure.

b. Removal of rear axle assembly left section or cover half. (For repairs not involving ring gear and pinion.)
   1. Raise and support the rear of machine with a dolly or suitable support under the rear section of machine frame, so the tires clear the surface. Lower hydraulic crane completely.
   2. Drain the lubricant from the axle and final drives.
   3. Remove the rear wheels and tires from machine.
   4. Remove the left rear fender.
   5. Remove the four bolts and nuts holding left axle shaft housing to machine frame.
   6. Remove left wheel hydraulic brake line at wheel cylinder.
   7. Remove eight nuts and lock washers from axle housing flange side of final drive case cover, left and right side and remove final drive and axle shaft assemblies.
   8. Insert a pipe or shaft slightly smaller in diameter than the splined shaft end of the axle shaft about 1.5" diameter and about 6 feet long through axle shaft housing and into differential carrier from the housing (right side) side of axle. This is to support the differential assembly when the axle cover side (left side) is removed.
   9. Remove the bolts and nuts and two cap screws holding the two axle housings together.
   10. Separate the two housings and remove the cover, (left) housing from machine.
   11. With the pipe or shaft previously installed to support the differential assembly, remove same.
   12. The installation is reverse of above procedure. Use new gaskets at axle housing halves and between axle shaft housing and final drive.

c. Final drive disassembly and repair procedures.

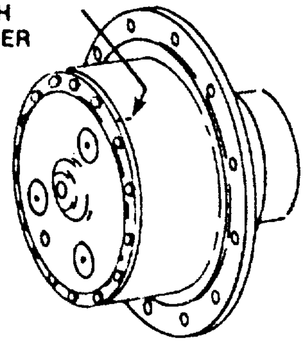
PREPARE FOR DISASSEMBLY

Before starting the disassembly of the axle, the following procedure and precautions should be taken:

a. Jack up both ends of axle so that tires clear the ground. Due to the extreme weight of vehicles under which planetary type axles are used, the axle should then be blocked up under each spring seat to safely support the weight and hold axle at this level. The jacks may then be removed to provide adequate working space with no danger of axle end falling or shifting.
b. Remove the wheel nuts.
c. Remove the tire and wheel.
d. Rotate hub assembly so that the drain plug is at the bottom.
e. Remove the plug and drain lubricant.

REMOVE PLANETARY SPIDER ASSEMBLY

A. Before disassembly match mark the spider and wheel hub for identification of correct alignment when reassembling. Use a punch and hammer and mark both parts on the outer diameter.



B. Remove the planetary spider to hub capscrews or nuts and washers.
C. Pull the planetary spider assembly from the wheel hub and set it on a bench, flange side down.

NOTE: The adhesive effect of the liquid gasket material may necessitate the use of the pry bar slots provided in some models to assist In loosening the spider. If there are no pry bar slots break the spider loose from the hub by striking it with a rawhide mallet.

DISASSEMBLE PLANETARY SPIDER ASSEMBLY

A. Remove the set screws holding the planet pins in the spider. Set screws are located at small diameter ends of pins.
B. Support the spider assembly in a press, flange side down. Block up as required. To avoid damaging the pins place a block of wood under the press to cushion the pins as they are pressed out. Press the planet pins out through the spider and planet gears.

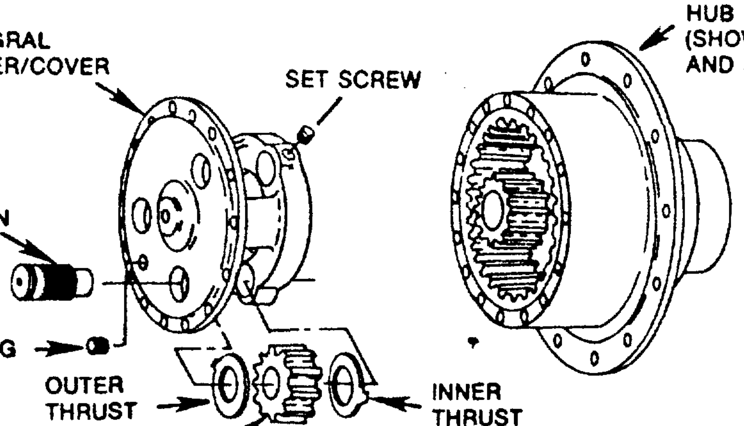
NOTE

If a press is not available use a brass drift and mallet to tap out the pins.

WARNING

Do not strike planet pins directly with a steel hammer as eye injury or damage to parts could result.

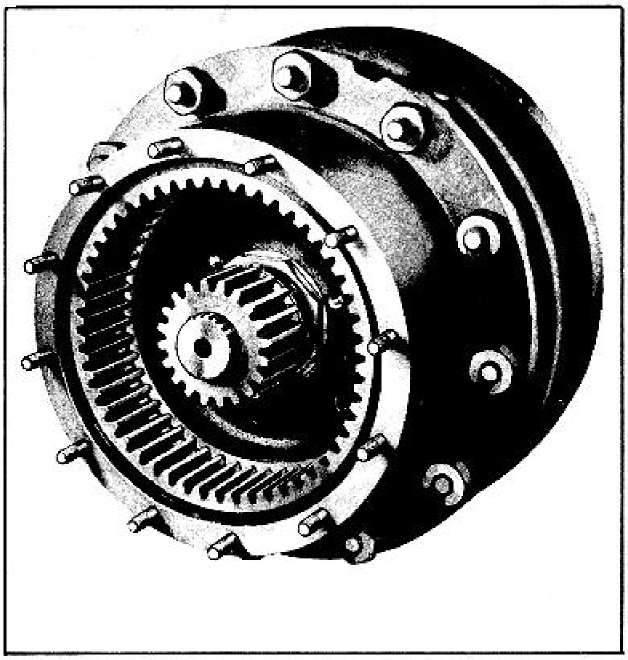
C. Remove the planet gears and thrust washers from the spider.



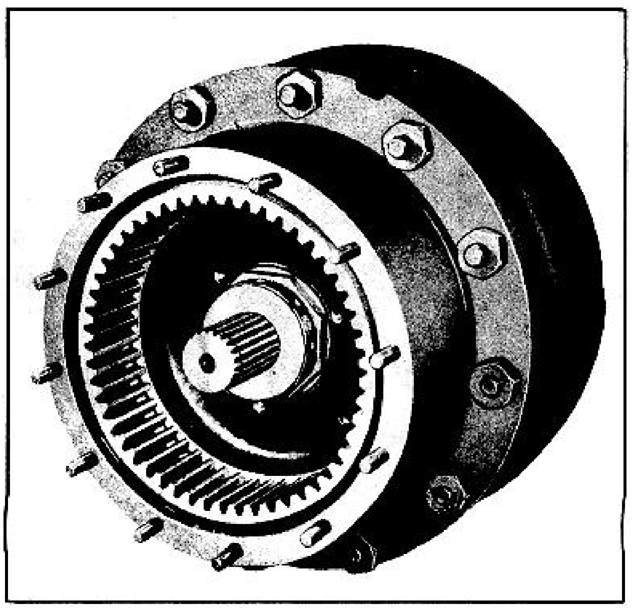
TYPICAL PLANETARY WHEEL END WITH INTEGRAL PLANETARY SPIDER AND COVER

TYPICAL PLANETARY WHEEL END WITH INTEGRAL PLANETARY SPIDER AND COVER

REMOVE THE FLOATING RING GEAR ASSEMBLY



a. Remove the lock ring from end of axle shaft.



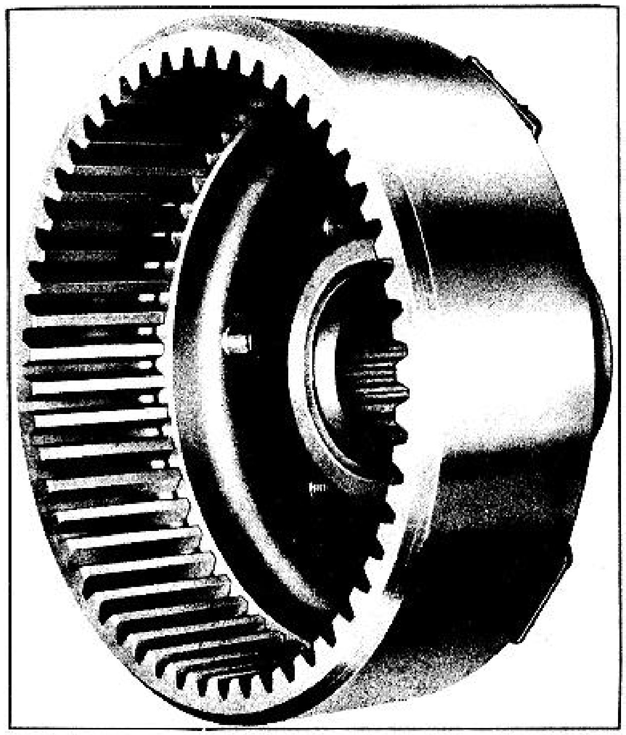
b. Remove the axle shaft sun gear.

c. Remove the sun gear thrust washer.

d. Remove the axle shaft.

e. Remove the wheel bearing adjusting nut lock, by removing the two capscrews and lock plate.

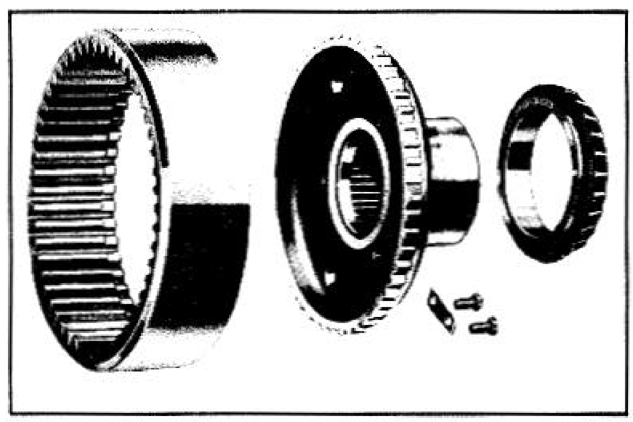
f. Remove the wheel bearing adjusting nut.



g. Remove the floating ring gear assembly. Puller screw holes are provided in the ring gear hub flange to start gear.

1. The floating ring gear is splined to the ring gear hub and secured by four evenly spaced plates, each plate being attached by two cap screws which are lockwired together.

2. The outer wheel bearing is mounted on the ring gear hub.



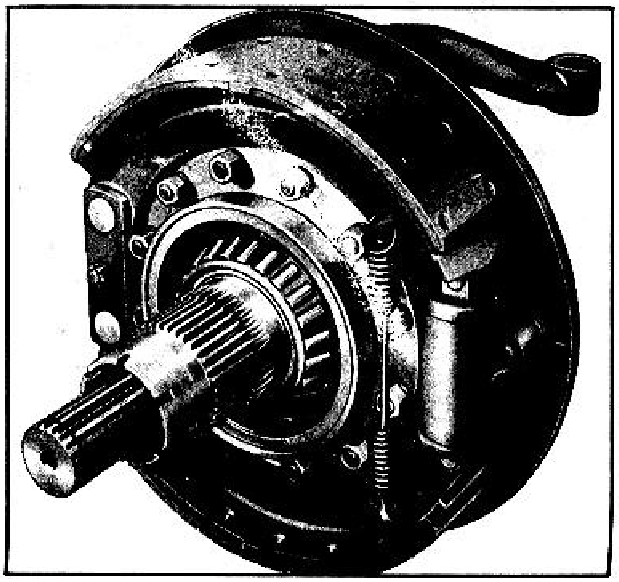
h. Separate the ring gear and ring gear hub by removing lock wire, cap screws and plates.

i. Remove outer wheel bearing from ring gear hub.

j. The ring gear hub assembly is made up of the hub and a hardened ring sleeve insert which is pressed into the hub from the outer side.

DISASSEMBLE BRAKE SHOE AND LINER ASSEMBLY

The complete disassembly of the brakes is not necessary for the removal of the hub spindle. Adequate working clearance is provided by only removing the brake shoe return spring.



PREPARE FOR ASSEMBLY

All parts should be cleaned, inspected and repaired where necessary before reassembly. Refer to the Cleaning, Inspection and Repair instructions on page 5-8.

INSTALL BRAKE ASSEMBLIES

If the brakes were removed during the wheel end disassembly follow the procedures below:

a. Install brake cylinder and push rods.

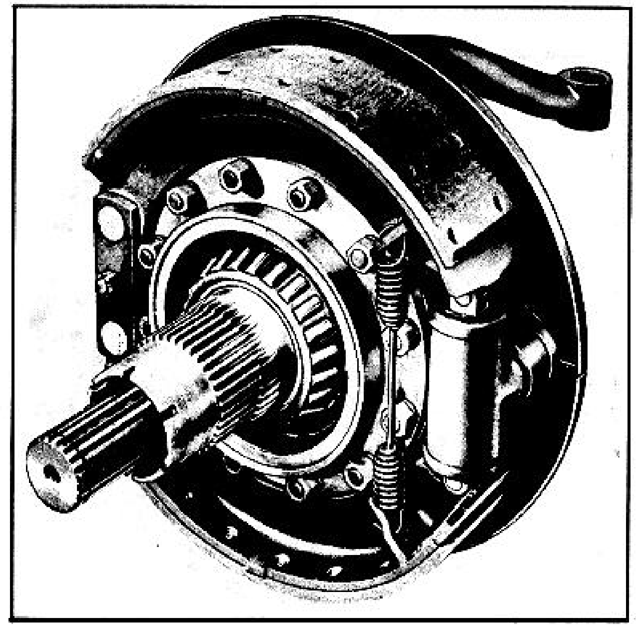
b. Install brake shoe and liner assemblies over anchor pins.

c. Install anchor pin plate, nut and cotter key.

d. Align push rods with shoe webs and hook brake shoe return spring.

e. For further detailed information, consult the "H" Series Brakes section on page 3-1.

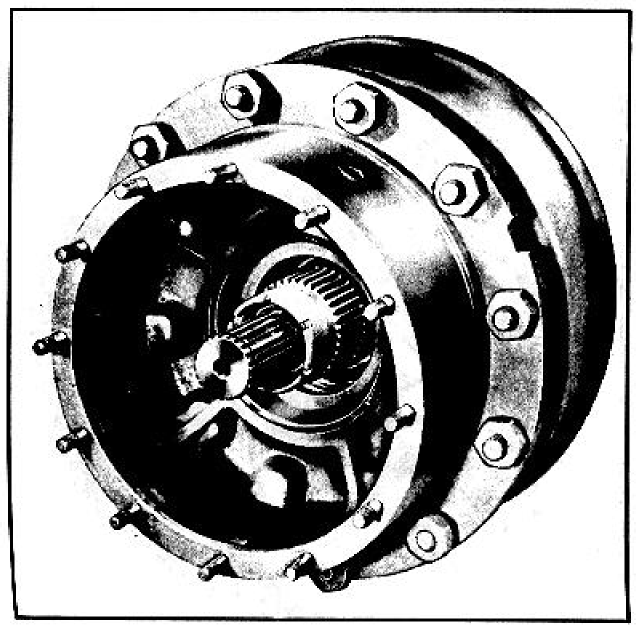
If hub bearings cups have been removed for replacement, install new cups with a suitable driving sleeve.



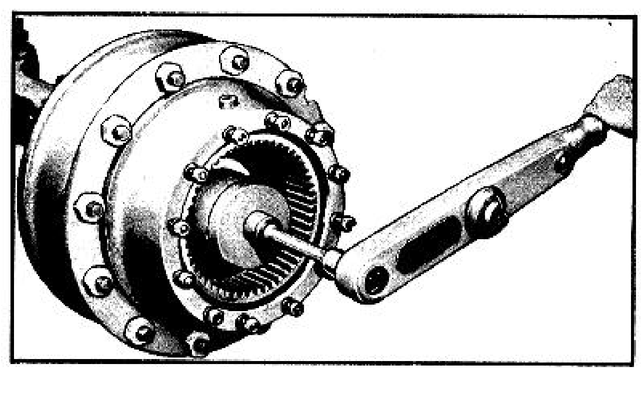
ASSEMBLE HUB AND DRUM ASSEMBLY AND INSTALL

a. Lift the hub and drum assembly onto the hub spindle and position so that the inner cup rests on the inner bearing rolls.

b. Install the floating ring gear assembly, while at the same time lifting the weight of the hub and drum assembly to allow the outer bearing to mate with outer hub bearing cup.



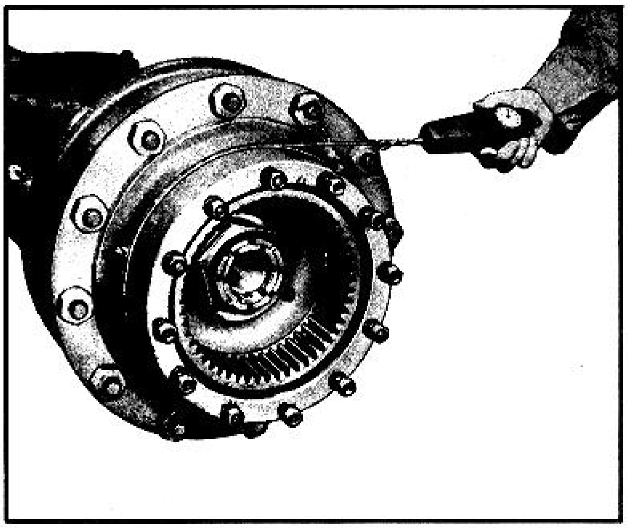
c. Install the wheel bearing adjusting nut.



WHEEL BEARING ADJUSTMENT

a. Tighten the adjusting nut against the ring gear hub to 100 pound feet while wheel is being rotated. Rotate the wheel in both directions to make sure bearings and related parts are fully seated.

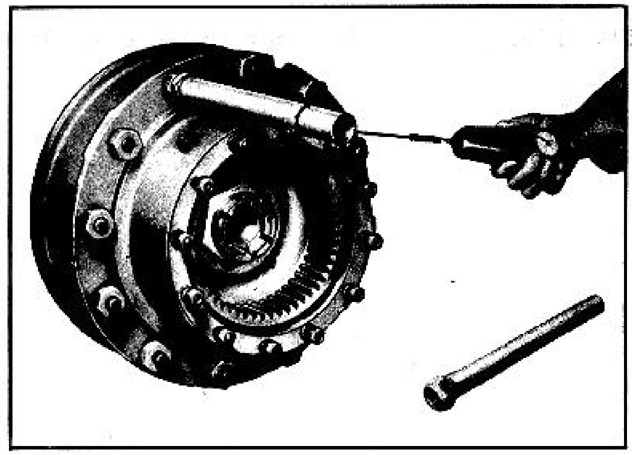
b. Back off adjusting nut / turn to relieve pre-load on bearings.



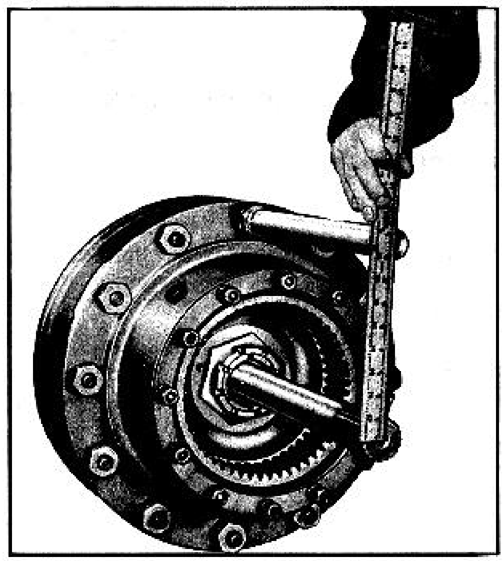
c. If wheel bearings have been replaced with new bearings, check the rotating torque (not starting torque) by means of a pull scale and cord and advance the adjusting nut in small increments until the proper preload is obtained. The proper preload torque is 5 to 9 lb. ft.

NOTE

The above torque specification allows for the drag of the hub spindle oil seal. However, if a felt dust seal is used in the inside of the brake drum, the torque specifications should be increased by 5 lb. It. If wheel bearings are being reused, they should be put back in same position as before. Advance the adjusting nut in small increments and check rotating torque until an increase is noted. If increase is slight, install nut lock in this position or back off nut enough to install nut lock. If increase is appreciable, back off nut until increase is only slight or none and then install nut lock, with two capscrews and lock plate.



d. If it is not convenient to remove the wheels of the vehicle, check the wheel bearing preload torque. The extension (see inset) permits a reading to be taken without interference from the tire.

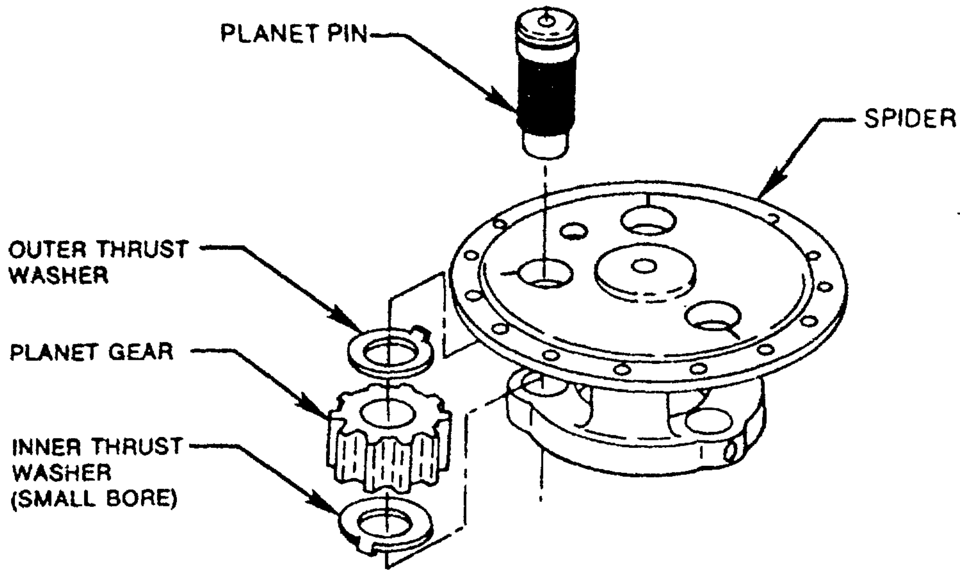


e. Bearing preload torque is figured by multiplying the radius (the distance from the center of the wheel to the center of the extension) by the reading on the pound scale.

For Example: Assume the distance from the center of the wheel to the center of the extension is 9 inches and the reading on the pound scale is 7 pounds - multiplying 9 inches by 7 pounds, we get 63 pound inches. Since our preload specifications are listed in *pound feet*, we simply divide the 63 pound inches by 12 and arrive at a reading of 5.25 pound feet.

This method of converting pound inches to pound feet also applies to Step "c" above.

REASSEMBLE PLANETARY SPIDER ASSEMBLY



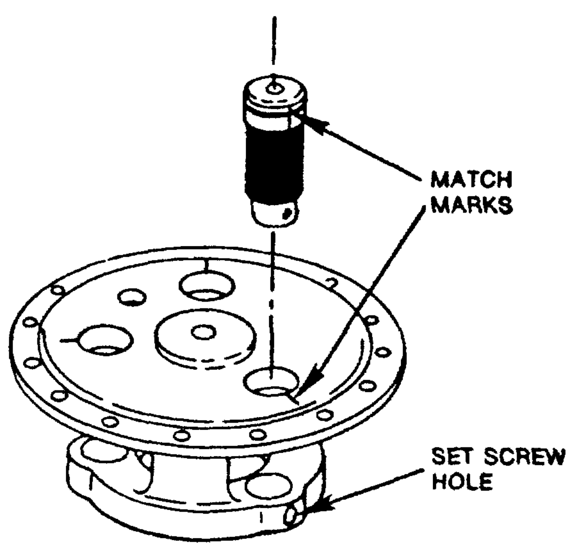
A. Place the spider in a press with the flange side up. Block up as required.

B. Install inner thrust washer with the rasher tab engaged in the spider indent and the washer bore aligned with the spider bore.

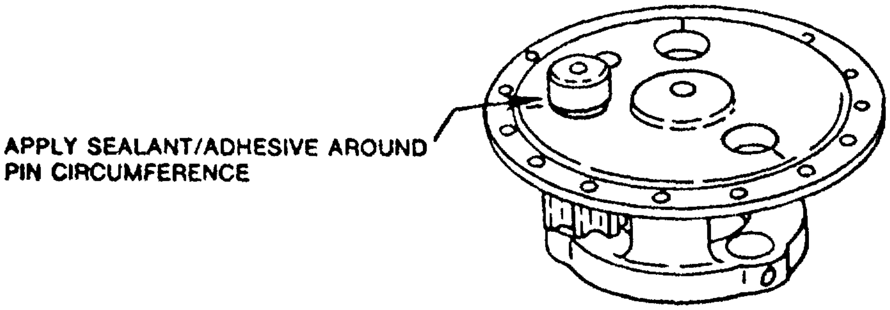
C. Coat the bore of the planet gear with a film of the same GL-5 gear lube used in the wheel end. Slide planet gear and outer thrust washer into the spider. Align the bores of the parts and engage the outer thrust washer tab in the spider Indent.

D. Install the planet pin into the spider and through the planet gear and thrust washers by hand. The large end of the planet pin will bind in the spider bore due to an Interference fit.

E. Align the small mark on the pin large diameter with the mark on the spider. These match marks are pre-stamped into the parts to provide proper alignment of the set screw hole in the small end of the pin and the tapped set screw hole in the spider boss



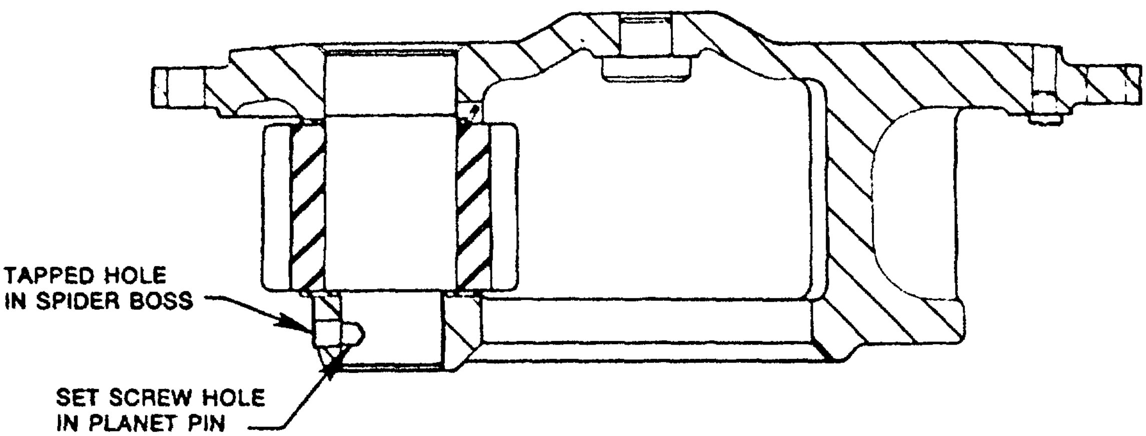
F. Brush Loctite 271 (Rockwell Part No. 11990B-3720) sealant/adhesive on the planet pin O.D. protruding from the cover.



G. Being careful to keep match marks aligned, press the planet pin into the spider until the shoulder of the pin bottoms against the Inner thrust washer.

NOTE: It a press Is not available use a brass drift and mallet to tap the pin through the spider and planet gear.

WARNING: Do not strike planet pins directly with a steel hammer as eye injury or damage to parts could result.



H. Install set screw Into spider and planet pin. New set screws, if used, have pre-applied locking agent on the threads. If original set screws are used, apply one or two drops of Loctite 277 (Rockwell Part No. 2297-C-3747) to threads of spider before installing. Tighten set screw to 15-25 lb. ft. torque.

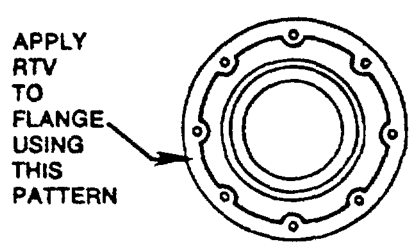
I. Repeat the reassembly procedures to install the second and third sets of pins, washers and gears.

INSTALL PLANETARY SPIDER ASSEMBLY

A. Apply a bead of silicone RTV gasket material (approximately 3/32' diameter) to the mounting flange of the planetary spider.

NOTE: Where silicone RTV gasket material is used, Dow Silastic No. RTV-732 Black and General Electric No. RTV-1473 Black meet our requirement. However, silicone RTV is also available in bulk under Rockwell Part No. 1199-Q-2911; In 10 OL tubes, part number 1250-X-388; or in 3 oz. tubes, part number 1199-T-3842

The bead of RTV gasket material must always be around the Inner side of the flange holes (between holes and spider pilots The spider assembly must be Installed in hub within 30 minutes of liquid gasket application.



TWO SPEED NOSE BOX TRANSMISSION

GENERAL

The two speed nose box transmission is attached to the front of the traction drive axle. It provides a gear reduction of 5.938:1 in the low range. In the high range the ratio is 1:1 with the transmission of power being direct from the hydrostatic motor to the traction drive axle.

DISASSEMBLY

1. Drain oil - position with input up.
2. Remove transmission dowels and capscrews.
3. Remove shift shaft (17) detent plug.
4. Remove transmission cover (33).

NOTE: Assembled position of clutch shift collar; the tapered portion of collar is toward low speed driven gear.

5. Remove idler gear assembly (7), (8), (9).
6. Remove shift shaft (17) and fork assembly (19) with clutch shift collar (36).

NOTE: Clutch shift collar may have lockup type feature which may require alignment of clutch teeth to remove.

7. Remove three each clutch detent balls (39) and springs (38) from clutch pinion (37).
8. To remove low speed driven gear (42) or clutch pinion (37), locate and remove set screw (40) from clutch
   pinion (37).
9. Remove clutch drive pinion retaining nut (35) (1-7/8" socket required).
10. Remove clutch drive pinion (37).
11. Remove low speed driven gear (42), this allows access to the bevel pinion bearing oil seal (43), and transmission case to differential carrier capscrews (44).
12. Disassemble input drive pinion (34) and motor adapter (28).
    A. Remove input motor adapter to transmission cover stud nuts (29).
    B. Unlock locking tab (24) at input drive pinion bearing adjusting nut (23).
    C. Remove input drive pinion nut (23), nut lock (24) and washer (25).
    D. Remove input drive pinion (34), keep bearing cups and cones paired.
13. To remove bevel pinion or transmission case, will require disassembly of differential carrier.

Refer to Drive Unit disassembly instructions on page 5-1.

CLEANING

Refer to Drive Unit cleaning instructions on page 5-12.

INSPECTION

It is impossible to overstress the importance of careful and thorough inspection of drive unit parts prior to reassembly. Thorough visual inspection for indications of wear or stress, and the replacement of such parts as are necessary will climinate costly and avoidable drive unit failure.

A. Inspect all bearings, cups and cones, including those not removed from parts of the drive unit and replace if rollers or cups are pitted or damaged in any way. Remove parts needing replacement with a suitable puller or in a press with sleeves.

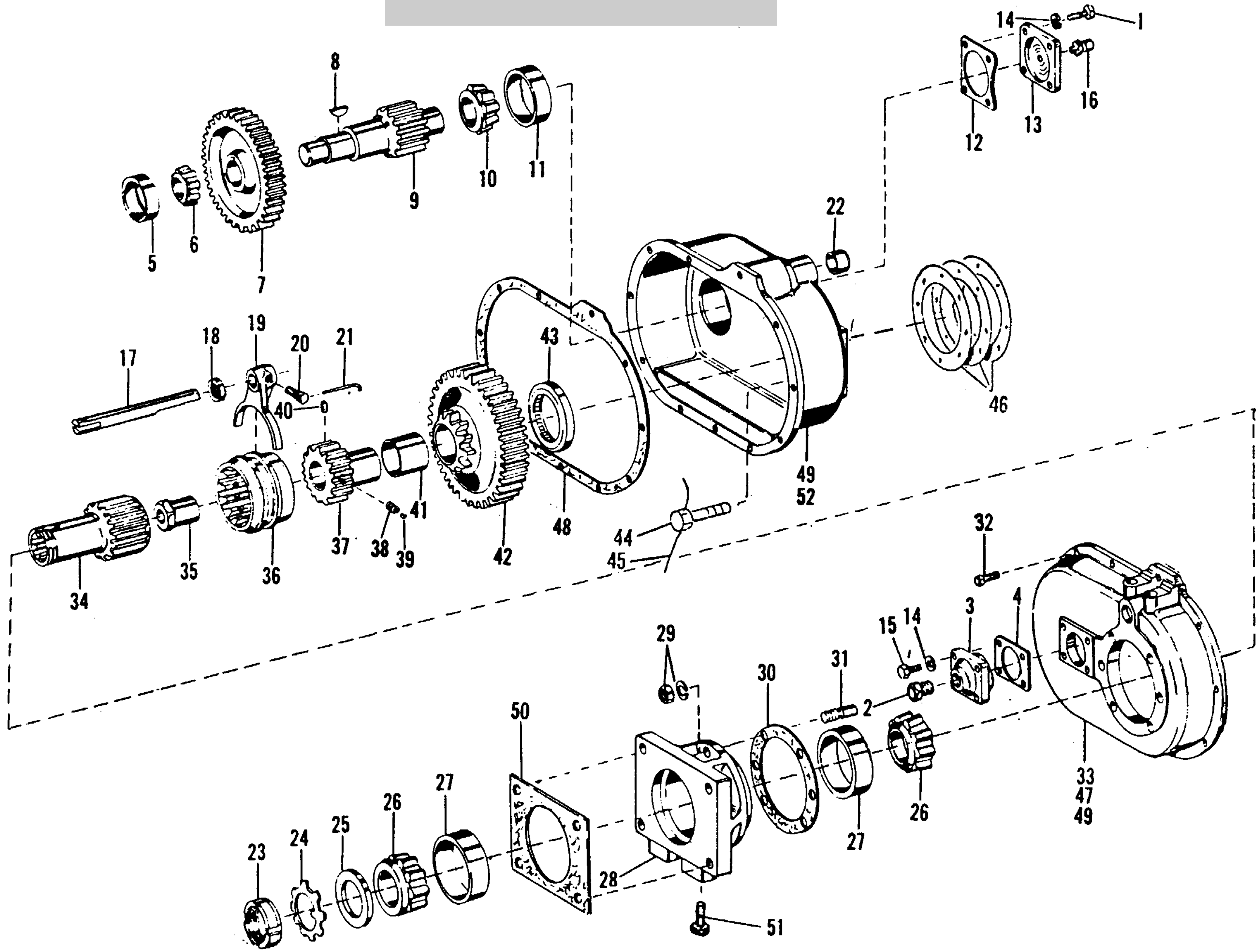
   Avoid the use of drifts and hammers. They may easily mutilate or distort component parts.
B. Inspect shift shaft, shift fork, shift clutch collar, and clutch pinion. Replace if clutch engagement teeth are worn, chipped or mutilated.
C. Inspect spur gears for wear or damage. Gears which are pitted, galled or worn or broken through case hardening should be replaced. Inspect bushings for wear or scoring.
D. Inspect clutch engagement teeth of input drive pinion and low speed spur gear. Replace if worn, chipped or mutilated.
E. Inspect internal spline of input drive pinion for wear or damage.

REPAIR

A. Replace all worn or damaged parts. Hex nuts with rounded corners, all lock washers, oil seals and gaskets should be replaced at the time of overhaul.

   Use only genuine Rockwell-Standard parts for satisfactory service. For example, using gaskets of foreign material generally leads to mechanical trouble due to variations in thickness and the inability of certain materials to withstand compression, oil, etc.
B. Remove nicks, mars and burrs from machined or ground surfaces. Threads must be clean and free to obtain accurate adjustment and correct torque. A fine mill file or India stone is suitable for this purpose. Studs must be tight prior to reassembling the parts.
C. When assembling component parts use a press where necessary. Avoid hammering.
D. Tighten all nuts to specified torque. See torque limits following service instructions.

TWO SPEED NOSE BOX TRANSMISSION



Lock wire must not be brittle; use soft iron wire to prevent possibility of wire breakage.

ASSEMBLY

NOTE.: Use non-hardening type sealer on all gaskets, oil seal bores and capscrew threads.

1. Input Drive Pinion (New cups and cones).
   A. Press bearing cups (27) into cup bores of hydraulic motor adapter (28) until seated firmly against shoulders of motor adapter.
   B. Press inner bearing cone (26) to shoulder of input drive pinion (34).
   C. Assemble motor adapter (28) to input drive pinion (34).
   D. Assemble outer bearing cone (26), input bearing washer (25), adjusting hut lock (24), and adjusting nut (23).
   E. Tighten adjusting nut (23) until rotating torque is 5 to 15 pound-inches. To check torque, wrap soft wire around cage or pilot portion of motor adapter, and pull on horizontal line with pound scale.

      EXAMPLE: Assuming cage diameter to be 6 inches the radius would be 3 inches and with 5 pounds pull would equal 15 pound-inches pre-load torque.
   F. With bearing preload adjusted to 5 to 15 pound-inch pre-load, lock adjusting nut (23) with locking tab of adjusting nut lock (24).
2. Adjusting Idler Shaft Bearings.
   A. With bearing cups and cones pressed to position for idler shift (9), install idler shaft into transmission case (49).
   B. With case to cover gasket (48) in position, install transmission cover (33) using about 6 case to cover bolts. (49-53 pound ft. torque).
   C. Increase or decrease shims (4) at idler shaft bearing cap (3) to obtain .000" to .003" loose bearing adjustment. Rotate idler shaft to assure proper bearing contact.
   D. After adjusting idler shaft bearings, remove bolts, cover and idler shaft.
3. Assemble Low Speed Driven Gear.
   A. Case capscrews torqued to 138 to 160 pound ft. and lockwired with soft-iron type wire.
   B. Wipe oil seal journal with film of grease or oil. Coat bronze bushing (41) of low speed gear (42) will gear oil.
   C. Assemble gear to bevel pinion oil seal (43), using care not to damage oil seal.
   D. Assemble pinion clutch (37) to bevel pinion spline.
   E. Assemble and tighten clutch and drive pinion nut (35) 300 to 500 pounds ft. torque.
   F. Low speed driven gear (42) should be checked for side journal clearance. Check with dial indicator or feeler gauge between mating thrust surfaces should have .008" to .012" clearance.
   G. Tighten drive pinion nut setscrew (40) and stake. Set- screw is located in pinion clutch (37).
4. Shifting Assembly.
   A. Shift fork and shifter shaft lockscrew (20) should be tight and lockwired with soft-iron type lockwire. Lockscrew torque 69-73 pounds ft.
   B. Assemble detent springs (38) and balls (39) to clutch pinion (37), apply grease to assist in retaining balls in position.
   C. Assemble clutch shift collar to shift fork. NOTE: The tapered portion of the shift collar is toward the low speed driven gear.
   D. Assemble shift collar (36) and fork (19) to clutch pinion (37), compressing detent springs and balls and entering the shift shaft into shaft bore of transmission case.
5. Complete Assembly.
   A. Install idler shaft assembly (7), (8), (9) into position in transmission case.
   B. Assemble transmission cover gasket (48), cover (33), cover to case dowels and cover to case bolts, lockwashers and nuts. Torque bolts 49-53 pounds ft.
   C. Assemble hydraulic motor adapter (28) and gasket (30) to transmission cover. Assemble stud lockwashers and nuts, torque nuts 106-113 pounds ft.
   D. Using suitable sleeve type driver, assemble shift shaft oil seal (18).
   E. Shift transmission and manually rotate transmission input to determine if shifts are completed.

TRACTION DRIVE AXLE

GENERAL

The Rockwell-Standard Company Unit-Type Housing Drive Unit is a single-reduction drive of hypoid design. The differential and gear assembly is mounted on tapered roller bearings with the cups assembled in the case and cover halves of the housing. The straddle mounted pinion has two tapered roller bearings located forward of the pinion teeth and a radial bearing at the inner end.

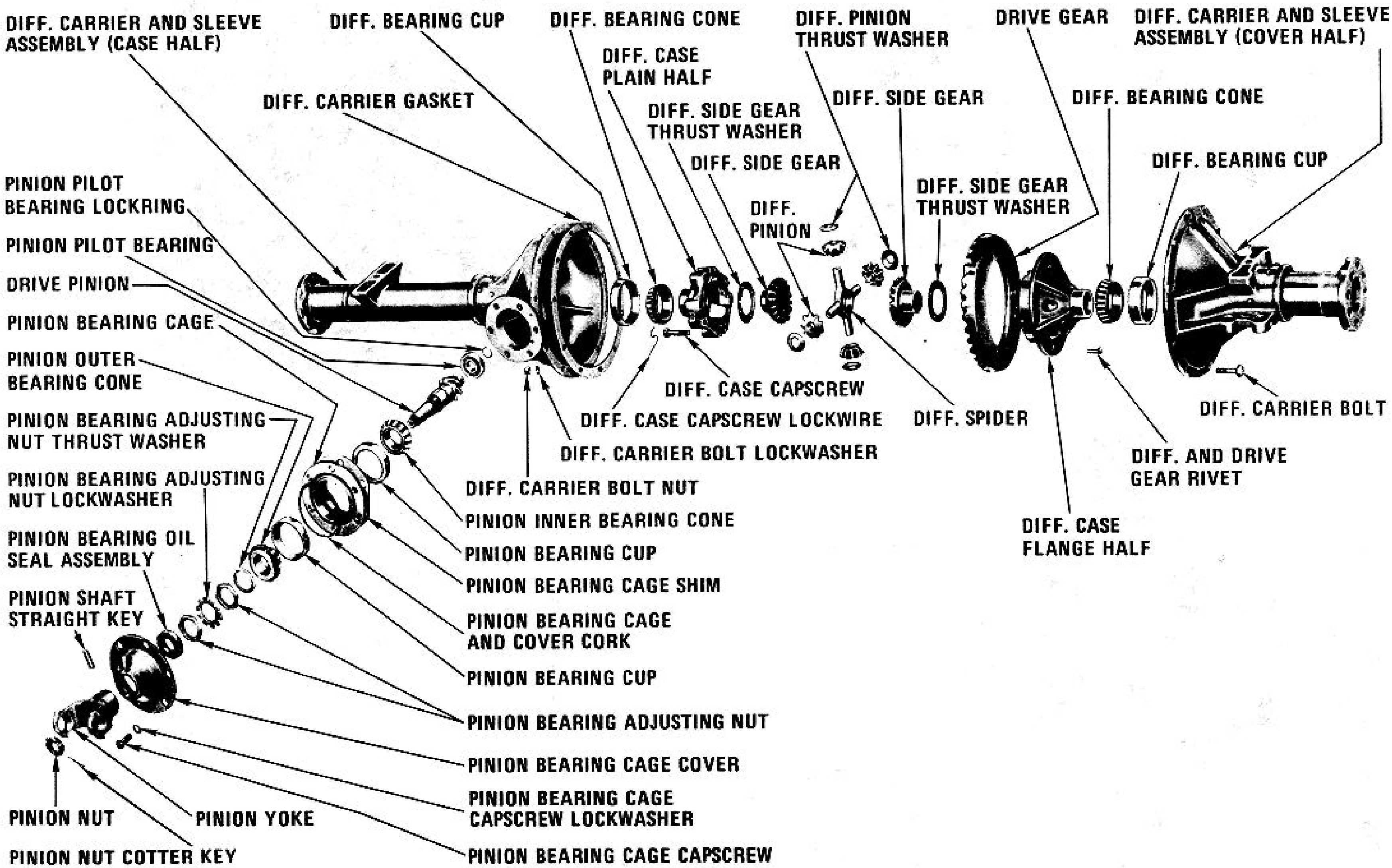
The pinion shaft is splined to accommodate the flange and the bearing pre-load controlled by hardened and ground spacers of the correct thickness between the bearings. Bearings are retained in position by the companion flange nut.

DISASSEMBLE AXLE

A. Before disassembling, place length of pipe or suitable support, slightly smaller than axle shaft splines, approximately two-thirds through axle from the case side to prevent dropping the differential assembly.
B. Remove bolts, nuts and washers from case and cover and remove cover half.
C. Remove differential and gear assembly.
D. Remove pipe.

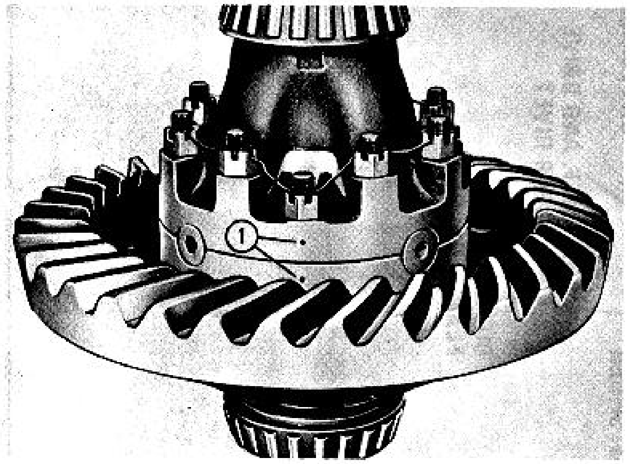
EXPLOSION VIEW OF UNIT TYPE HOUSING DRIVE AXLE

TRACTION DRIVE AXLE



DISASSEMBLE DRIVE UNIT

DISASSEMBLE DIFFERENTIAL AND GEAR ASSEMBLY

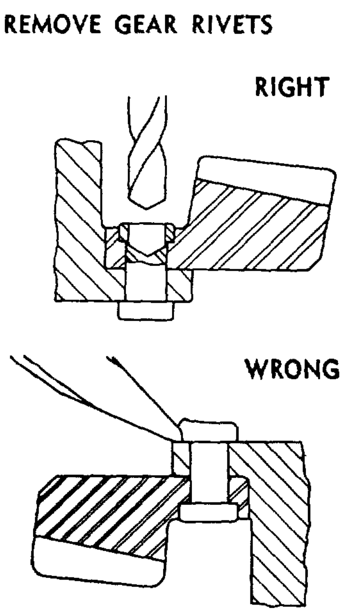


A. If original identification marks are not clear, mark differential case halves with a punch or chisel (as shown in photograph above) before disassembling, for correct alignment when reassembling.

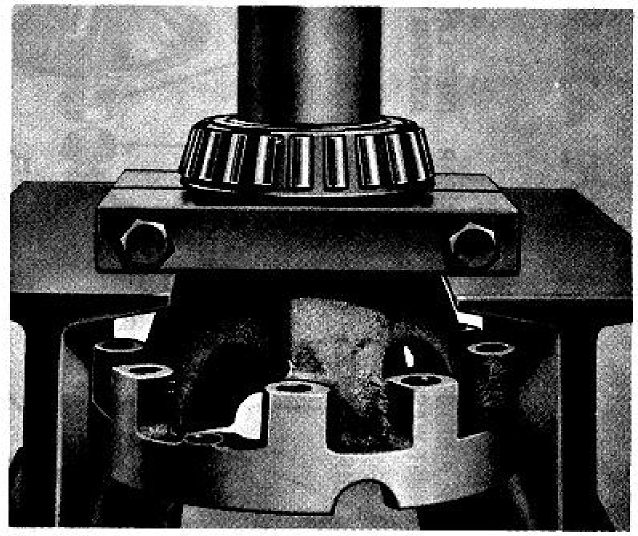
B. Cut lock wire, remove bolts or cap screws and separate case halves.

C. Remove spider, pinions, side gears and thrust washers.

D. Remove rivets and separate gear and case if required.



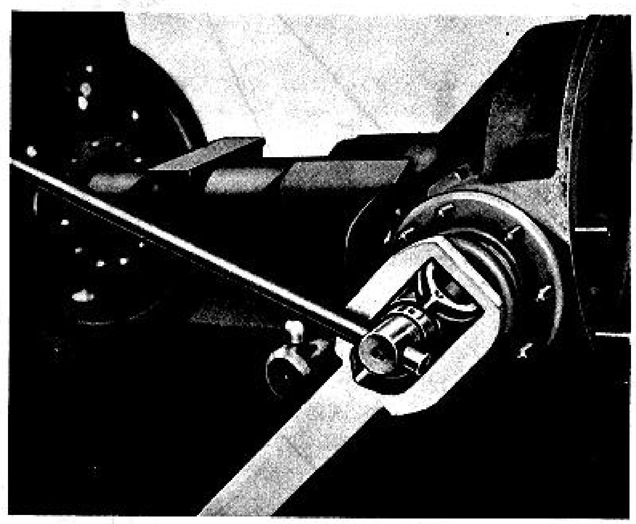
1. Carefully centerpunch rivets in center of head.
2. Use drill '1,2t" smaller than body of rivet to drill through head.
3. Press out rivets.



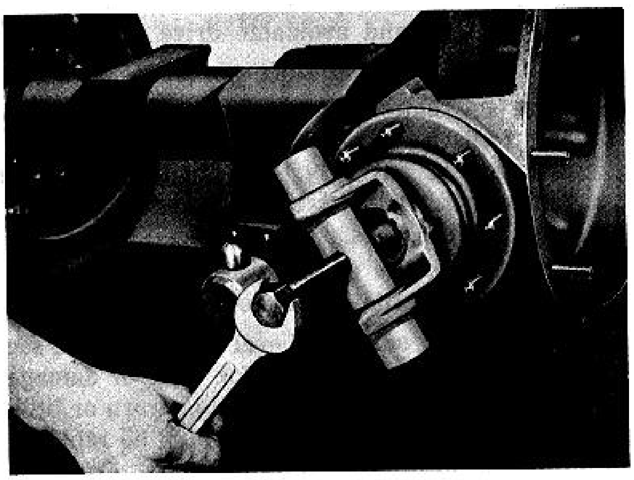
E. Remove differential bearings with bearing puller if necessary to replace.

REMOVE PINION AND CAGE ASSEMBLY

The differential and gear assembly must be removed before the pinion and cage assembly can be disassembled.

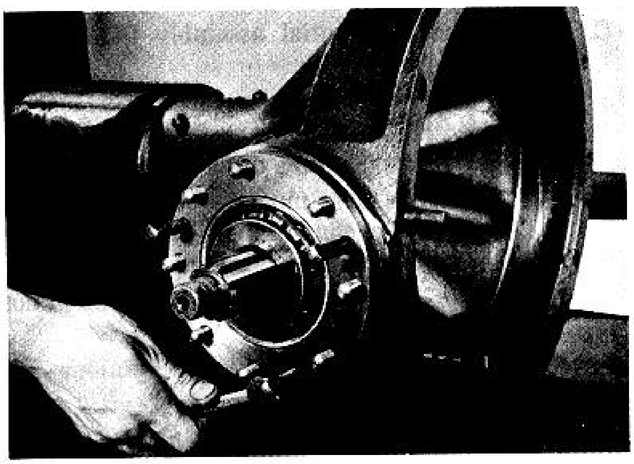


A. Secure yoke with holding tool and remove pinion shaft nut and washer.



B. Insert puller through yoke and remove.

C. Remove pinion bearing cover and oil seal assembly.



D. Remove pinion and cage assembly using puller screws in holes provided.

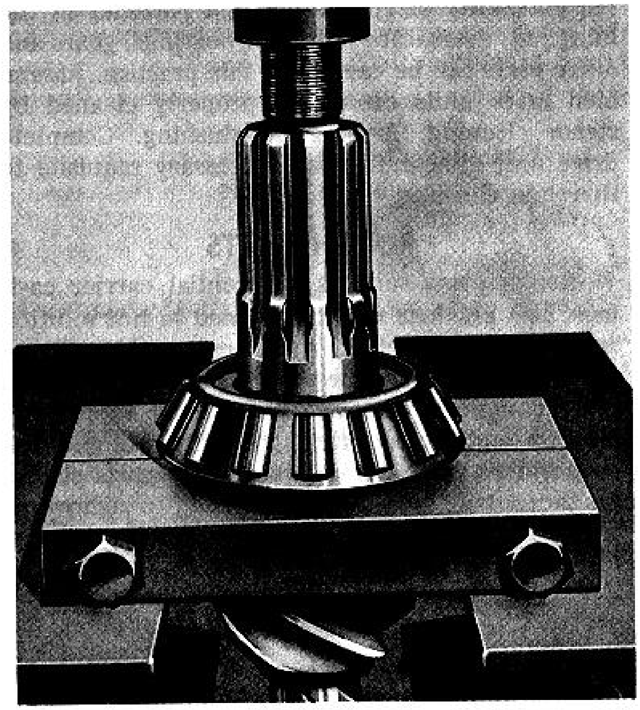
Driving pinion from inner end with a drift will damage the bearing lock ring groove.

DISASSEMBLE PINION AND CAGE ASSEMBLY

A. Tap shaft from cage with soft mallet or press shaft from cage.

B. Remove outer bearing from cage.

C. Remove spacer or spacer combination from pinion shaft.



D. Remove rear thrust bearing and radial bearing with bearing puller if necessary to replace.

E. Remove oil seal assembly from bearing cover.

F. IF NECESSARY TO REMOVE DIFFERENTIAL BEARING CUPS, WIRE THE SELECTIVE SPACERS WHICH ARE BEHIND THE CUPS TO THEIR RESPECTIVE AXLE HALVES.

PREPARE FOR REASSEMBLY

CLEAN

Parts having ground and polished surfaces such as gears, bearings, shafts and collars, should be cleaned in a suitable solvent such as SD-2 kerosene or diesel fuel oil.

GASOLINE SHOULD BE AVOIDED.

WARNING

Potentially dangerous. Do not use near open flame or heat.

Do NOT clean these parts in a hot solution tank or with water and alkaline solutions such as sodium hydroxide, orthosilicates or phosphates.

We do NOT recommend steam cleaning assembled drive units after they have been removed from the housing. When this method of cleaning is used, water is trapped in the cored passage of the castings and in the close clearances between parts as well as on the parts. This can lead to corrosion (rust) of critical parts of the assembly and the possibility of circulating rust particles in the lubricant. Premature failure of bearings, gears and other parts can be caused by this practice. Assembled drive units cannot be properly cleaned by steam cleaning, dipping or slushing. Complete drive unit disassembly is a necessary requisite to thorough cleaning.

ROUGH PARTS

Rough parts such as differential carrier castings, cast brackets may be cleaned in hot solution tanks with mild alkali solutions providing these parts are not ground or polished. The parts should remain in the tank long enough to be thoroughly cleaned and heated through. This will aid the evaporation of the rinse water. The parts should be thoroughly rinsed after cleaning to remove all traces of alkali.

WARNING

Exercise care to avoid skirt rashes and inhalation of vapors when using alkali cleaners.

COMPLETE ASSEMBLIES

Completely assembled axles may be steam cleaned on the outside only, to facilitate initial removal and disassembly, providing all openings are closed. Breathers, vented shift units, and all other openings should be tightly covered or closed to prevent the possibility of water entering the assembly.

DRYING

Parts should be thoroughly dried immediately after cleaning. Use soft, clean, lintless absorbent paper towels or wiping rags free of abrasive material, such as lapping compound, metal filings or contaminated oil. Bearings should never be dried by spinning with compressed air.

CORROSION PREVENTION

Parts that have been cleaned, dried, inspected and are to be immediately reassembled should be coated with light oil to prevent corrosion. If these parts are to be stored for any length of time, they should be treated with a good RUST PREVENTIVE and wrapped in special paper or other material designed to prevent corrosion.

INSPECT

It is impossible to overstress the importance of careful and thorough inspection of drive unit parts prior to reassembly. Thorough visual inspection for indications of wear or stress, and the replacement of such parts as are necessary will eliminate costly and avoidable drive unit failure.

A. Inspect all bearings, cups and cones, including those not removed from parts of the drive unit and replace if rollers or cups are pitted or damaged in any way. Remove parts needing replacement with a suitable puller or in a press with sleeves.

   Avoid the use of drifts and hammers. They may easily mutilate or distort component parts.

B. Inspect first reduction bevel or hypoid and second reduction spur gears for wear or damage. Gears which are pitted, galled or worn or broken through case hardening should be replaced. When necessary to replace the pinion or gear of a gear set, the entire gear set should be replaced. We assume no responsibility for gears of these types when replaced in any other manner.

C. Inspect the differential assembly for the following:

1. Pitted, scored or worn thrust surfaces of differential case halves, thrust washers, spider trunnions and differential gears. Thrust washers must be replaced in sets. The use of a combination of old and new washers will result in premature failure.
2. Wear or damage to the differential pinion and side gear teeth.

Always replace differential pinions and side gears in sets.

D. Spur pinions for wear or damage to teeth.

E. Check end of pinion for indications of brinelling caused by worn splines. Replace the parts if the splines of the pinion and/or thru-shaft are worn, permitting movement of the pinion on the thru-shaft.

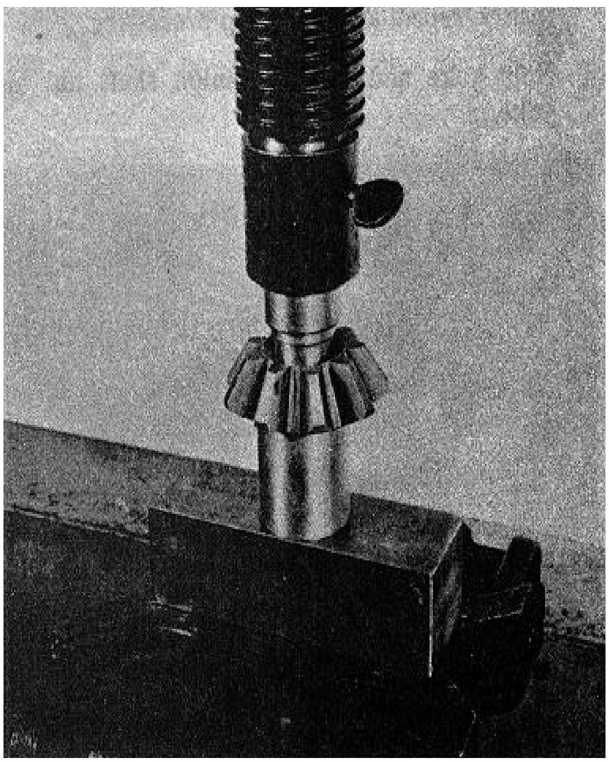
F. Axle shafts for indications of torsional fractures and runout. Axle shafts should be inspected between centers to ascertain the amount of runout of the ground surfaces. Runout at the shaft flange and splines should not exceed .005" total indicator reading.

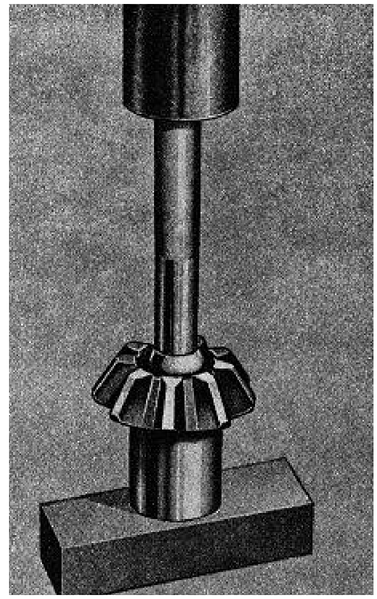
REPAIR

A. Replace all worn or damaged parts. Hex nuts with rounded corners, all lock washers, oil seals and gaskets should be replaced at the time of overhaul.

   Use only genuine Rockwell-Standard parts for satisfactory service. For example, using gaskets of foreign material generally leads to mechanical trouble due to variations in thickness and the inability of certain materials to withstand compression, oil, etc.

B. Remove nicks, mars and burrs from machined or ground surfaces. Threads must be clean and free to obtain accurate adjustment and correct torque. A fine mill file or India stone is suitable for this purpose. Studs must be tight prior to reassembling the parts. bushings where used as follows:
   1 Remove worn bushing. The bushing may be split with a hacksaw and the halves easily removed.
   2 Remove burrs or sharp corner from inner edge of pinion bore to prevent shearing or buckling of bushing on installation.
   3. Place pinion on anvil. Position bushing in inner end of pinion bore and press squarely into position. Use adaptor with correct size offset to fit bushing.



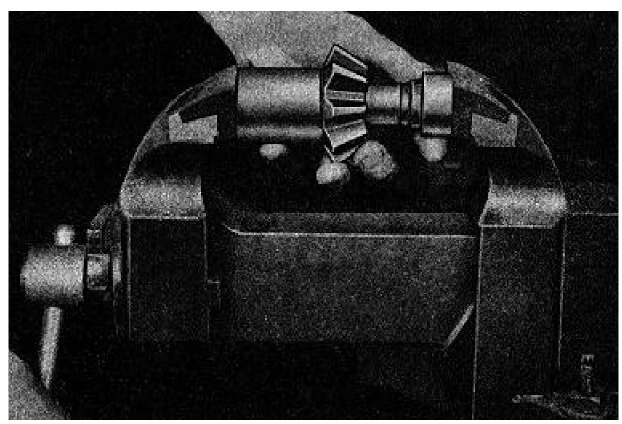


   4. Use bar to press burnishing ball through bushing.

      If desired, the bar may be shortened to permit the use of a bench vise to install and burnish bushing.

D. When assembling component parts use a press where necessary. Avoid hammering.
E. Tighten all nuts to specified torque. See torque limits following service instructions.

   Lock wire must not be brittle; use soft iron wire to prevent possibility of wire breakage.

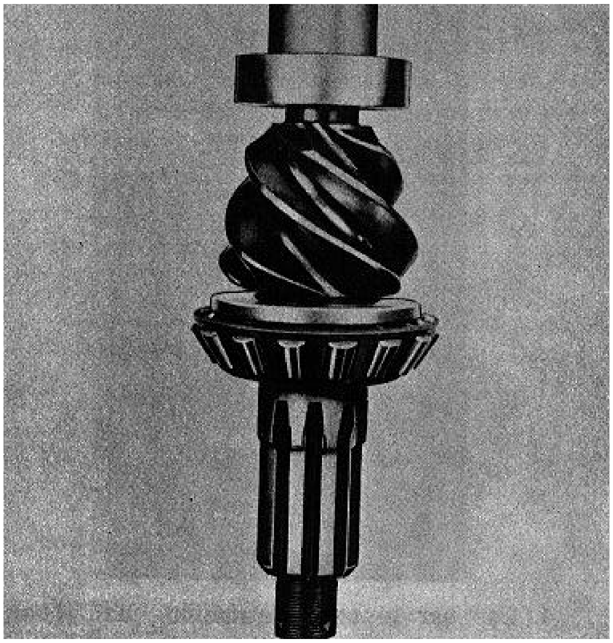


REASSEMBLE AXLE

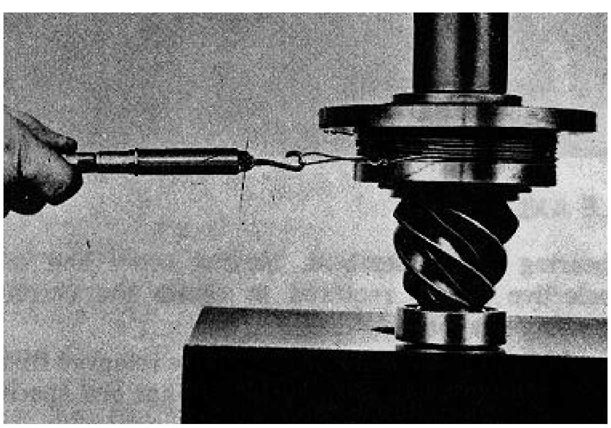
REASSEMBLE PINION AND CAGE ASSEMBLY

When a new pinion cage is required, the bearing and cage assembly furnished for service purposes should be used. This includes the cage with bearing cups assembled, bearing cones and the selective spacer required to obtain the correct bearing pre-load.

The used bearing cones should be removed from the pinion shaft and the new bearings and spacer used in the assembly.



A. Press rear thrust and radial bearings firmly against the pinion shoulders with a suitable sleeve.
B. Install radial bearing lock ring and squeeze ring into pinion shaft groove with pliers.
C. If new cups are to be installed, press firmly against pinion bearing cage shoulders.
D. Lubricate bearings and cups with light machine oil.
E. Insert pinion and bearing assembly in pinion cage and position spacer or spacer combination over pinion shaft.
F. Press front bearing firmly against spacer.
G. Rotate cage several revolutions to assure normal bearing contact.



H. While in press at 25,000 pounds pressure, check bearing pre-load torque. Wrap soft wire around cage and pull on horizontal line with pound scale. If a press is not available, the yoke may be installed and the pinion nut tightened to specified torque for checking.

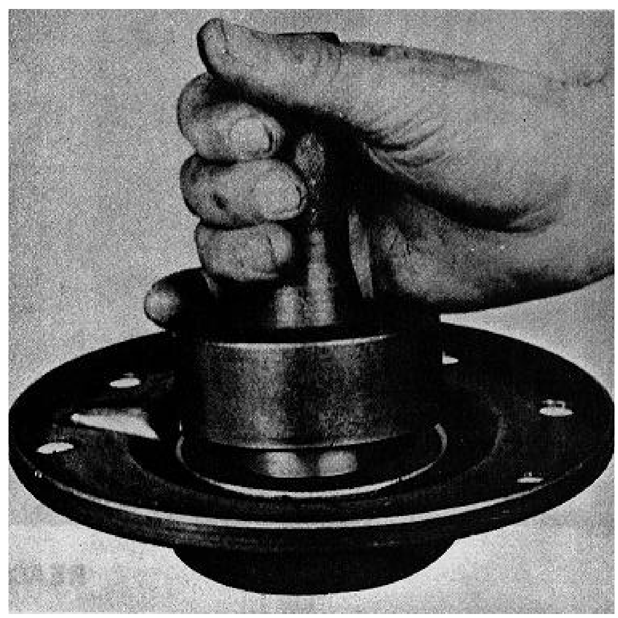
If rotating torque is not within 5 to 15 pound-inches, use thinner spacer to increase or thicker spacer to decrease pre-load.

Example: Assuming pinion cage diameter to be 6 inches the radius would be 3 inches and with 5 pounds pull would equal 15 pound-inches pre-load torque.

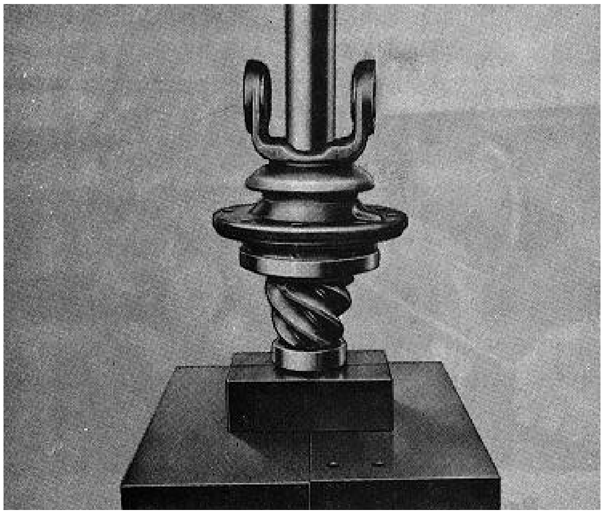
I. Press yoke against forward bearing and install washer and pinion shaft nut.
J. Place pinion and cage assembly over carrier studs, hold yoke and tighten pinion shaft nut to specified torque. The yoke must be held with a suitable tool or fixture to tighten nut.
K. Recheck pinion bearing pre-load torque.

If rotating *torque is not within 5 to 15 pound-inches, repeat the foregoing procedure.*

L. Hold yoke and remove pinion shaft nut and yoke.

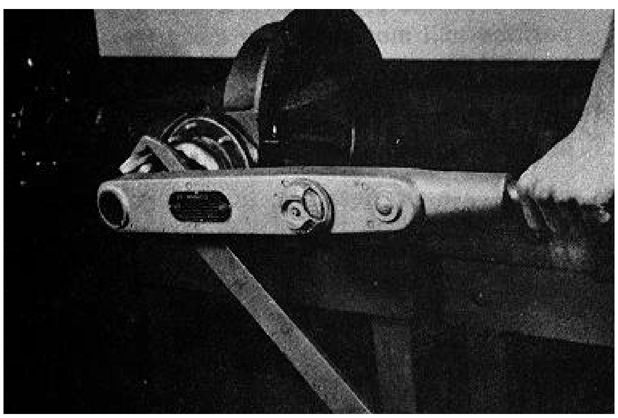


M. Lubricate pinion shaft oil seal and cover outer edge of seal body with a non-hardening sealing compound. Press seal against cover shoulder with seal driver.
N. Install new gasket and bearing cover.



O. Press yoke against forward bearing and install washer and pinion shaft nut.

P. Tighten to specified torque and install cotter key. Do not back off nut to align cotter key holes.



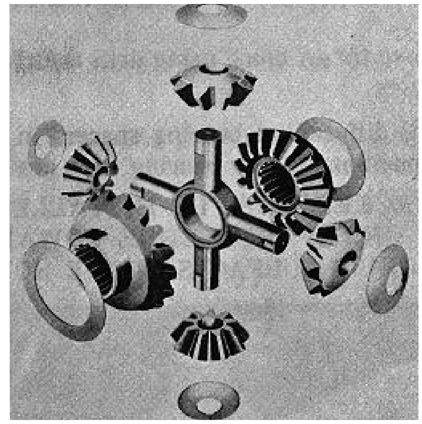
ASSEMBLE DIFFERENTIAL AND BEVEL GEAR

A. Rivet bevel gear to case half with new rivets.

If a new gear or differential case is to be used in the assembly, the rivet holes in the gear and case should be checked for alignment and line reamed if necessary. The gear must be tight on the case pilot and riveted flush with the differential case flange. Check with a .002" feeler gauge.

Rivets should not be heated, but should be upset cold. When the correct rivet and rivet set is used the head being formed will be at least 1/8" larger in diameter than the rivet hole.

The head will then be approximately the same height as the preformed head. The formed head should not exceed 1/16" less than the preformed head as excessive pressure will cause distortion of the case holes and result in gear eccentricity.

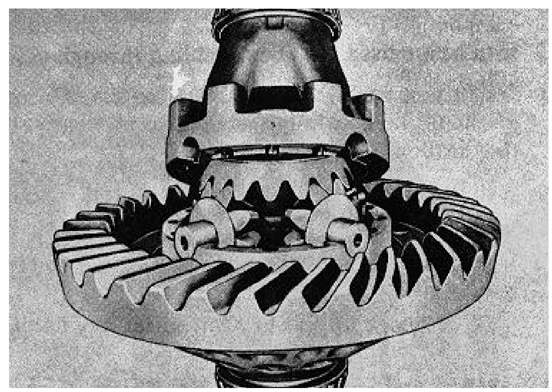


B. Lubricate differential case inner walls and all component parts with axle lubricant.

C. Position thrust washer and side gear in bevel gear and case half assembly.

D. Place spider with pinions and thrust washers in position.

E. Install component side gear and thrust washer.



F. Align mating marks, position component case half and draw assembly together with four bolts or cap screws equally spaced.

G. Check assembly for free rotation of differential gears and correct if necessary.

H. Install remaining bolts or cap screws, tighten to specified torque and thread with lock wire.

I. If bearings are to be replaced, press squarely and firmly on differential case halves.

DIFFERENTIAL BEARING PRE-LOAD AND GEAR LASH ADJUSTMENTS

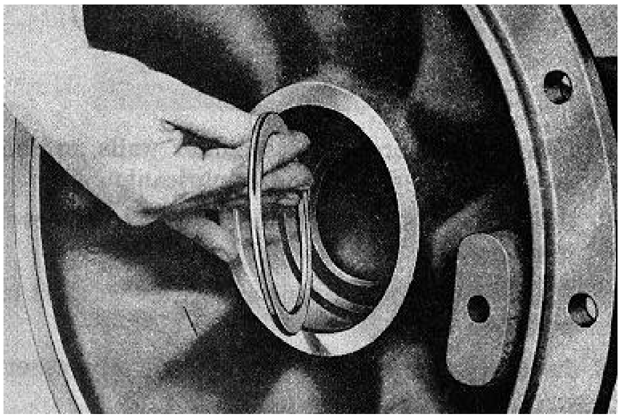
The differential bearing pre-load and gear lash adjustments are obtained by the use of hardened and ground spacers of the correct thickness located between the differential bearing cups and the axle housing. On this type assembly, no shim pack is required between the pinion cage and axle housing.

ADJUST DIFFERENTIAL BEARING PRE-LOAD

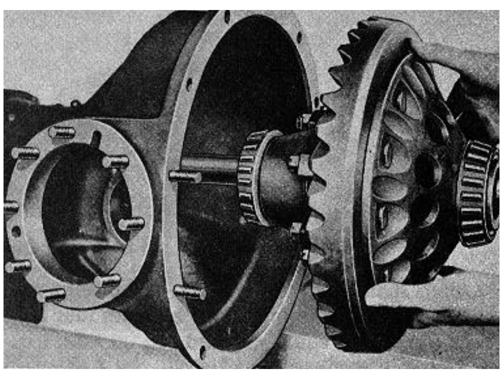
A. Remove thrust block using drift to drive pin out of cover.

B. Install differential bearing spacers in the original positions if new bearing cups are installed.

SPACERS MUST BE INSTALLED WITH THE CHAMFERED EDGE TOWARD THE MACHINED SURFACES IN THE HOUSING.



C. Insert pipe used for disassembling through case half.



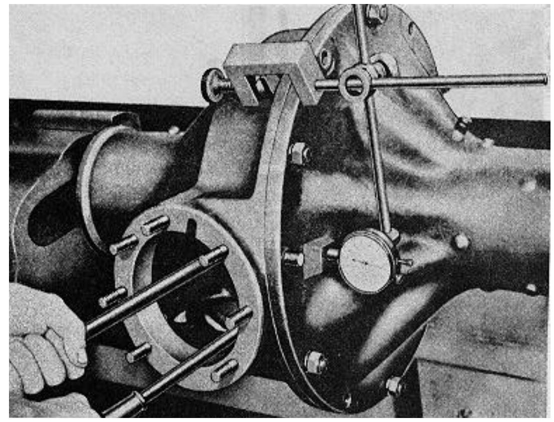
D. Position differential and gear assembly over pipe with gear facing the case half and slide into position.

E. Install new gasket over case flange.

F. Position cover half over pipe and draw axle halves together with six bolts equally spaced.

G. Check differential and gear assembly end play with dial indicator through thrust block pin hole against gear.

Both the differential bearing pre-load and gear lash are controlled by selective spacers, available in increments of .003", which are installed between the differential bearing cups and the case and cover halves of the axle housing.



Bearing pre-load may be increased or decreased by using a thicker or thinner spacer respectively in the cover half of the assembly.

The gear may be moved toward the pinion, decreasing the gear lash, by decreasing the thickness of the spacer in the case half and increasing the thickness of the spacer by the same amount in the cover half. Reversing this transposition will move the gear away from the pinion and increase the gear lash.

The correct pre-load of .006" to .010" tight is obtained as follows:

1. Increase or decrease the thickness of the spacer used in the COVER HALF to obtain a freely rotating gear with from .000" to .005" end play.
2. Remove spacer in cover half and install a spacer ".006" plus the end play" thicker than the spacer used to obtain the adjustment in the above paragraph.
3. If a new gear or case has been installed, check runout at back face of gear. Correct and recheck if runout exceeds .005".
4. When adjustment is satisfactory, remove cover and move differential and gear out on support sufficient to permit installation of pinion and cage assembly.

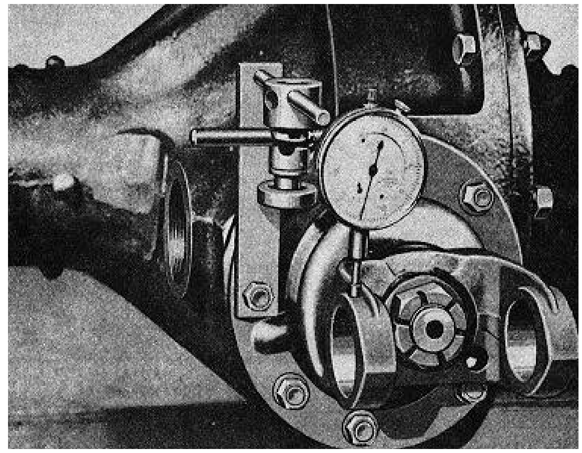
H. Install thrust block and pin.

INSTALL PINION AND CAGE ASSEMBLY

A. Coat cage flange contact surface with non-hardening sealing compound. Position cage assembly over studs and tap into position with soft mallet.

B. Install lockwashers and stud nuts. Tighten to specified torque.

CHECK AND ADJUST GEAR LASH



A. Install differential and gear assembly and assemble cover using new gasket with six bolts equally spaced. Tighten to specified torque.

B. Check gear lash with dial indicator on universal joint yoke 2" from pinion shaft center. An indicator reading of between .013" and .033" will show the recommended backlash of between .006" and .012" is present in the gear set.

C. Transpose spacers used in both the case and cover, decreasing the thickness of the spacer used on the side in the direction which the gear is to be moved and increasing the thickness of the opposite spacer exactly the same amount as required to obtain the correct gear lash.

D. Install remaining bolts, washers and nuts in housing assembly and tighten all nuts in bolt circle to specified torque.

LUBRICATION

Fill axle to correct level with specified lubricant and lubricate universal joint. Refer to lubrication chart on page 15-1.

TORQUE SPECIFICATIONS

LOCATION	DIAM-ETER	NO. THREADS	TORQUE-LB. ¾ FT.	
			Min.	Max.
Cover to case bolt nuts	3/8"	16	27	35
	3/8"	24	31	39
	7/16"	20	42	54
	½"	20	75	96
Pinion cage cap screws and stud nuts	3/8"	16	27	35
	3/8"	24	31	39
	7/16"	20	42	54
	9/16"	12	94	120
Differential case bolt nuts and cap screws	3/8"	16	33	43
	½"	13	81	104
	½"	20	92	118
Pinion shaft nuts	7/8"	20	175	200
	1"	20	300	400
Gear to case cap screws	3/8"	24	38	49

Torques given apply to parts coated with machine oil; for dry (or "as received") parts increase torques 10%; for parts coated with multi-purpose gear oil decrease torques 10%. Nuts on studs to use same torque as for driving the stud.

SUBSECTION 6 HYDROSTATIC PUMP AND MOTOR

RECOMMENDED REPAIR OF PUMPS AND MOTORS IN THE FIELD

Certain repairs can be made by mechanics who use care not to damage new parts and use precaution to keep contamination out of the system. For instance, the seals on the driving end of both pumps and motors are replaceable without much trouble.

On the pump the charge pump, gasket, relief valve check valves and displacement control valve are easily replaced.

On the motor, the entire relief valve manifold can be changed. The high pressure relief valves, low pressure relief valve and shuttle valve are easily replaceable.

The above repairs can be made without affecting the pump or motor warranty.

A COMPLETE OVERHAUL OF BOTH PUMPS AND MOTORS CAN BE MADE ONLY BY FACTORY APPROVED AND TRAINED SERVICEMEN. CUSTOMERS ARE CAUTIONED AGAINST ATTEMPTING AN OVERHAUL OF A HYDRAULIC PUMP OR MOTOR AS THIS WILL VOID THEIR WARRANTY. THE FOLLOWING PARAGRAPHS ARE PROVIDED FOR BACKGROUND INFORMATION ONLY AND SHOULD NOT BE CONSTRUED TO MEAN THAT REXWORKS RECOMMENDS FIELD OVERHAUL OF EQUIPMENT BY CUSTOMERS. EXCEPT FOR THE MINOR REPAIRS SPECIFIED ABOVE, WE STRONGLY RECOMMEND THE COMPLETE REPLACEMENT OF DEFECTIVE PUMPS AND MOTORS.

GENERAL

The hydrostatic mixer drive consists of a diesel powered engine, a variable displacement over-center piston type pump, a fixed displacement piston type motor, a reduction gear case, suitable hydraulic lines, and other components such as oil reservoir, filter, charge pump, relief valves, and control system.

The variable displacement pump is driven by the engine by means of a universal joint driveline. The remote control lever for travel speed is mounted on the control panel and is connected to the pump control lever by means of push-pull control cables.

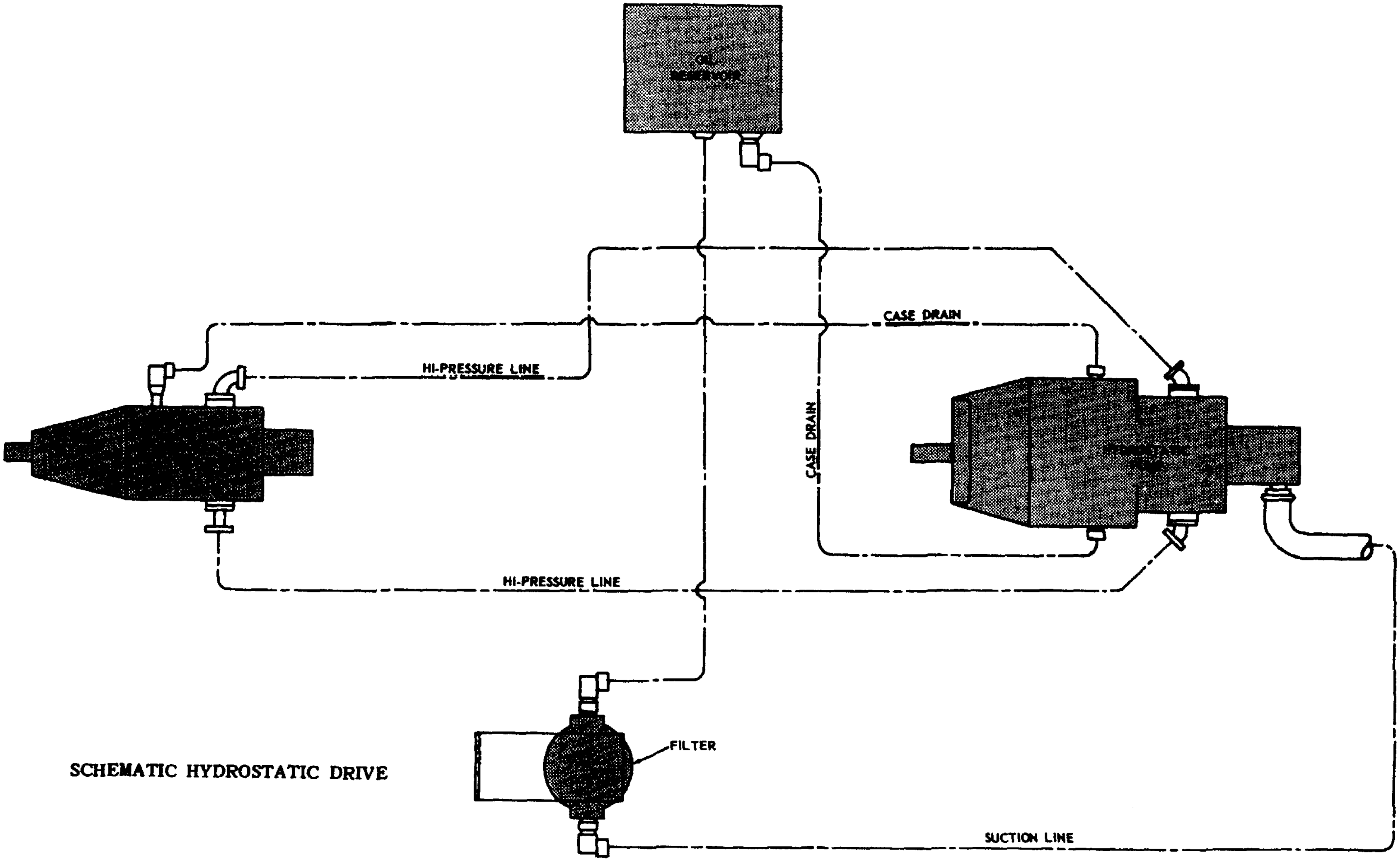
The variable displacement pump has a neutral position in which no fluid is pumped to the motor. Moving the control lever forward or rearward of neutral, while the engine is running causes oil to be pumped to the motor; one side turning the motor in a forward direction, the other side in a reverse direction. The further the control lever is moved from the neutral position, the faster the machine runs. Changing the engine speed will also change the travel speed providing the pump control lever is not in neutral position. If it is in the neutral position, the machine will not travel.

The hydrostatic motor is coupled directly to the reduction gear case of the rear axle differential. Hydraulic lines connect the pump and motor and other components in the hydrostatic circuit.

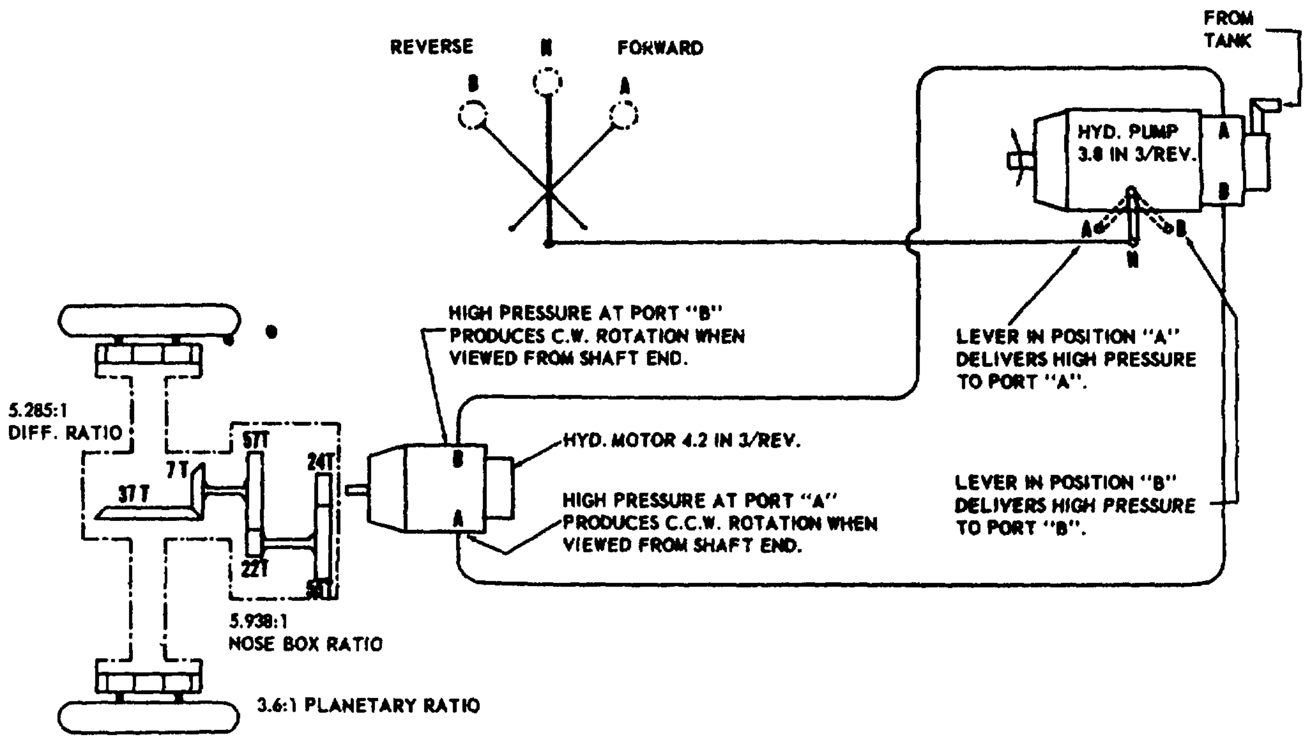
CAUTION AND IMPORTANT:

The most serious thing to have happen to the hydrostatic system is for dirt or foreign material to be introduced into the oil in any way. Introducing solids of any kind or liquids other than clean hydraulic oil will cause almost immediate failure. If for any reason, any component is removed for repair, the connections must be first cleaned with a solvent and dried before disassembly. Plug or protect openings to keep foreign matter from entering the hydraulic system. Do not use cloth or paper as a material for protection.

When adding or changing oil, pour oil thru a clean #200 mesh screen funnel. Do not use cloth as a filter. If necessary to seal pipe threads, use Permatex Sealer Grade #2 on male threads only. <u>Keep the sealer back from the end of the male threads by at least 1/8.</u>



SCHEMATIC HYDROSTATIC DRIVE



HYDROSTATIC TRACTION DRIVE AND GEARING ARRANGEMENT DIAGRAM

MAINTENANCE INFORMATION

HYDROSTATIC PUMP AND MOTOR

The Variable Displacement Pump can be operated with fixed or variable input speeds and provides an infinitely variable output flow between 0 and maximum flow in either direction. A variety of controls are available for the Variable Displacement Pumps and Motors which are described on the following pages.

The Fixed Displacement Motor can be operated in either direction of rotation with infinitely variable output speeds between its 0 and maximum speed.

Manual Displacement Control

The Standard Displacement Control provides a pump output flow (displacement), in either direction, that is approximately proportional to the angular movement of the control handle. The control will return to neutral if the control handle is released. **The internal centering mechanism is not sufficient to overcome external control linkage friction.**

This control has an orifice for controlling maximum acceleration or deceleration (control response). The orifice is available in various sizes for matching the control to the system.

NOTE:
Torque on the Control handle shaft must not exceed 150 in. lbs.

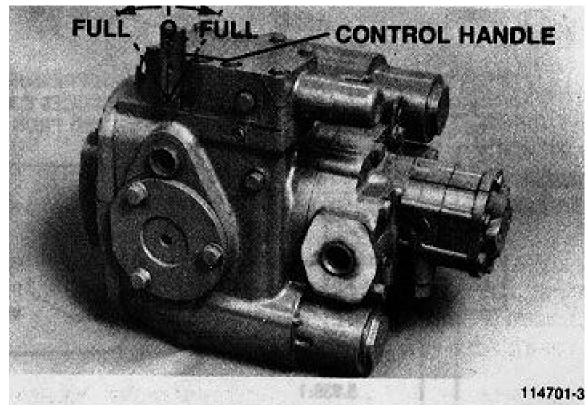
Specifications and Requirements

Sundstrand Heavy Duty Hydrostatic transmissions have certain pressures that must be maintained as well as some requirements and limitations which must be observed.

SPECIFICATIONS

Displacement		Maximum Recommended Working Pressure*		Max. Speed @ Max. Disp.
IN^3/REV	CC/REV	PSI	BAR	(RPM)
4.26	69.8	5,000	345	3,200

*6,000 PSI (414 BAR) maximum working pressure with written approval.



SYSTEM REQUIREMENTS

Charge Pressure* (Neutral)	190 - 210 PSI	13 - 15 BAR
Charge Pressure* (Forward or Rev)	160 - 180 PSI	11 - 12.5 BAR
Case Pressure	40 PSIG Max.	3 BAR Max.
Inlet Vacuum**	10 In. Hg. Max.	254 mm Hg Max.
Inlet Filtration	10 Micron Nominal No Bypass	

*Above case pressure. Some units may have special charge pressure settings. Consult machine specifications.

**Measured at charge pump inlet. (May be exceeded during cold weather start up).

Fluids

The hydraulic fluids used with Sundstrand products should be carefully selected following the guidelines presented in the “Hydraulic Fluid Requirements” bulletin, F-00.01 and in the original equipment manufacturer's specifications.

Start Up Procedure

Prior to installing both pump and motor, inspect the units for damage incurred during shipping and handling. Make certain all system components (reservoir, hoses, valves, fittings, etc.) are clean prior to filling with fluid.

Fill the reservoir with recommended hydraulic fluid which should be passed through a 10 micron (nominal no bypass) filter prior to entering the reservoir. Never reuse fluid.

The inlet line leading from the reservoir to the pump must be filled prior to start up. Check inlet line for properly tightened fittings and make sure it is free of restrictions and air leaks.

Be certain to fill the main pump and motor housing with clean hydraulic fluid prior to start up by pouring filtered oil in the uppermost case drain port.

Install a pressure gauge (500 PSI) in the Charge Pressure Gauge Port (Ref: Troubleshooting Section). It is recommended the external control linkage be left disconnected until after initial start up to allow pump to remain in neutral.

Start the prime mover and run at lowest possible RPM until 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.

CAUTION

Do not start prime mover unless pump is in neutral (0 swashplate angle). Take safety precautions to prevent machine movement in case pump is actuated during initial start up.

Once charge pressure has been established, increase speed to normal operating RPM. Charge pressure should be at 190-210 PSI minimum. If charge pressure is not at proper value, shut down and determine cause (Ref: Troubleshooting Section).

Shut down prime mover and connect external control linkage. Start prime mover, checking to be certain pump remains in neutral. With prime mover at normal operating speed, slowly check for forward and reverse machine operation.

CAUTION

Take necessary safety precautions before moving machine.

Charge pressure should remain at 160-180 PSI minimum during forward or reverse operation. Continue to cycle slowly from forward to reverse for five (5) minutes.

Shut down prime mover, remove gauges and plug ports. Check reservoir level and add fluid if necessary.

The transmission is now ready for operation.

System Maintenance For satisfactory service, regular maintenance of fluid and filters must be performed. The following are recommended intervals for changing these items.

Air Breathing Type Reservoir 500 hrs.

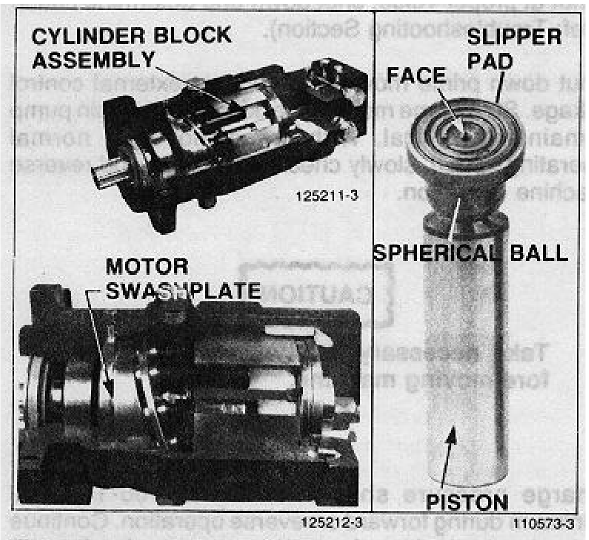
Check fluid level daily. Change fluid more often if it becomes contaminated with any foreign matter (dirt, water, grease, etc.).

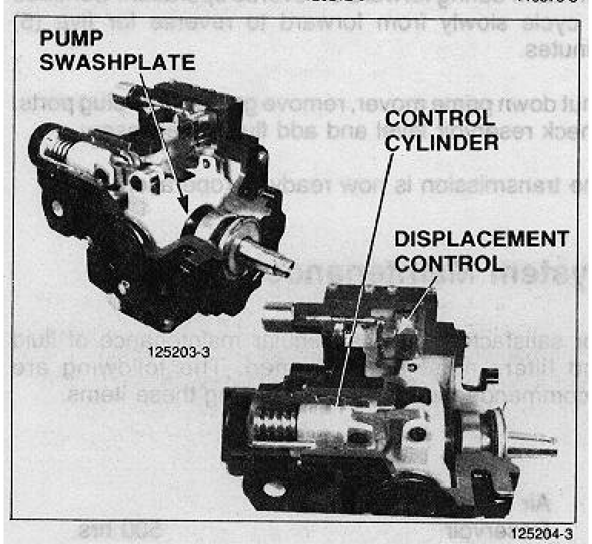
Change inlet filter whenever fluid is changed and whenever filter indicator shows a change is necessary.

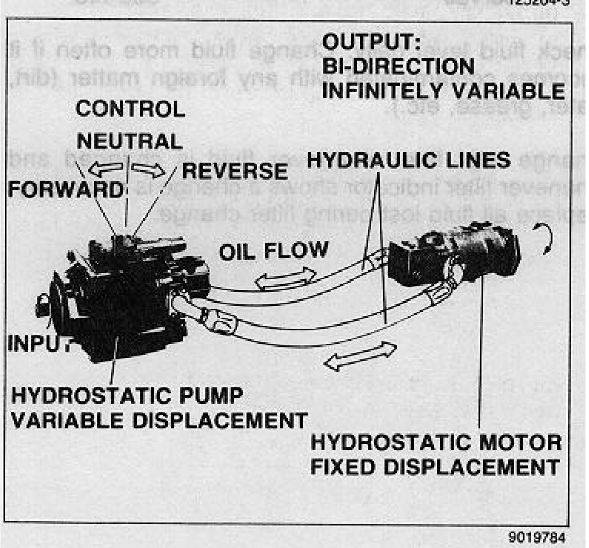
Replace all fluid lost during filter change.

BASIC OPERATION

HYDROSTATIC PUMP AND MOTOR







Axial Piston, Slipper Pad Design

Sundstrand hydrostatic pumps and motors are an axial piston, slipper pad design. There are nine (9) pistons mounted in the cylinder block. As the cylinder block rotates, these pistons are forced in and out of their bores by the angle of the swashplate. This results in a specific amount of fluid being displaced for every revolution of the cylinder block. In a pump, the fluid is forced out as the angle of the swashplate pushes the pistons into the bores. In a motor, system pressure against the piston causes it to slide down the inclined face of the swashplate resulting in output rotation.

The slipper pad attaches to a spherical ball on the end of the piston forming a ball and socket joint. This allows the slipper pad to tilt at any angle and make contact with the swashplate. The face of the slipper pad slides on a hydrostatic fluid film which uses fluid pressure to balance internal forces.

Variable Pump Tilting Swashplate

The variable displacement pumps use a tiltable swashplate to vary displacement (output flow). The swashplate 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 swashplate to tilt and change displacement of the pump. The swashplate can be tilted in either direction from 0 angle and provide pump flow in either direction.

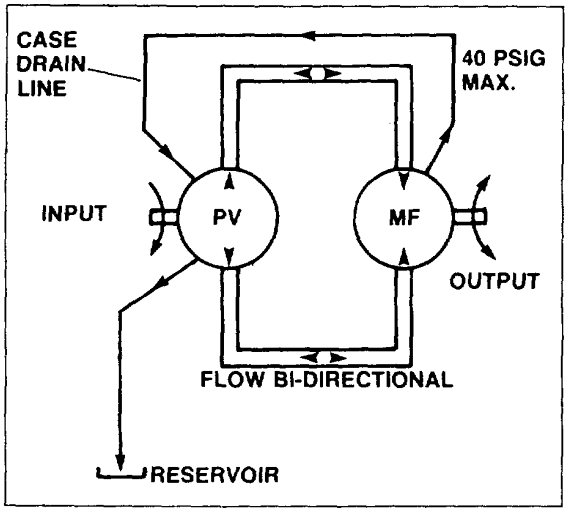
Since the angle of the swashplate causes the pistons to stroke in and out of the cylinder block bores as it is rotated, changing this angle varies the piston stroke and, therefore, the amount of fluid being displaced (pumped) to the motor. This results in a change in the output speed of the motor. Tilting the swashplate 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 swashplate to return to neutral position.

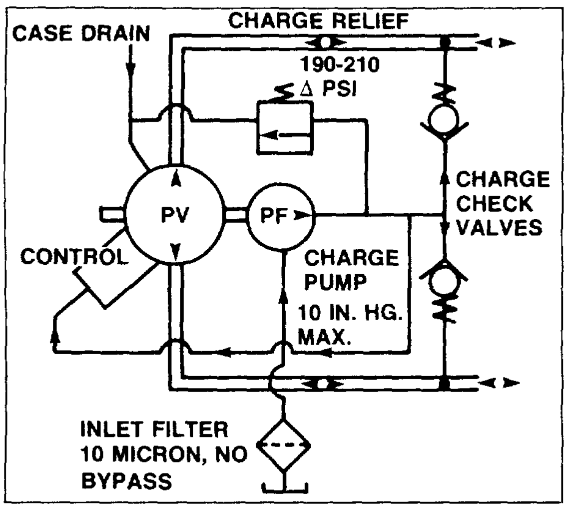
Hydrostatic Transmission

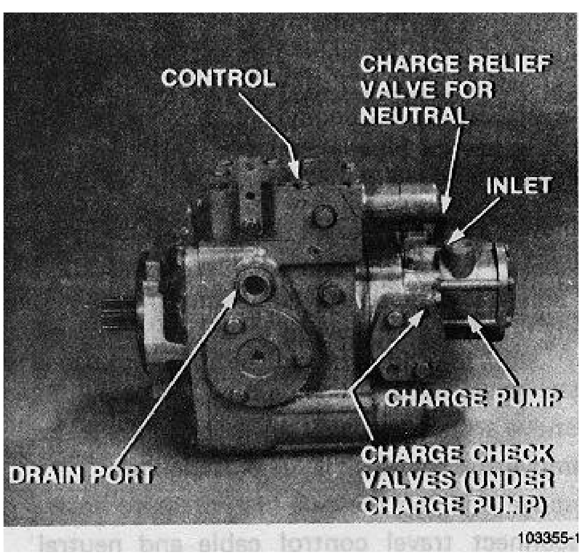
The hydrostatic transmission consists of a variable displacement pump connected by hydraulic lines to a fixed displacement motor. The pump rotates in one direction and requires a change of internal parts to rotate in the opposite direction. The motor rotates in either direction.

With the hydrostatic transmission, machine control can be achieved with a single operator control which provides smooth, stepless speed and direction changes. Placing the control in neutral (0 swashplate angle) stops transmission (motor) output which usually eliminates the need for clutching mechanisms. **This feature, however, does not eliminate the need for a service brake or parking brake.**

HYDRAULIC SUPPORT SYSTEM







The Sundstrand hydrostatic transmission is easy to install, requiring no adjustments and few auxiliary components. It has its own hydraulic support system which is discussed in this section.

Basic Closed Circuit

The main ports of the pump are connected by hydraulic lines to the main ports of the motor. Fluid flows, in either direction, from the pump to the motor then back to the pump in this closed circuit. Either of the hydraulic lines can be under high pressure. The position of the swashplate determines which line is high pressure as well as the direction of fluid flow.

Case Drain

The pump and motor require case drain lines to remove hot fluid from the system. The motor should be drained from its topmost drain port to insure the case remains full of fluid. The motor case drain is then connected to the lower drain port on the pump housing and out the upper port.

CAUTION

Case pressure should not exceed 40 PSIG.

Charge System and Inlet Filter

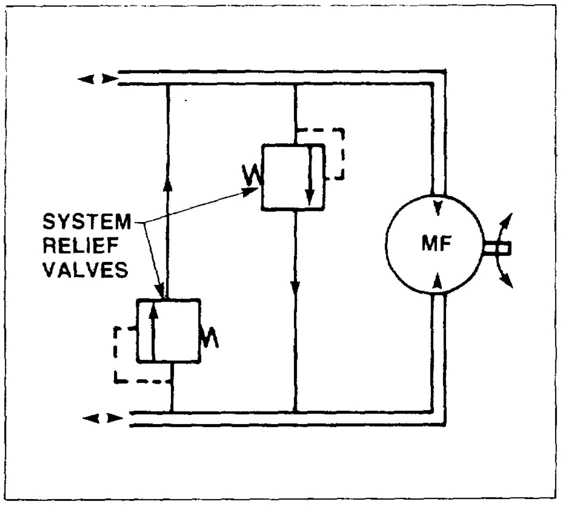
A fixed displacement (gear type) charge pump is mounted on the variable displacement pump and driven off the main pump shaft. The charge pump supplies cool fluid to the system, keeps the system charged and supplies fluid to operate the control system. Charge pressure, with the pump in neutral (O flow), is limited by a relief valve which is normally factory set for 190-210 APSI (above case pressure).

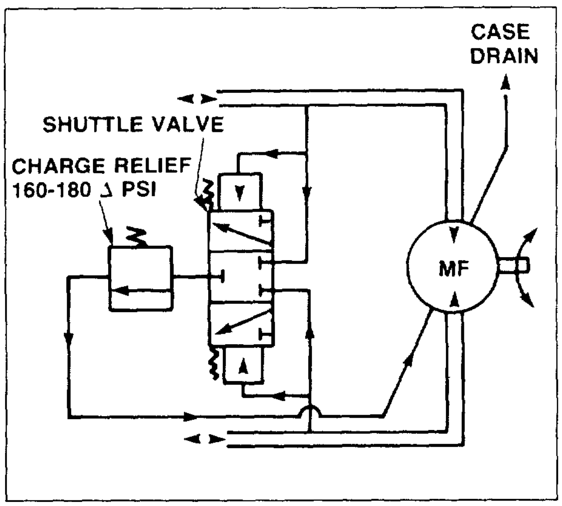
Since either of the main hydraulic lines can be high pressure, two (2) charge check valves are used to direct the charge supply into the low pressure line. The check valves are contained in the pump end cap beneath the charge pump.

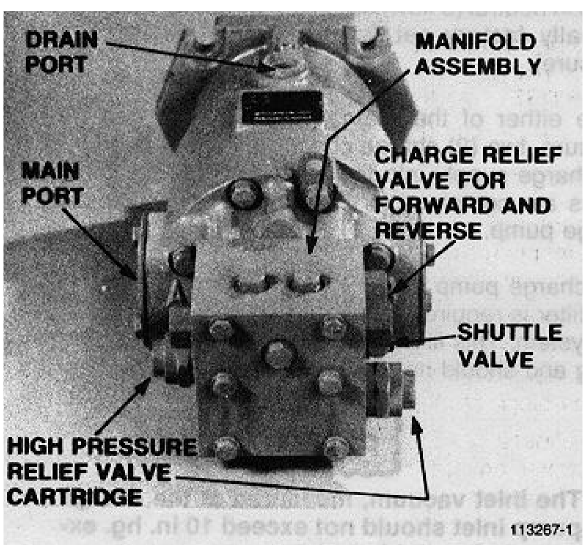
The charge pump draws the fluid from the reservoir. An inlet filter is required to insure that only clean fluid enters the system. This filter should have a 10 micron (nominal) rating and should not have a bypass.

CAUTION

The inlet vacuum, measured at the charge pump inlet should not exceed 10 in. hg. except during cold starts.







System Relief Valves

Two (2) System Relief Valves are provided for overload protection and are located in the Manifold Assembly mounted on the motor. These relief valves are factory set and are of the pilot operated, cartridge type. Changing the setting of these relief valves can be accomplished by installing cartridges with the desired setting. The first two (2) digits of the pressure setting are stamped on the end of the relief valve cartridge.

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 a second Charge Relief Valve are included in the 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 A 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 (swashplate 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.

Charge Pressure

When the pump is in neutral (0 swashplate angle) the Charge Pressure should be at 190-210 ΔPSI (above case pressure). When the pump is in forward or reverse (other than 0 swashplate angle) the Charge Pressure should be at 160-180 ΔPSI (above case pressure).

CAUTION

Charge Pressure must not be less than 160 DPSI for satisfactory operation.

REMOVAL AND INSTALLATION

PUMP REPLACEMENT

1. Remove dust shield from underside of front main frame.
2. Place a large oil drain pan under pump area.
3. Remove the two universal joint U-bolts that attach the drive line to the pump yoke.
4. Remove and cap the pump suction line.
5. Remove and cap the two case drive lines.
6. Remove and cap the two high pressure hoses.
7. Disconnect travel control cable and neutral start switch wires from pump.
8. Place lifting sling around the pump.
9. Remove the pump mounting bolts and lower pump out of mixer frame.

10. Place pump in clean area for repair.
11. Installation is the reverse procedure.

IMPORTANT

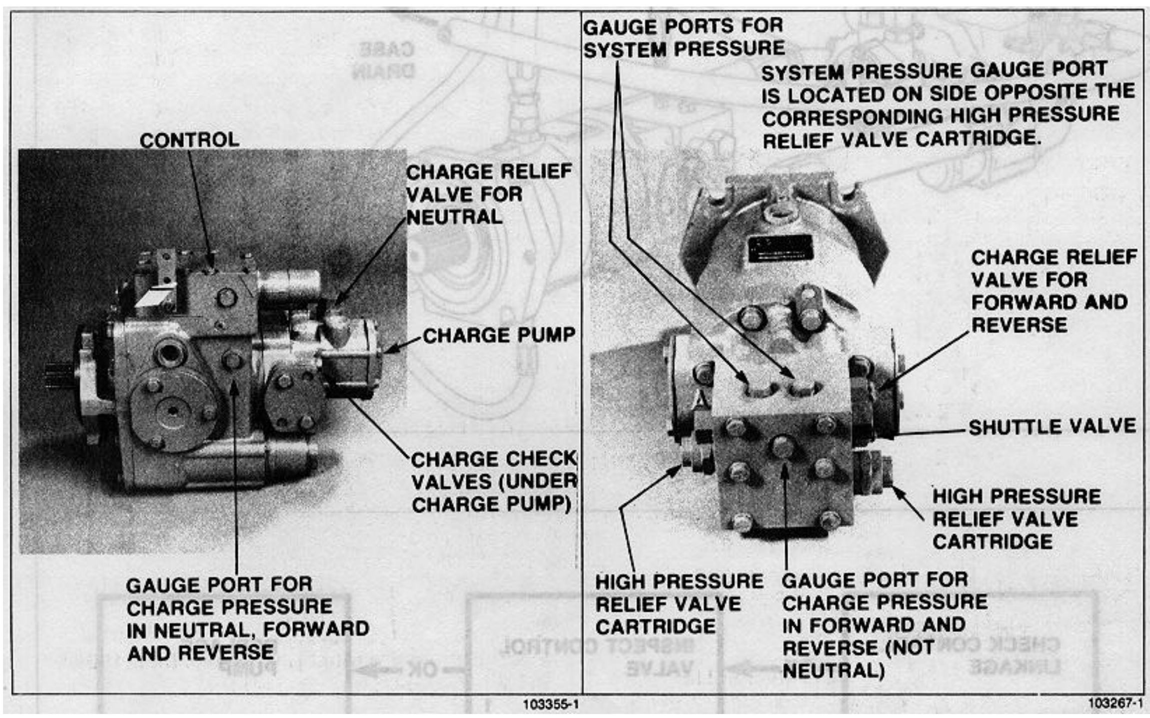
The proper hydrostatic system start up procedure must be followed after installation. - See page 6-5.

MOTOR REPLACEMENT

1. Remove operators seat and lift open the operators platform.
2. Place oil drain pan under motor.
3. Remove and cap the case drain line.
4. Remove and cap the two high pressure lines.
5. Place sling around motor.
6. Remove the motor mounting capscrews.
7. Remove motor from mixer frame.
8. Place motor in a clean area.
9. Installation is the reverse procedure.

IMPORTANT

The proper hydrostatic system start up procedure must be followed after installation - see page 6-5.



Instructions

The areas indicated in these troubleshooting procedures may be inspected, adjusted or replaced, following the procedures in this manual, without voiding the warranty. For specific instructions on adjustments, removal and replacement, refer to the appropriate sections in this manual.

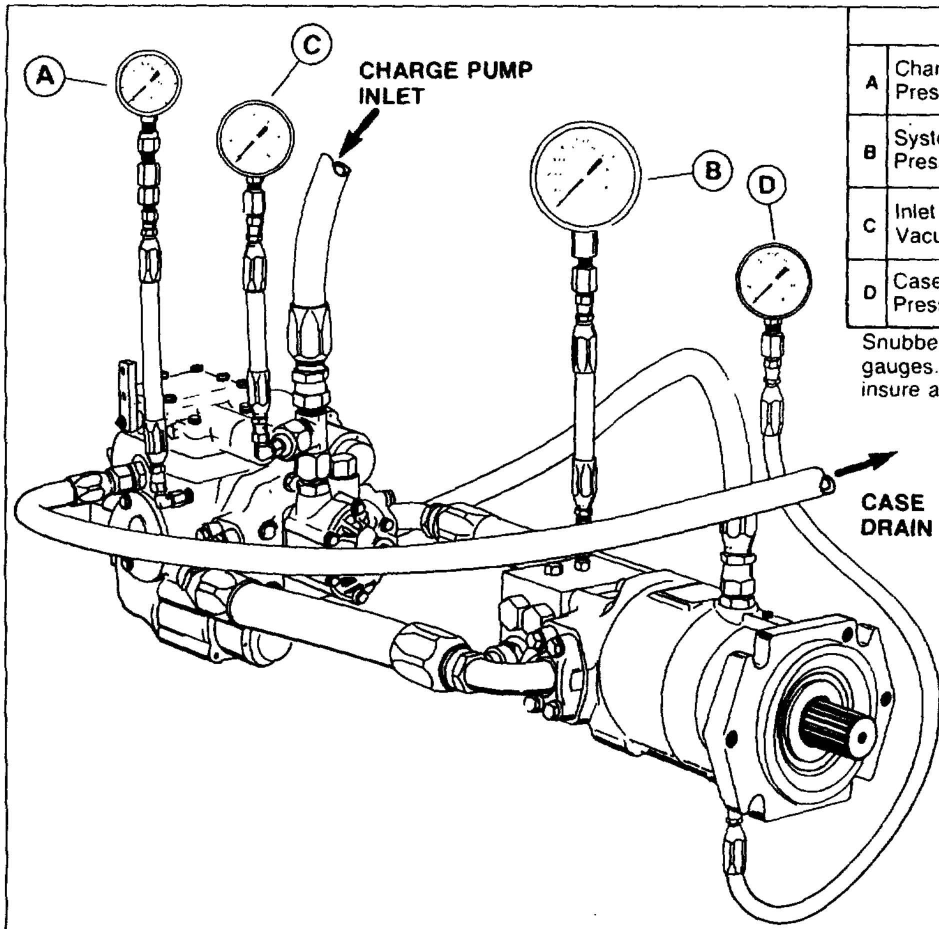
The information contained in this section provides a guide for troubleshooting the Sundstrand Heavy Duty hydrostatic transmissions. It is a problem solving tool aimed at eliminating unnecessary machine downtime. Following the fault-logic approach should result in the expedient correction of transmission problems.

Our experience shows that there are five (5) problem statements that cover the majority of problems encountered with these transmissions. These problem statements have been set up in fault-logic diagrams on the following pages.

Following the fault-logic diagrams are descriptions of some of the action steps shown in the diagrams. Where applicable, a number for this description appears in the action block of the diagram.

Cleanliness is a primary means of insuring satisfactory transmission life, on either new or repaired units. Cleaning parts by using a solvent wash and air drying is adequate, providing clean solvent is used. As with any precision equipment, the internal mechanism and related items must be kept free of foreign materials and chemicals.

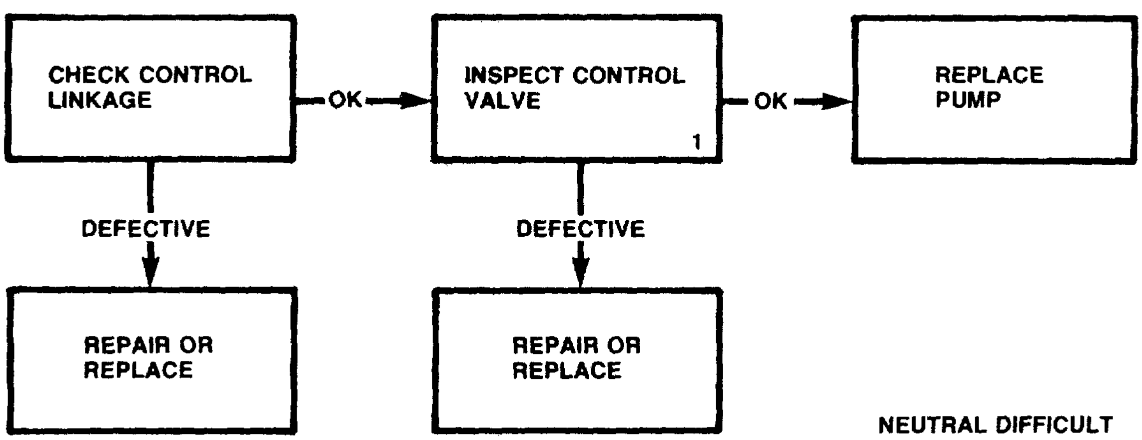
Protect all exposed sealing surfaces and open cavities from damage and foreign material.



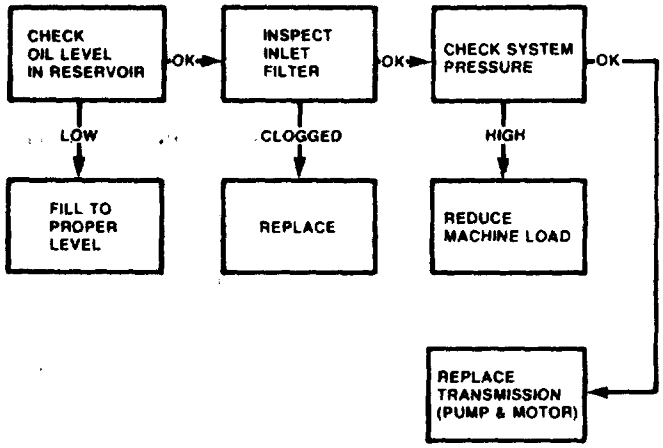
GAUGE INFORMATION		
A	Charge Pressure	500 PSI - Gauge 7 16-20 O-Ring Fitting
B	System Pressure	10,000 PSI Gauge 7 16-20 O-Ring Fitting
C	Inlet Vacuum	Vacuum Gauge Tee into Inlet Line
D	Case Pressure	500 PSI Gauge Adapt to Bottom Drain Port

Snubbers are recommended to protect gauges. Gauge calibration is necessary to insure accuracy of readings.

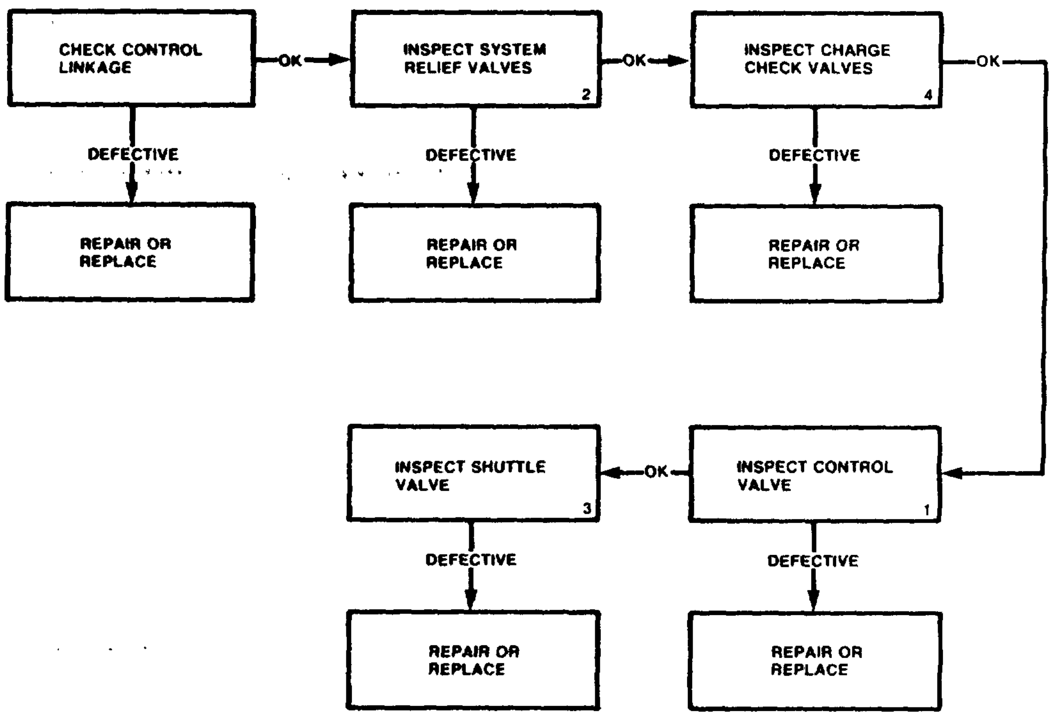
TROUBLESHOOTING GAUGE INSTALLATION AND INFORMATION



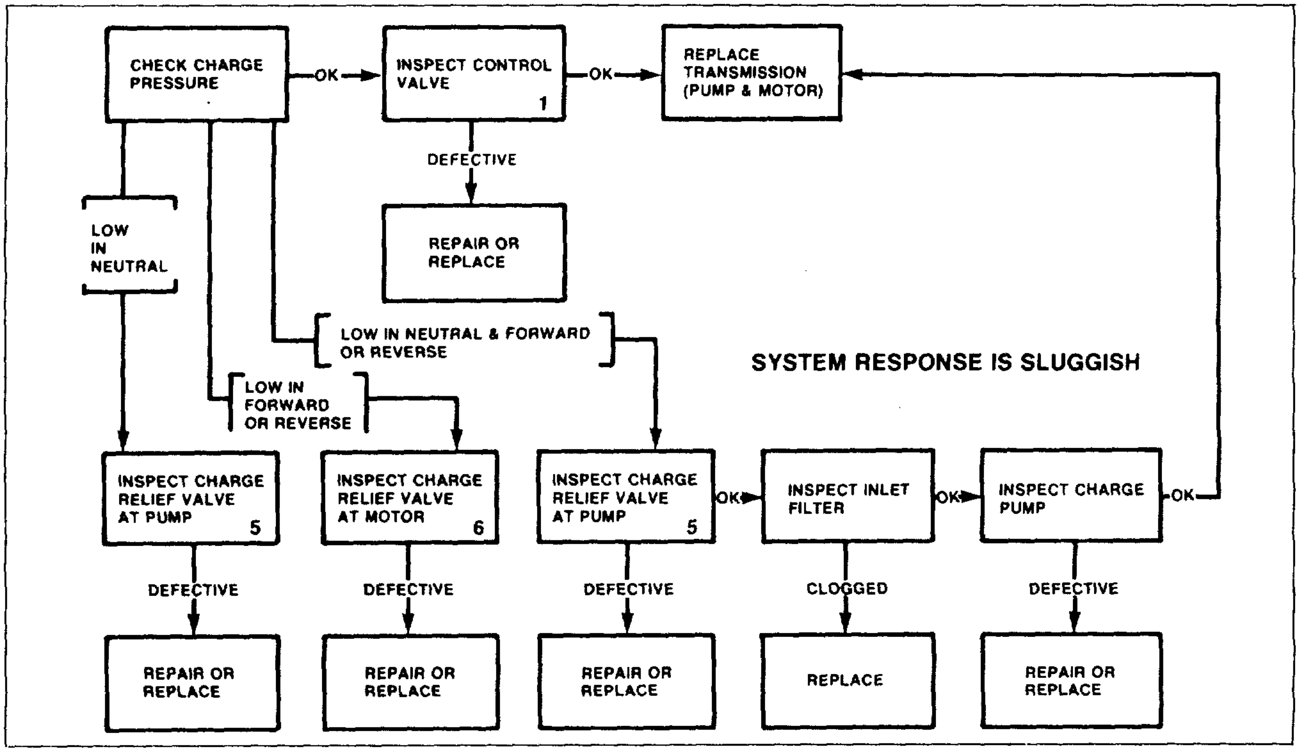
NEUTRAL DIFFICULT OR IMPOSSIBLE TO FIND



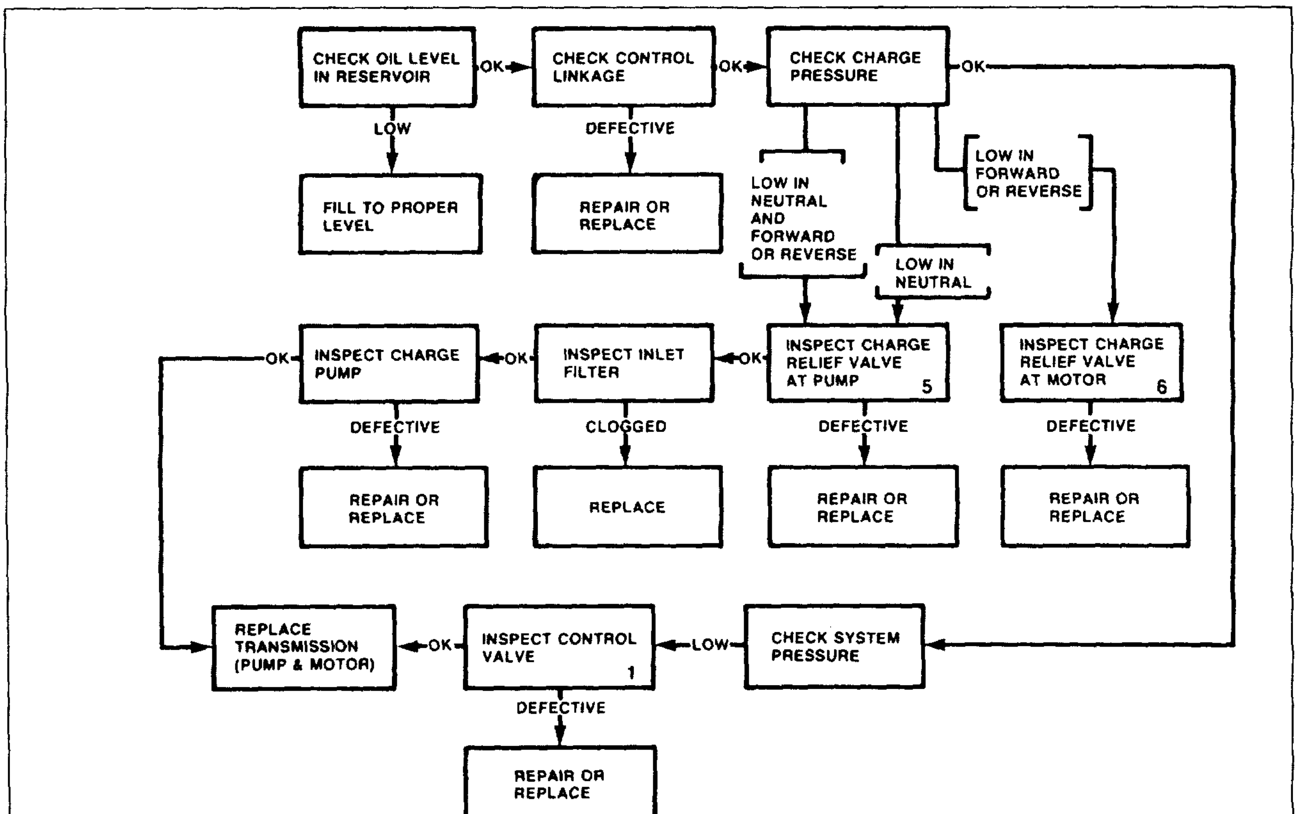
SYSTEM OPERATING HOT



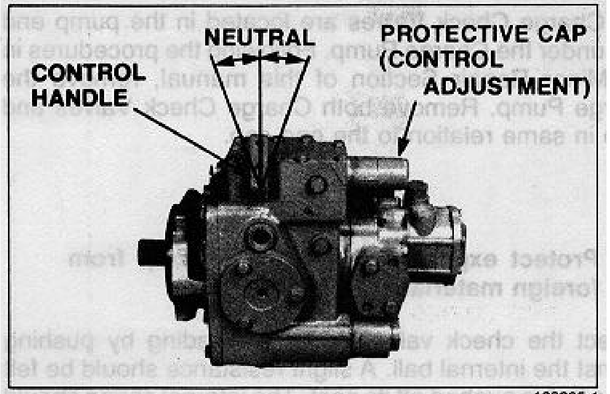
TRANSMISSION OPERATES IN ONE DIRECTION ONLY



SYSTEM RESPONSE IS SLUGGISH



SYSTEM WILL NOT OPERATE IN EITHER DIRECTION



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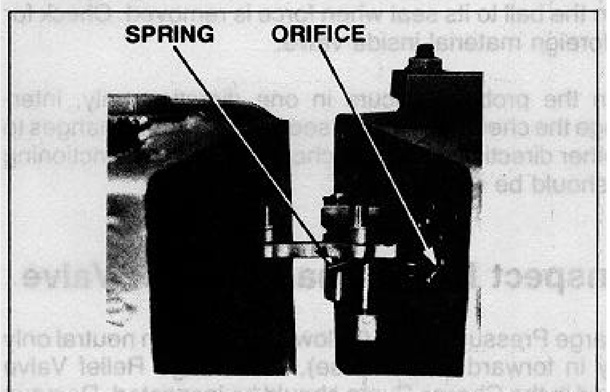
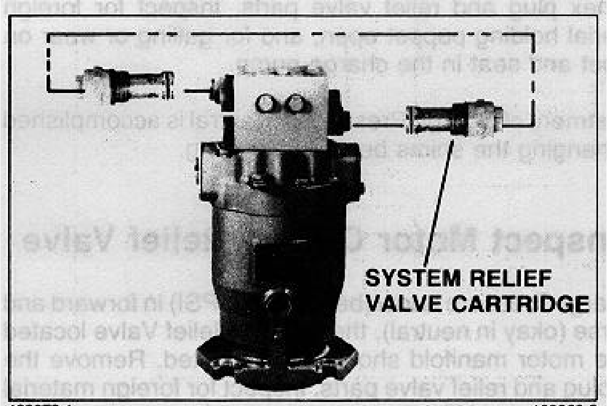


103361-2



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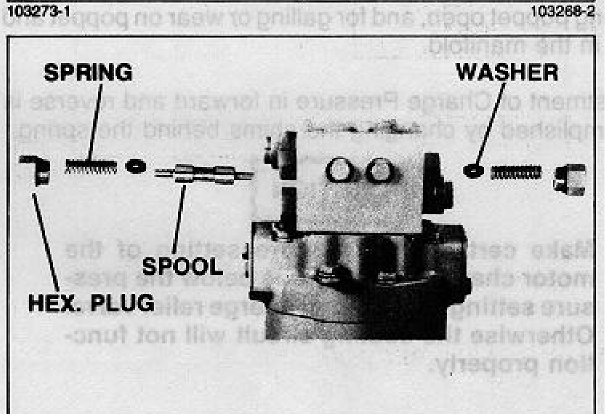

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1. Inspect Manual Displacement Control

Disconnect the external control linkage from the control handle and check for neutral operating with control handle. Releasing control handle should allow the pump to return to neutral. If operation is satisfactory with external control linkage disconnected, the problem is not in the hydrostatic transmission.

If operation is not satisfactory with external control linkage disconnected from control handle, the control may be misadjusted. Adjustment procedures are contained in this manual.

NOTE:

Before proceeding with control adjustment the following inspection is recommended.

Remove the cap screws holding the control in place, and swing it away from housing and remove. Inspect visible linkages, torsion spring, and O-rings. Inspect for missing, plugged, or improper orifice.

2. 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. If so, one relief valve cartridge is either malfunctioning or does not have the proper setting. The first two (2) digits of the pressure setting are stamped on the end of the cartridge. Compare to machine specification.

CAUTION

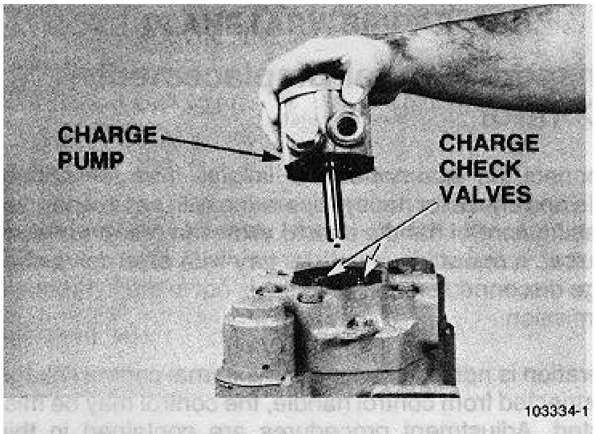
The relief valves are factory set and should not be disassembled further.

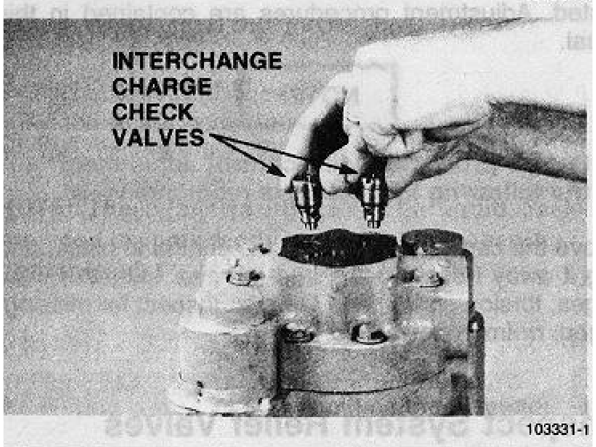
3. Inspect Shuttle Valve

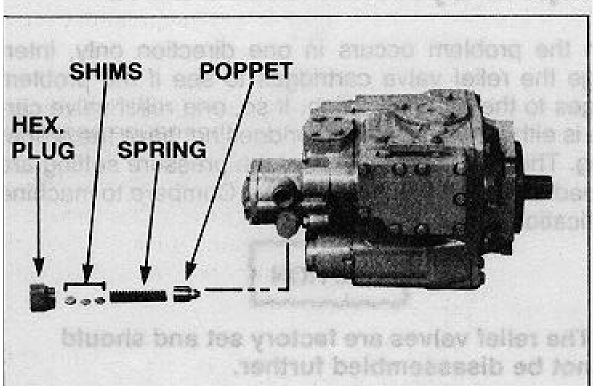
Remove the two (2) hex plugs and the shuttle valve parts. Inspect for broken or damaged parts and proper orientation. Washers must go between spool and springs. Inspect to see if spool moves smoothly in its bore.

NOTE:

The spool and manifold are matched and cannot be replaced separately.







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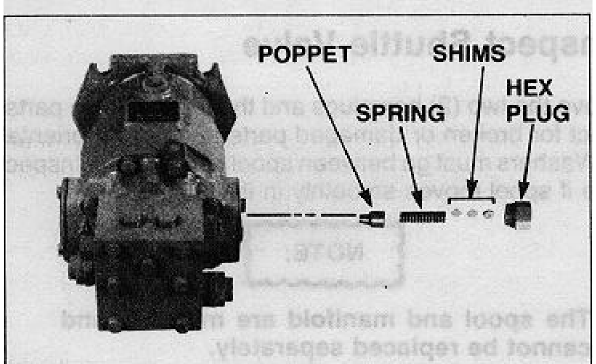

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4. Inspect Charge Check Valves

The Charge Check Valves are located in the pump end cap, under the Charge Pump. Following the procedures in the Minor Repair Section of this manual, remove the Charge Pump. Remove both Charge Check Valves and keep in same relation to the end cap.

NOTE:
Protect exposed cavities into pump from foreign material.

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 valve.

When the problem occurs in one direction only, interchange the check valves and see if the problem changes to the other direction. If so, one check valve is malfunctioning and should be replaced.

5. Inspect Pump Charge Relief Valve

If Charge Pressure is low (below 190 ΔPSI) 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. Inspect for foreign material holding poppet open, and for galling or wear on poppet and seat in the charge pump.

Adjustment of Charge Pressure in Neutral is accomplished by changing the shims behind the spring.

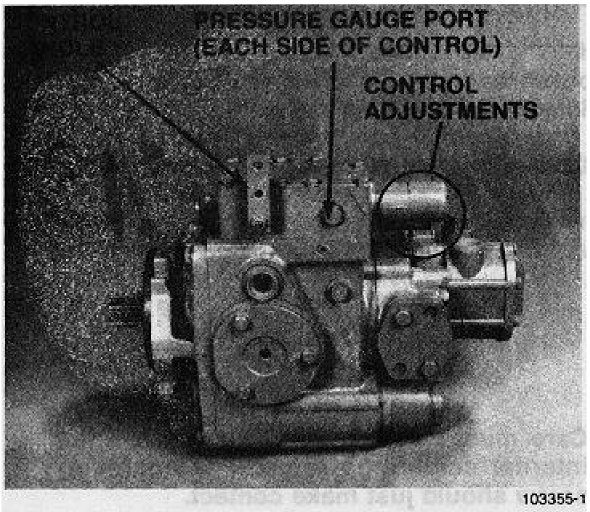
6. Inspect Motor Charge Relief Valve

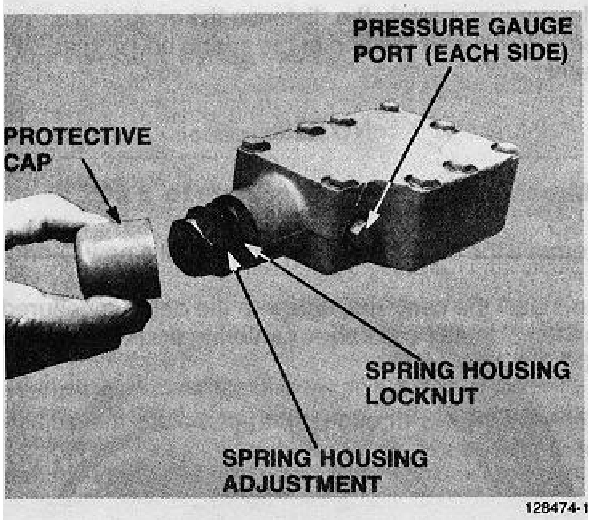
If Charge Pressure is low (below 160 a ΔPSI) in forward and reverse (okay in neutral), the Charge Relief Valve located in the motor manifold should be inspected. Remove the hex plug and relief valve parts. Inspect for foreign material holding poppet open, and for galling or wear on poppet and seat in the manifold.

Adjustment of Charge Pressure in forward and reverse is accomplished by changing the shims behind the spring.

CAUTION
Make certain the pressure setting of the motor charge relief valve is below the pressure setting of the pump charge relief valve. Otherwise the cooling circuit will not function properly.

CONTROL ADJUSTMENTS





Manual Displacement Control

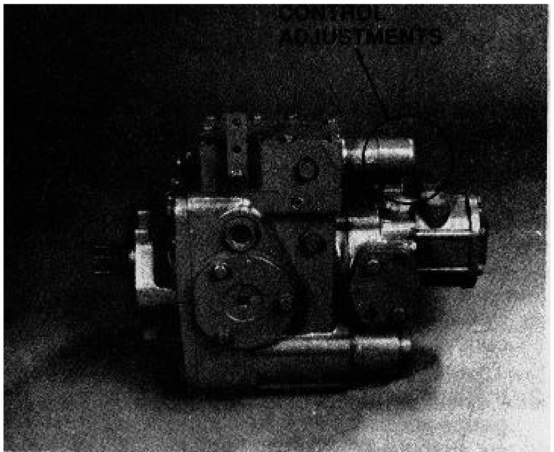
Spool Centering

CAUTION

The following procedure requires that steps be taken to disable the machine in the event the pump should go into stroke (raise drive wheels off ground, etc.).

1. Remove the external control linkage from the control handle.
2. Install two 300 PSI gauges into the pressure gauge ports on either side of the control (7/16-12 str. thd O-ring).
3. Start the prime mover and operate at normal speed.
4. Remove the protective cap. Loosen the spring housing locknut. Turn the spring housing adjustment CW or CCW until the two gauges read the same pressure. This equal pressure will be the “base” pressure.
5. Turn the spring housing adjustment CW until one of the gauges begins to raise above the “base” pressure. Note the amount of adjustment rotation.
6. Keeping track of the amount of rotation, turn the adjustment CCW until the other gauge begins to raise above the “base” pressure.
7. Note the amount of rotation from the previous adjustment position (amount turned CCW in Step 6). Turn the adjustment CW by one-half (½) that amount.
8. Holding the adjustment in place, tighten the spring housing locknut to 60-100 ft. lbs.
9. If the pump consistently returns to neutral, after cycling the control several times, the neutral adjustment is complete.
10. If the pump does not consistently return to neutral, stop the prime mover and refer to the procedure on the following page.
11. Stop the prime mover, install protective cap, remove the two (2) pressure gauges and install the pressure port plugs. Torque to 10-20 ft. lbs.

    Install and adjust, if necessary, the external directional control linkage.



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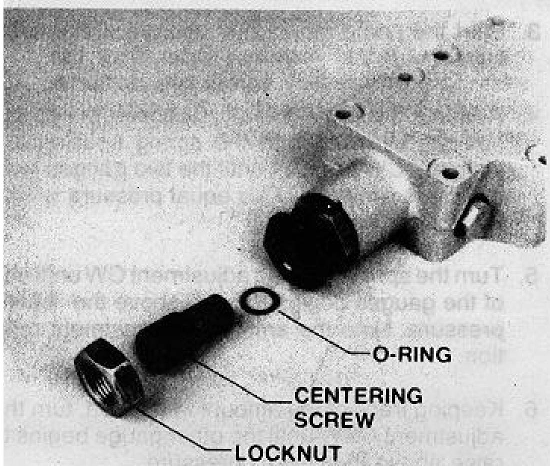

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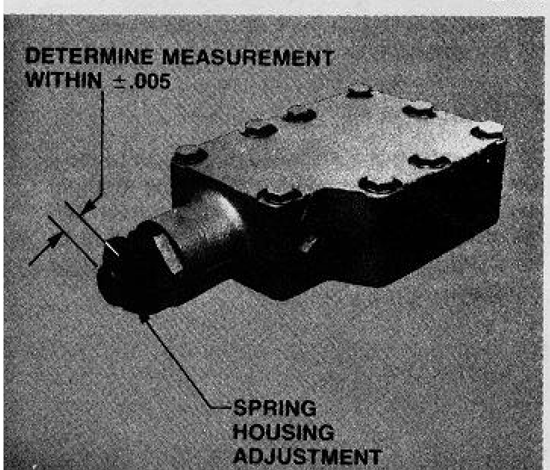

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Centering Spring

12. Holding the spring housing adjustment in place, loosen and remove the centering screw locknut. Remove the centering screw.

13. Remove the O-ring from centering screw and discard.

14. Install the centering screw, back into the control, until it just contacts the internal centering mechanism.

CAUTION

Care must be taken not to compress the internal centering spring. The centering screw should just make contact.

15. Measure accurately the distance the centering screw extends beyond the end of the spring housing adjustment.

NOTE:

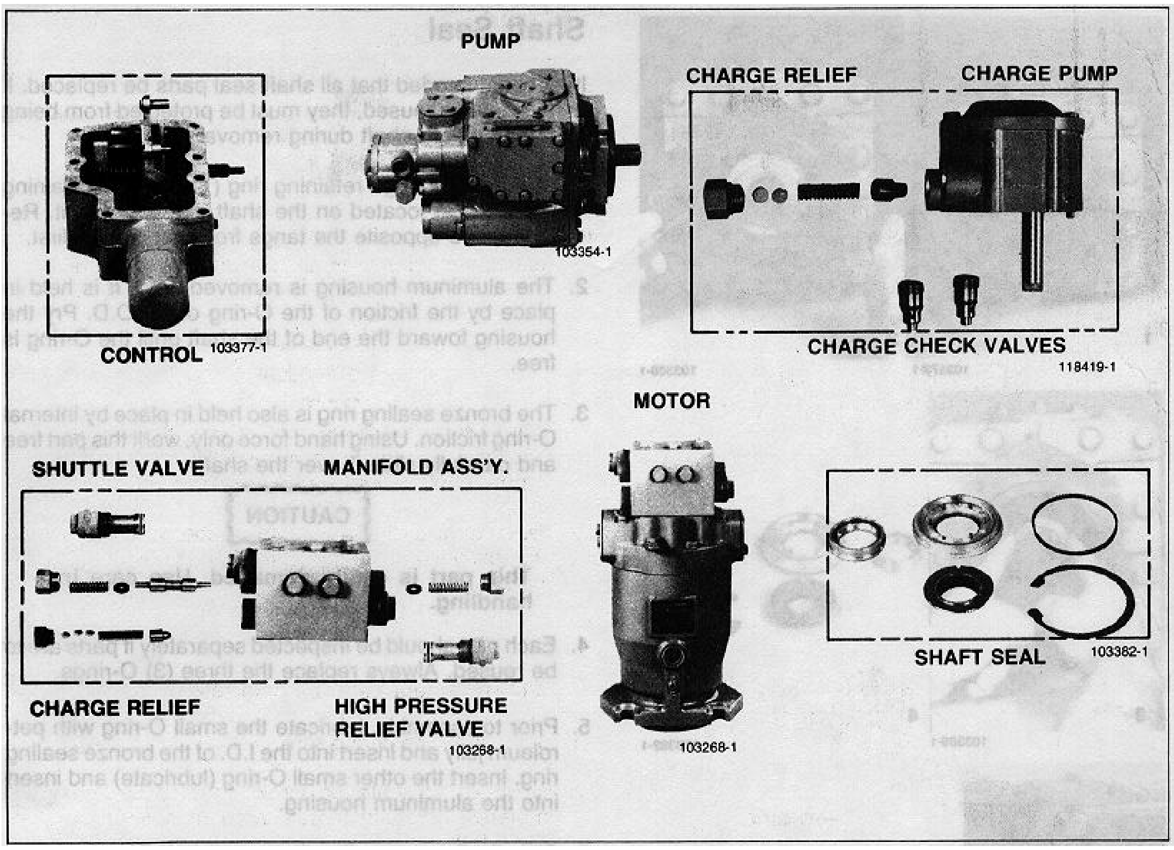
Measurement must be accurate to ± .005".

16. Remove the centering screw and install a new O-ring.

17. Re-install the centering screw to the depth measured in Step 5. Install and torque centering screw locknut to 30-50 ft. lbs.

18. Repeat Steps 3 through 11 to complete the adjustment procedure.

MINOR REPAIRS



Introduction

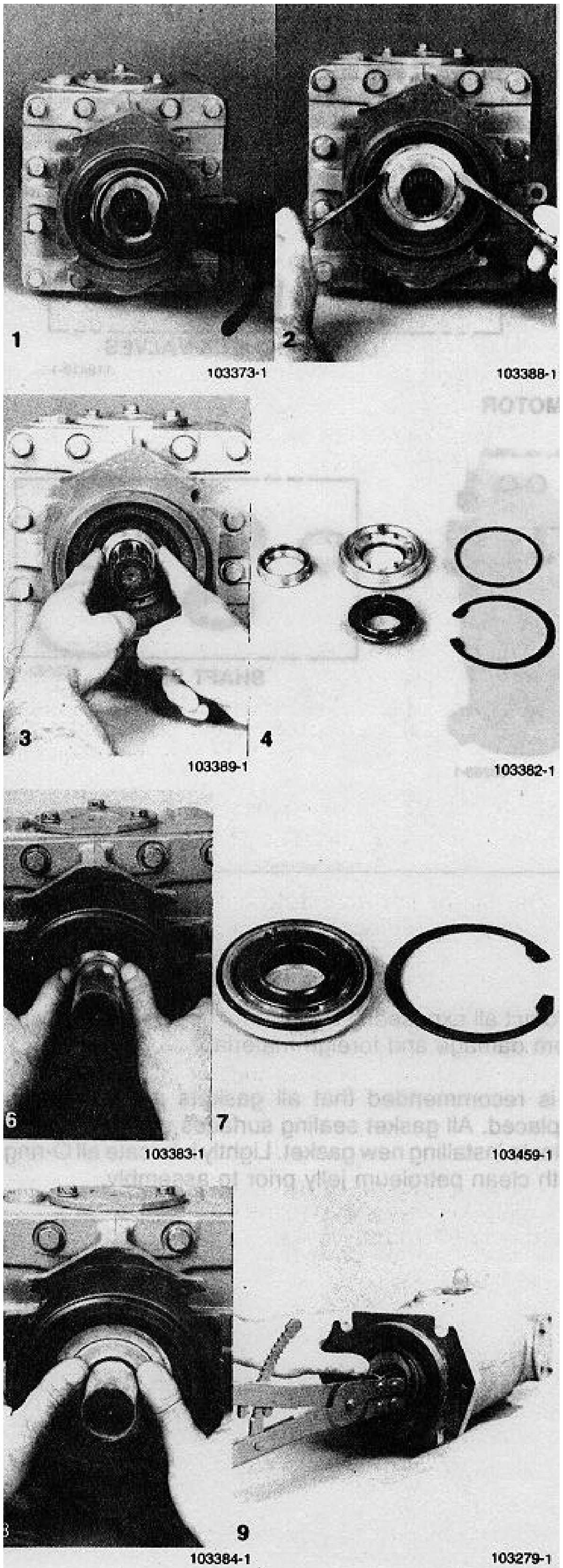
The areas of repair indicated are classed as minor repairs and may be performed, following the procedures in this section, without voiding the unit warranty. Although specific units are illustrated, these procedures apply to all series and types of units in the Heavy Duty Family.

General

Cleanliness is a primary means of insuring satisfactory transmission life, on either new or repaired units. Cleaning parts by using a solvent wash and air drying is adequate, providing clean solvent is used. As with any precision equipment, the internal mechanism and related items must be kept free of foreign materials and chemicals.

Protect all exposed sealing surfaces and open cavities from damage and foreign material.

It is recommended that all gaskets and O-rings be replaced. All gasket sealing surfaces must be cleaned prior to installing new gasket. Lightly lubricate all O-rings with clean petroleum jelly prior to assembly.



Shaft Seal

It is recommended that all shaft seal parts be replaced. If parts are to be reused, they must be protected from being damaged by the shaft during removal.

1. Remove the large retaining ring (Truarc #7 Retaining Ring Pliers) located on the shaft end of the unit. Remove side opposite the tangs from the groove first.
2. The aluminum housing is removed next. It is held in place by the friction of the O-ring on its O.D. Pry the housing toward the end of the shaft until the O-ring is free.
3. The bronze sealing ring is also held in place by internal O-ring friction. Using hand force only, work this part free and carefully slide it over the shaft.

CAUTION

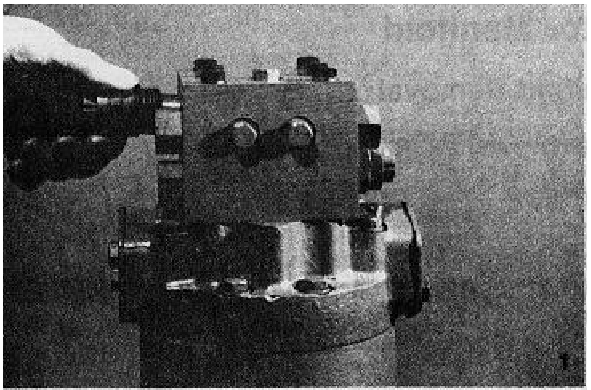
This part is easily damaged. Use care in handling.

4. Each part should be inspected separately if parts are to be reused. Always replace the three (3) O-rings.
5. Prior to assembly, lubricate the small O-ring with petroleum jelly and insert into the I.D, of the bronze sealing ring. Insert the other small O-ring (lubricate) and insert into the aluminum housing.
6. Slide the bronze sealing ring over the shaft and onto the shaft pilot diameter with the O-ring facing the unit. Work the O-ring into place using hand force only until it snaps into place.

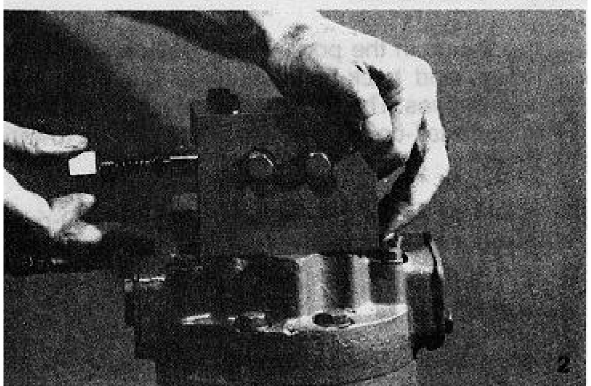
CAUTION

Protect parts from damage by the shaft.

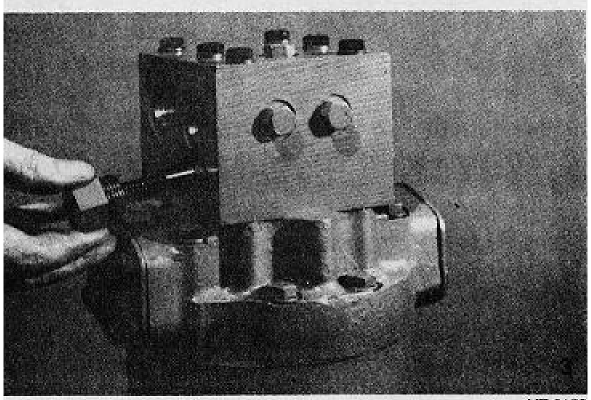
7. Insert the stationary seal pilot into the aluminum housing, locating the notch in the stationary seal over the pin in the housing. Lubricate the large O-ring and place on the housing. The stationary seal should have a slight spring load due to the springs in the housing. Make certain all six (6) springs are in place in the aluminum housing before sliding it into position.
8. Slide the aluminum housing into place against the bronze sealing ring using hand force only.
9. Compress the aluminum housing to expose the retaining ring groove. Install the retaining ring, with the beveled side out, putting the side opposite the tangs into the groove first. Be certain that the retaining ring has snapped into its groove completely.



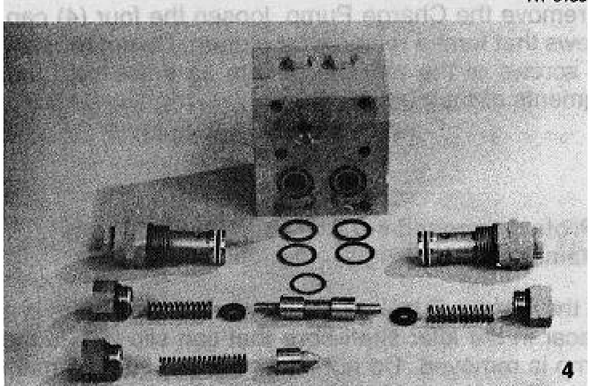
HT 3154



HT 3153



HT 3158



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Manifold Assembly Components

System Relief Valve

1. The System Relief Valves are cartridges that can be removed from the manifold (using 1 3/8" wrench) for inspection or replacement. These valves are interchangeable in either side of the manifold, providing the pressure settings are the same. The first two (2) digits of the pressure setting are stamped on the end of the valve.

CAUTION

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

When replacing, torque the cartridge to 30-70 ft. lbs.

Shuttle Valve

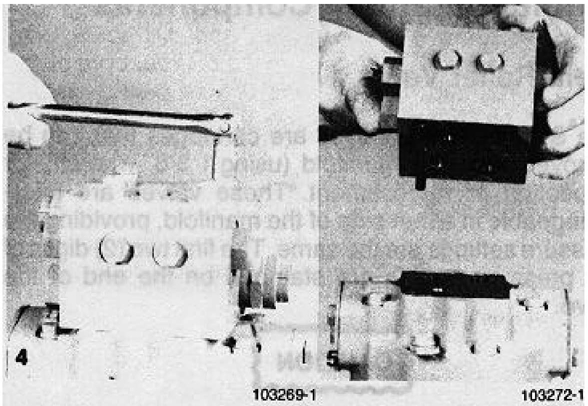
2. The Shuttle Valve can be removed for inspection by removing the two (2) hex plugs (using 1" wrench) and sliding out the springs, spacers, and spool. These parts are interchangeable and can be installed from either side. When assembling be certain the spacers are placed between the spool and springs. Torque the hex plugs to 60-100 ft. lbs.

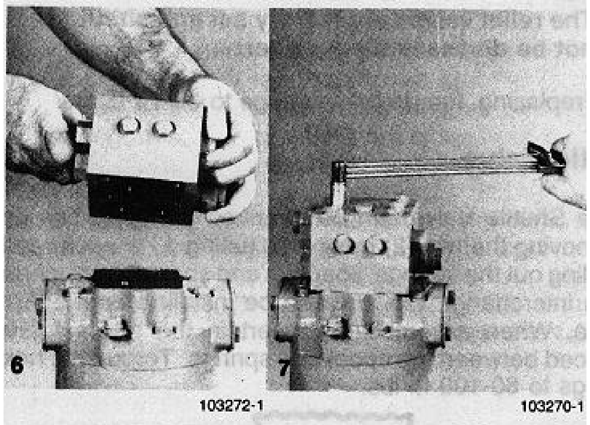
NOTE:

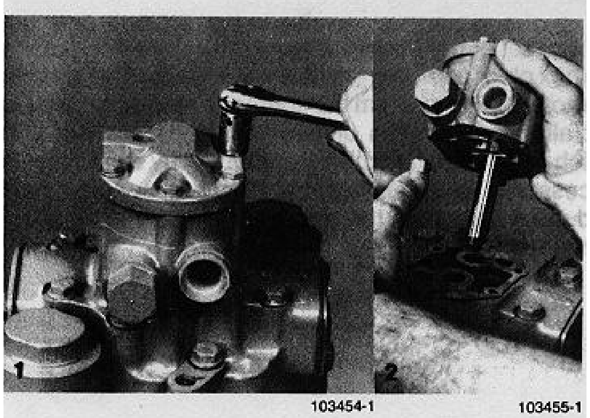
The spool and manifold are matched and cannot be replaced separately.

Charge Relief Valve

3. To inspect or replace the Charge Relief Valve, remove the hex plug (use 1" wrench) and the spring and poppet. Remove the shims from the counter bore of the plug. Do not alter these shims unless new parts are used, in which case adjusting the valve setting, by shimming, is necessary. To install, insert the poppet, spring, shims and plug. Be certain the shims are in place in the plug. Torque to 60-100 ft. lbs.







Motor Manifold

Manifold Removal

4. Remove the six (6) cap screws (use ½" wrench).
5. Lift the manifold off the motor end cap. The three (3) ports are sealed with O-rings. The two (2) ports adjacent to each other also have back-up rings on top of the O-rings. These back-up rings have a rectangular cross section and are slightly cupped where they mate with the O-rings.

Manifold Installation

6. Place the O-ring in the port with the full counter bore. The O-rings and back-up rings fit in the ports with machined grooves. The O-rings should be installed first and then the back-up rings with the cupped side toward the O-ring.
7. Install manifold on end cap being certain the O-rings and back-up rings remain in place. Torque cap screws to 16-21 ft. lbs.

Charge Pump and Charge Check Valves

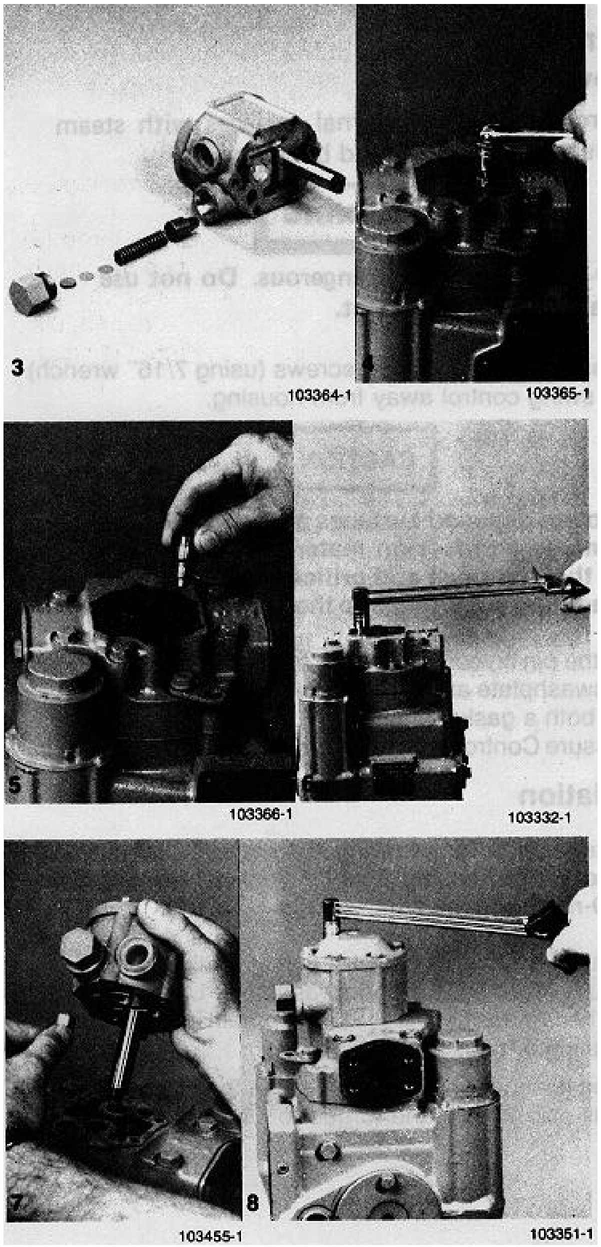
Removal

1. To remove the Charge Pump, loosen the four (4) cap screws that form a rectangular pattern. Do not remove the screws at the top and bottom as these hold the segments of the pump together.

NOTE:

Protect exposed surfaces and cavities from damage and foreign material.

2. Lift the Charge Pump off the pump end cap. There is a spacer in the idler shaft bore that can slip out as the pump is removed. Do not allow it to fall into the main pump. There is a gasket between the Charge Pump and end cap that should be discarded.



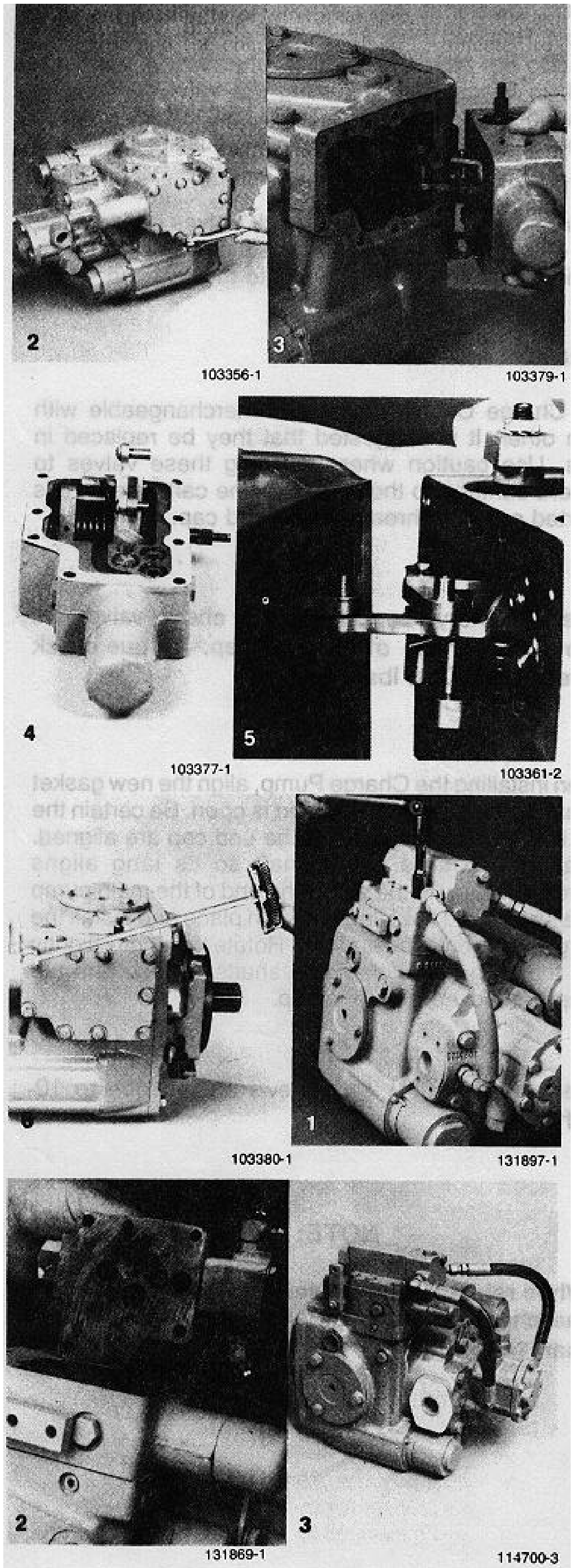
3. To inspect or replace the Charge Relief Valve, use a 1 wrench to remove the hex plug and the spring and poppet. Remove the shims from the counter bore of the plug. Do not alter these shims unless new parts are used, in which case adjusting the valve setting, by shimming, is necessary. To install, insert poppet, spring, shims and plug. Be certain shims are in place in plug. Torque to 30-60 ft. lbs.
4. The removal of the Charge Check Valves requires the use of a draglink socket. These check valves are cartridges which are threaded into the end cap.

Installation

5. The Charge Check Valves are interchangeable with each other. It is suggested that they be replaced in pairs. Use caution when installing these valves to prevent damage to the O-ring on the cartridge as it is inserted past the threads in the end cap.
6. **After assembly, be certain the check valves are below the surface of the end cap. Torque check valves to 30-40 ft. lbs.**
7. When installing the Charge Pump, align the new gasket so that the small relief valve port is open. Be certain the port in the charge pump and the end cap are aligned. Rotate the charge pump shaft so its tang aligns approximately with the slot in the end of the main pump drive shaft. Hold the idler spacer in place and install the charge pump onto the end cap. Rotate the pump slightly until the tang and slot on the shafts engage and the pump is solidly on the end cap.
8. Insert the four (4) cap screws and torque to 10-11 ft. lbs.

NOTE:

When reinstalling the vacuum inlet hose on the charge pump, do not tighten to more than 14 to 21 ft. lbs. torque.



Control

Removal

1. Thoroughly clean external surfaces with steam or clean solvent SD-2 and blow dry.

WARNING

SD-2 is potentially dangerous. Do not use near open flame or heat.

2. Remove the nine (9) cap screws (using 7/16" wrench) and swing control away from housing.

CAUTION

Protect exposed surfaces and cavities from damage and foreign material. Use caution so that the rings and orifice plate remain in place and do not fall into the pump housing.

3. Slip the pin on control linkage out of the link attached to the swashplate and remove control, The area is sealed with both a gasket and three (3) O-rings. The Variable Pressure Control does not have a linkage to disengage.

Installation

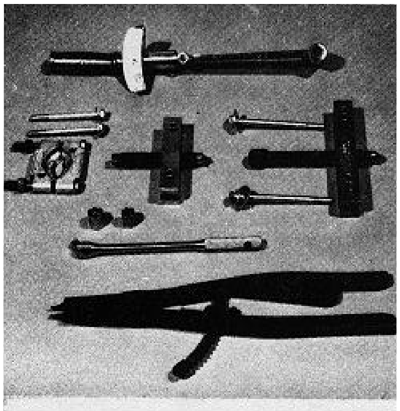
4. In preparation for installing the control, place a new gasket on the housing. Insert the orifice plate and three (3) O-rings into the control ports.
5. Engage the pin on the control linkage in the mating hole in the link attached to the swashplate. Use caution so that the O-rings and orifice plate remain in place and do not fall into the pump housing.
6. Swing the control into place against the pump housing. Install cap screws and torque to 10-11 ft. lbs.

MAJOR REPAIRS

FIXED DISPLACEMENT MOTOR

The procedures on the following pages are for complete disassembly and re-assembly of the unit. The equipment manufacturer should be consulted regarding any effect such repairs may have on warranty.

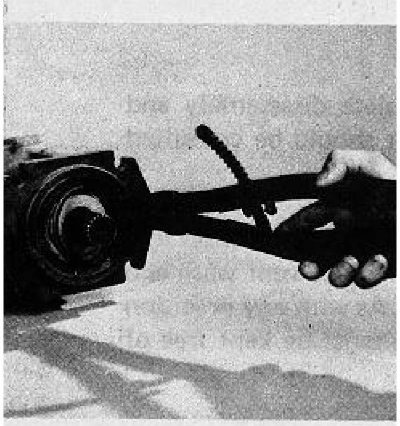
Cleanliness is the primary means of insuring satisfactory transmission life, either on new or repaired units. Cleaning parts by using a solvent wash and air drying is adequate, providing clean solvent is used. As with any precision equipment, the internal mechanism and related items must be kept free of chemical and particulate contaminants.



Special Tools

Certain tools are required that are not normally carried which are as follows:

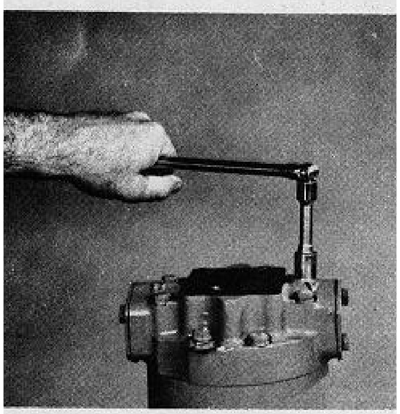
1. Waldes Truarc # 7 Retaining Ring Pliers
2. Torque Wrench
3. Tapered Bearing Puller
   Ref. Snap On Part Numbers
   Puller Bar CG350
   20-23- Series: Separator CJ950
   24-27 Series: Separator CJ951



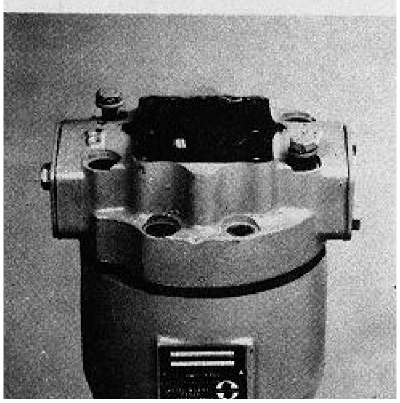
Remove the shaft seal as outlined under Minor repair procedures. The shaft seal must be removed before end cap screws are loosened to prevent the seal being damaged.

NOTE:
The end cap screws should not be loosened until the shaft seal has been removed.

Remove the valve manifold assembly as outlined under Minor repair procedures.



Remove all but two (2) of the hex head screws holding the end cap to the housing. Make sure the two remaining screws are opposing each other.

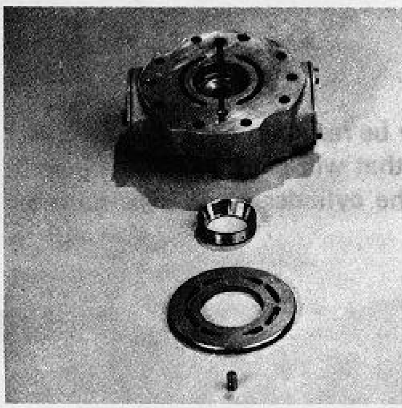


There is an internal spring loading on the end cap and as the last two (2) screws are loosened, it should begin to separate from the housing. Loosen these screws alternately until the end cap has fully separated from the housing, then remove the screws entirely.

The end cap can now be lifted off the motor; however, be certain that the valve plate does not fall and become damaged. If the valve plate tends to lift off with the end cap, hold it in place on the end cap and remove both parts together. If the valve plate remains on the bearing plate, remove it at this time.

CAUTION

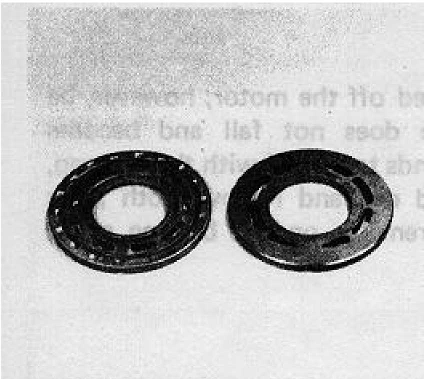
All surfaces exposed are critical and caution must be used to avoid damage.



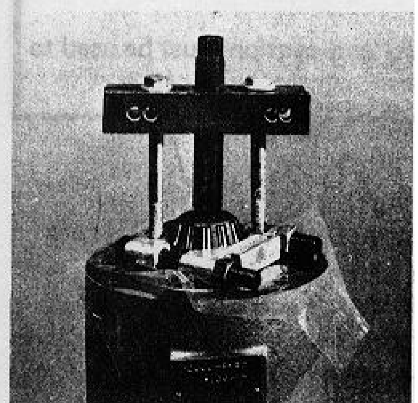
The end cap is actually an assembly consisting of a tapered bearing race which is a slip fit in the end cap and the valve plate locating pin. These parts should be removed from the end cap. There may or may not be a shim located under the bearing race which should be removed.

Remove the bronze bearing plate and pilot ring from the cylinder block.

If the pilot ring remains with the bearing plate, remove it at this time.



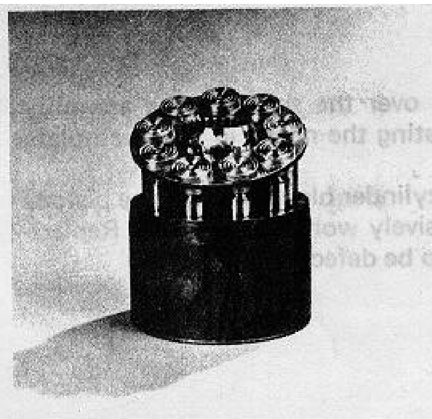
Note that the valve plate has four (4) tapered slots, two (2) at the top and two (2) at the bottom. These four (4) slots identify it as a motor valve plate and it is not interchangeable with the pump valve plate.



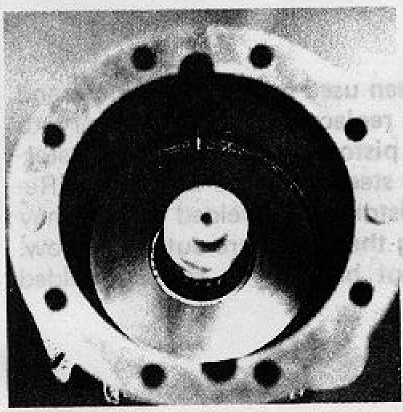
The tapered bearing must now be removed from the shaft. A bearing puller should be used that will pull against the inner race of the bearing. Protect the cylinder block face during this operation.

After removal of the bearing, slip the spacer out of the bore in the cylinder block.

Place the motor in a horizontal position. Slide the cylinder block assembly off the shaft while holding the external end of the shaft.

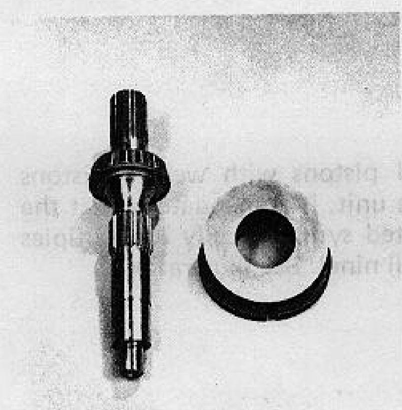


The cylinder block assembly usually comes out in one piece; however, some of the parts can separate. This does not present a problem as these parts can be reassembled later.



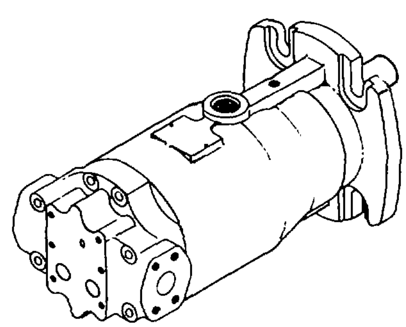
The swashplate has a notch which locates over a pin in the housing to prevent improper assembly; however, mark the housing for proper orientation of the swashplate during reassembly.

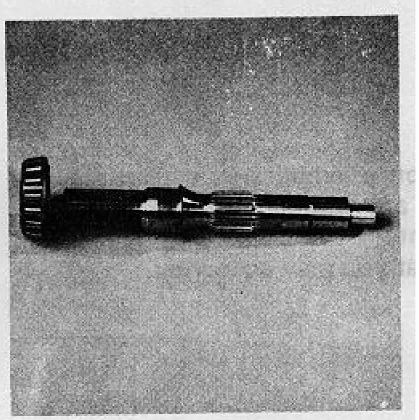
The fixed swashplate and shaft assembly can now be removed by grasping the shaft and lifting both parts out of the housing.



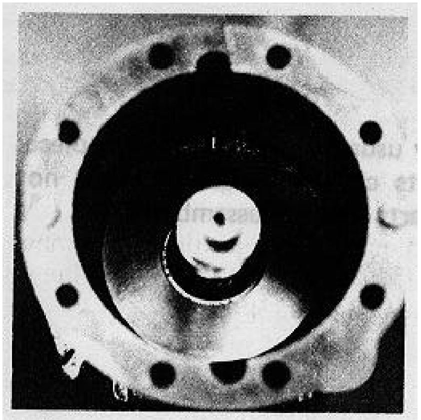
The tapered bearing can be pressed off the shaft if required. Be careful not to damage the seal diameter of the shaft while removing the bearing. The bearing race is press fit in the housing. If any of these parts are replaced, the shaft end play must be checked.

Drive Shaft
Bearings
End Cap
Housing



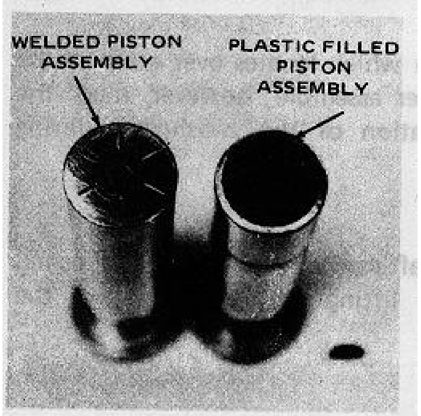


To check the shaft end play, assemble the shaft and bearings, housing, end cap and gasket. The shaft end play should be from .006" to .016". If adjustment is necessary, a shim can be placed under the bearing race in the end cap.

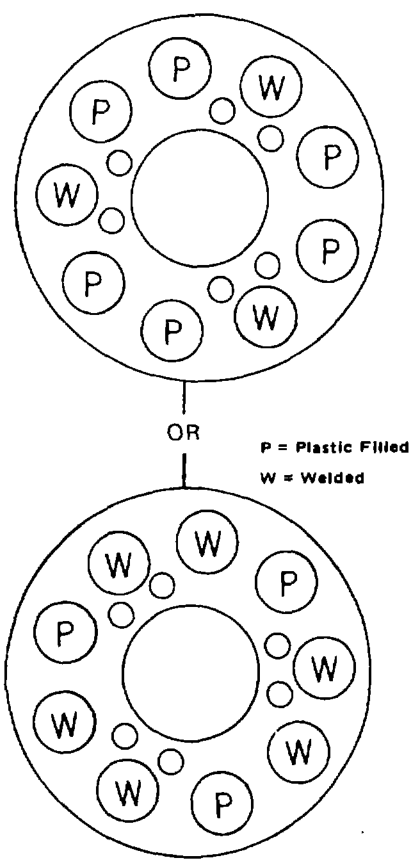


Place the fixed swashplate over the shaft-bearing assembly and place into housing locating the notch in the swashplate on the pin in the housing.

Prior to reassembly of the cylinder block, inspect the pistons for contamination or excessively worn slipper pads. Replace any pistons that are found to be defective.

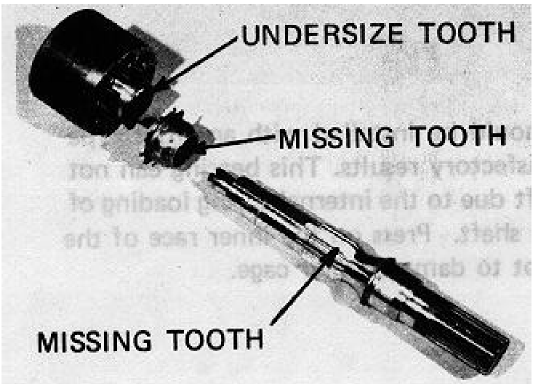


Two types of pistons have been used in 20 Series pumps and motors. Prior to any piston replacement it is necessary to check the construction of all pistons in the cylinder to determine if they are the welded steel or plastic filled type. Replacement of plastic filled pistons with welded pistons may be accomplished by following the procedure outlined below. Plastic filled pistons may not be used to replace welded piston assemblies.

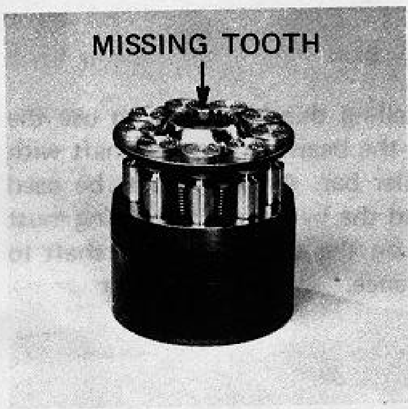


When replacing plastic filled pistons with welded pistons during overhaul or repair of a unit, it is mandatory that the welded pistons be incorporated symmetrically in multiples of three (either three, six, or all nine). See illustrations.

Do not replace welded piston assemblies with plastic filled piston assemblies; however, any plastic filled piston assemblies that you have in inventory can be used to replace existing plastic filled pistons that y6u may encounter.



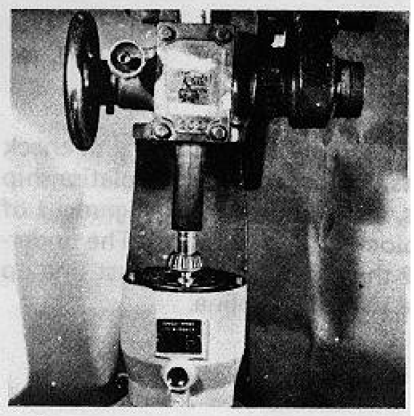
To install the cylinder block assembly it is necessary to check the alignment of certain parts. There is no special relationship of pistons to bores, springs, etc. However, the alignment of the ball guide and cylinder block splines iscritical. The undersized tooth in the spline of the cylinder block must line up with the missing tooth in the ball guide spline.



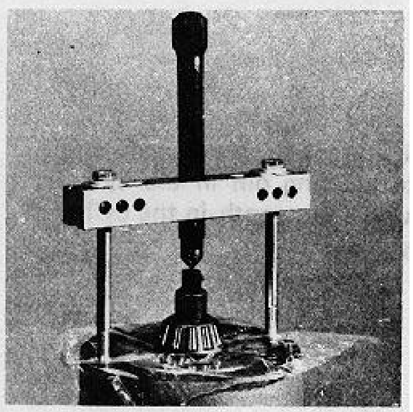
These in turn line up with a missing tooth on the shaft spline. The hole for the bearing plate locating pin in the cylinder block face is in line with the undersize tooth in the cylinder block and provides an assembly guide.

Lubricate the swashplate, slippers, pistons and bores with clean hydraulic oil. Hold the shaft on the external end, align the missing shaft tooth with the missing ball guide tooth using the locating pin hole as a guide. Slide the cylinder block assembly onto shaft and against swashplate face. When properly installed a spring load can be felt when pushing against the cylinder block.

Set the motor vertically and install the spacer in the center bore of the cylinder block.



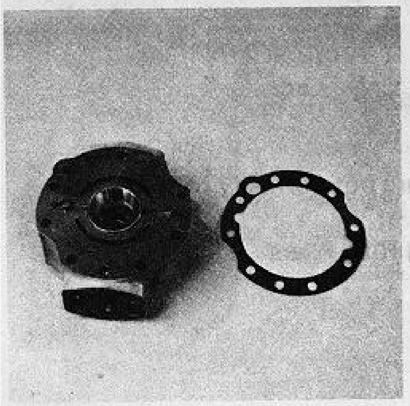
The tapered bearing should be installed with an arbor type press for the most satisfactory results. This bearing can not be driven onto the shaft due to the internal spring loading of the cylinder block and shaft. Press on the inner race of the bearing and use care not to damage roller cage.



An alternate method of installing this bearing is to use the bearing puller bar and press the bearing onto the shaft with the center screw of the puller bar. A spacer must be used between the center screw and the bearing. The bearing must be pressed on until it rests on the shoulder of the shaft to insure adequate bearing clearance.

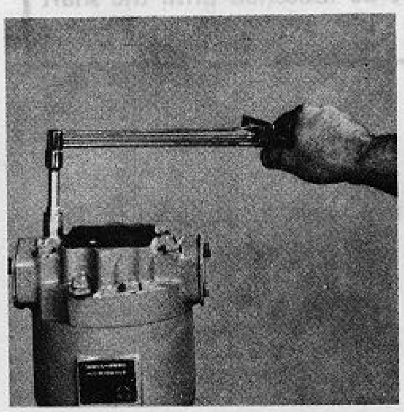
Install the pilot ring and the locating pin in the cylinder block.

Install the bearing plate so that the milled slot locates over the pin and the pilot ring fits in the center bore of the cylinder block. After installation lubricate the exposed surfaces with clean hydraulic oil.

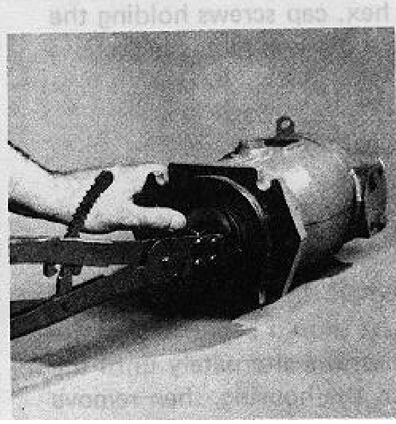


Assemble the bearing race shim (if required) and locating pin in the end cap. Lubricate the end cap face with clean hydraulic oil. Install the valve plate so that the milled slot locates over the pin and the center bore fits over the protruding bearing race. Check the valve plate to be certain it is a motor valve plate (has 4 tapered slots).

Place the end cap gasket on the housing, being certain the locating pins are in place, then install the end cap and valve plate. Hold the valve plate so it does not drop off during assembly. The end cap and gasket will only align with housing mounting holes in one position.



Install two (2) end cap screws and alternately tighten them until the internal spring has compressed far enough for the end cap to rest on the housing. Install the remaining screws.

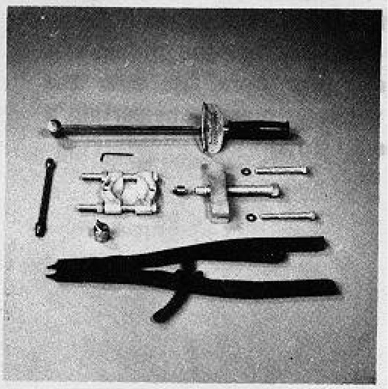


Install the shaft seal and valve manifold as outlined in the In-Warranty repair procedures.

Fill the motor housing with clean hydraulic oil.

MAJOR REPAIRS

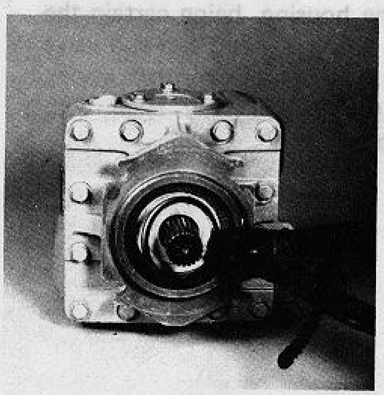
VARIABLE DISPLACEMENT PUMP



Special Tools

Certain tools are required that are not normally carried which are as follows:

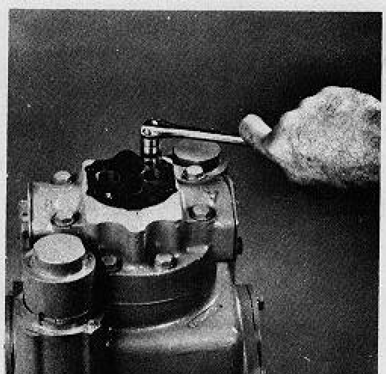
1. Waldes Truarc #7 Retaining Ring Pliers
2. Drag Link Socket
3. 12 Point, 3/16 Socket
4. Torque Wrench
5. Tapered Bearing Puller
   Ref. Snap on Part Numbers
   Puller Bar CG350
   Separator CJ950



Remove the shaft seal as outlined under Minor repair procedures. The shaft seal must be removed before the end cap screws are loosened to prevent the seal being damaged.

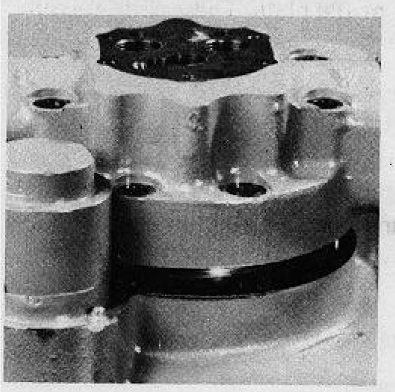
NOTE:

The end cap screws should not be loosened until the shaft seal has been removed.

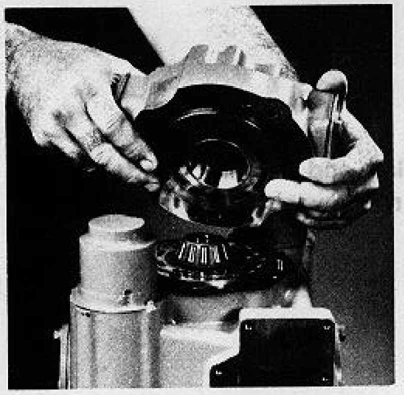


Remove charge pump and control valve as outlined under Minor repair procedures.

Remove all but two (2) of the hex. cap screws holding the end cap to the housing. Make sure the two remaining screws are opposing each other.



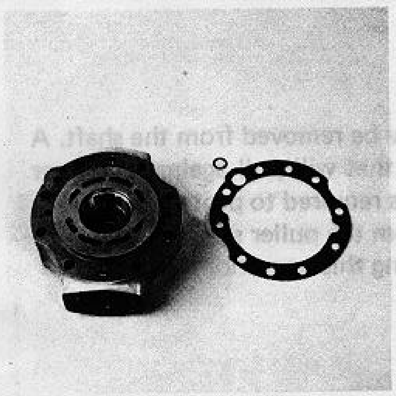
There is an internal spring loading on the end cap and as the last two (2) screws are loosened, it should begin to separate from the housing. Loosen these screws alternately until the end cap has fully separated from the housing, then remove the screws entirely.



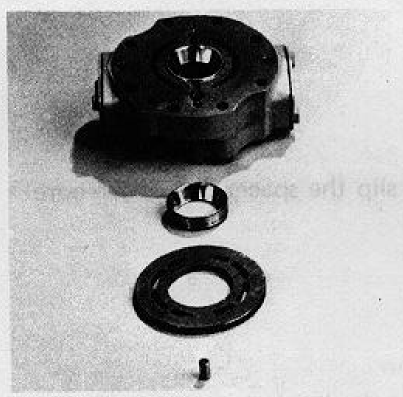
The end cap can now be lifted off the pump; however, be certain that the valve plate does not fall and become damaged. If the valve plate tends to lift off with the end cap, hold it in place on the end cap and remove both parts together. If the valve plate remains on the bearing plate, remove it at this time.

CAUTION

All surfaces exposed are critical and caution must be used to avoid damage.



Note that the end cap is sealed to the housing with both a gasket and an O-ring.

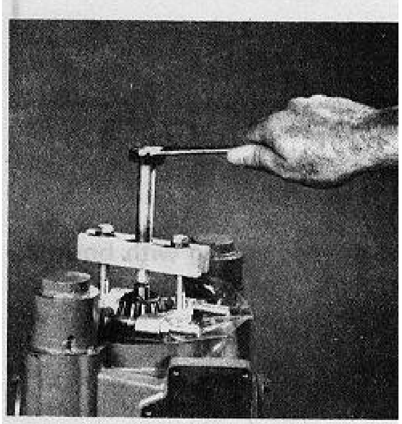


The end cap is actually an assembly consisting of a tapered bearing race which is a slip fit in the end cap and the valve plate locating pin. These parts should be removed from the end cap. There may or may not be a shim located under the bearing race which should be removed.

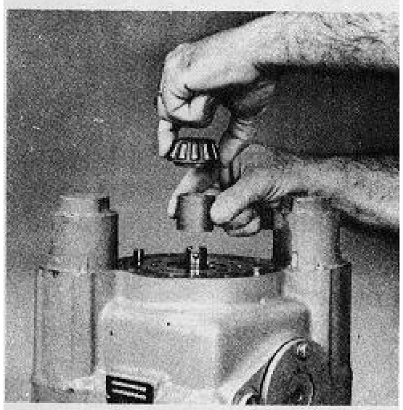
The pump valve plate has two (2) tapered slots, one (1) at the top and one (1). at the bottom of the plate. These slots are on opposite ports for different shaft rotations.

The valve plate on the left in the picture is for Left Hand (CCW) rotation. The valve plate on the right is for Right Hand (CW) rotation

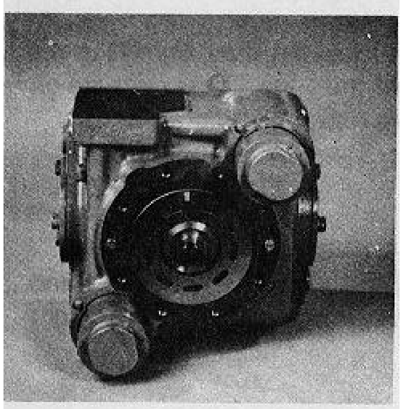
Remove the bronze bearing plate and the pilot ring from the cylinder block. If the pilot ring remains with the bearing plate, remove it at this time.



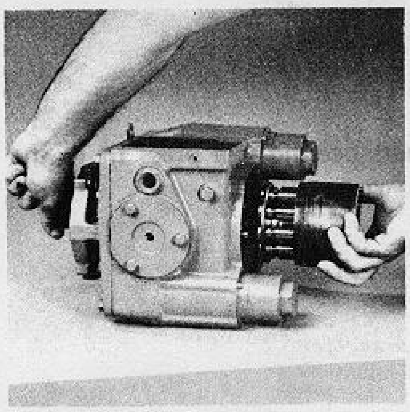
The tapered bearing must now be removed from the shaft. A bearing puller should be used that will pull against the inner race of the bearing. A spacer is required to protect the slot in the end of the pump shaft from the puller screw. Protect the face of the cylinder block during this operation.



After removal of the bearing, slip the spacer out of the bore in the cylinder block.

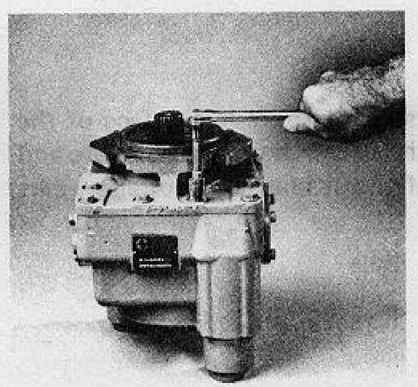


Place the pump horizontally in preparation for removal of the cylinder block assembly

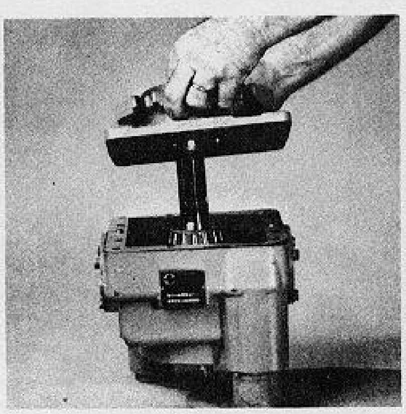


Slide the cylinder block assembly off the shaft while holding the external end of the shaft.

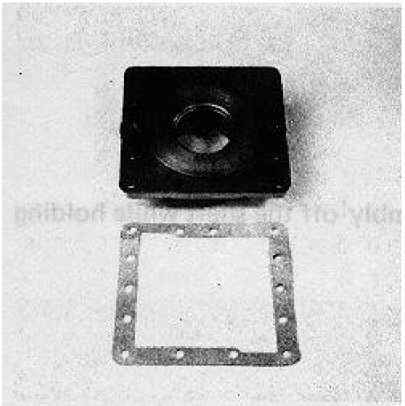
If the cylinder block assembly does not remain together during removal, it can be easily reassembled at a later time.



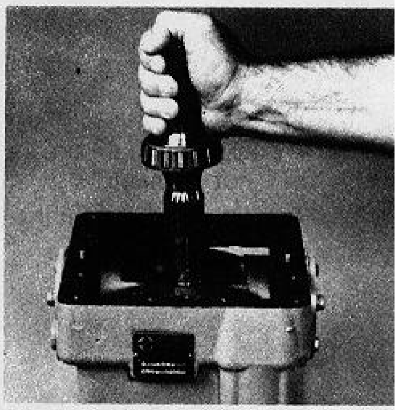
Set the pump on the servo housings and remove the front cover screws.



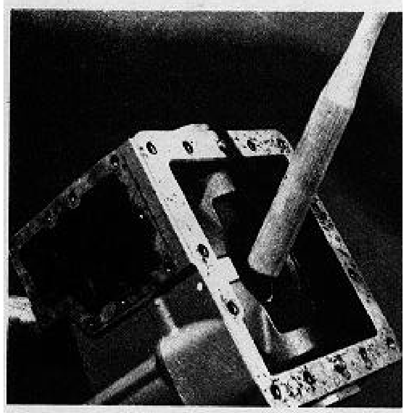
Lift off the front cover and gasket.



The race for the tapered shaft bearing is a press fit in the front cover.

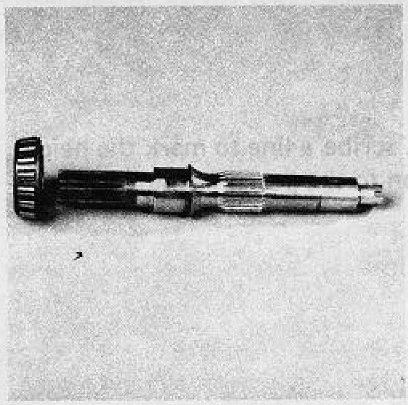


Lift the shaft and bearing out of the center hole of the swashplate.

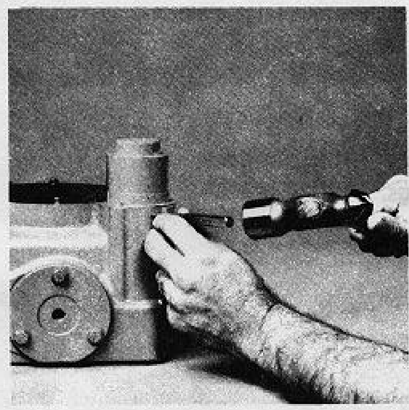


Remove thrust plate from its counterbore in the face of the swashplate. Reach through the center hole in swashplate and push against exposed edge of thrust plate. Do not allow part to fall and become damaged.

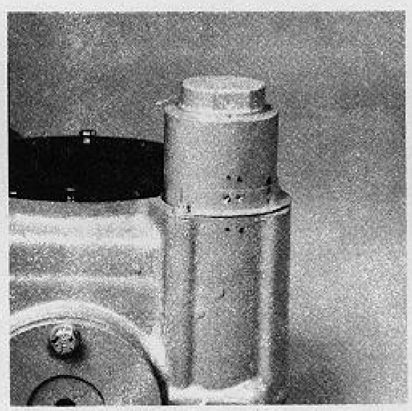
Thrust plate.



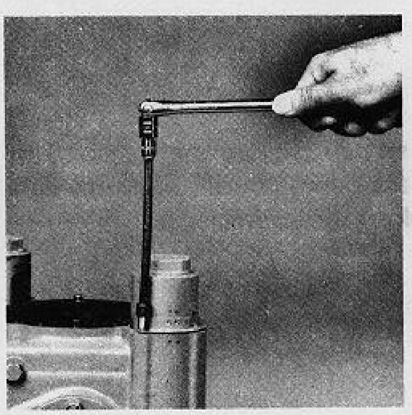
The tapered bearing can be pressed off the shaft if required. Be careful not to damage the seal diameter of the shaft while removing the bearing.



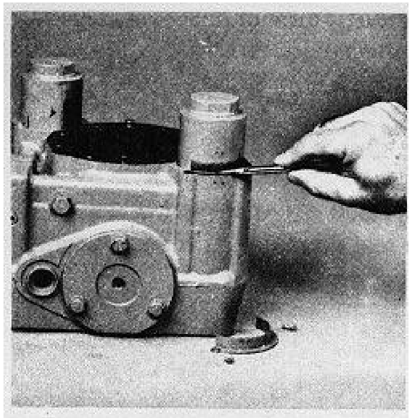
From this point on it is necessary to mark all parts so that neutral (zero swashplate angle) will be retained when the parts are reassembled. The swashplate is held in neutral by springs inside the servo housings. These springs are adjusted by turning the servo housings.



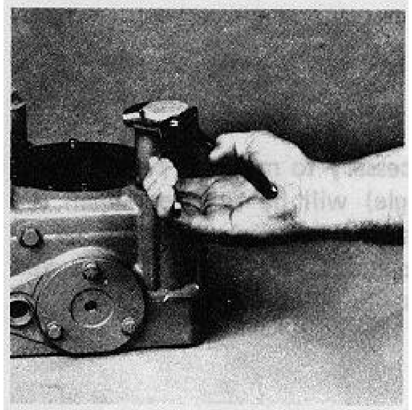
First, mark the servo housing for location to the pump housing. This set of marks should line up to show the rotational position of the servo housing to the pump housing.



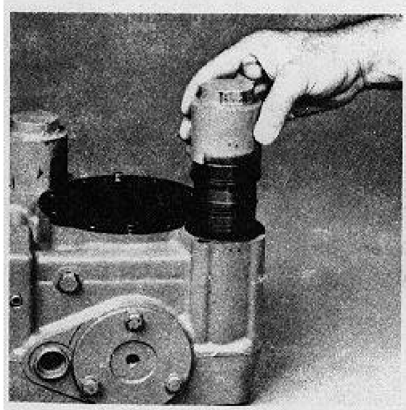
Remove the locking retainers using a 12 point, 3/16 socket for the cap screws.

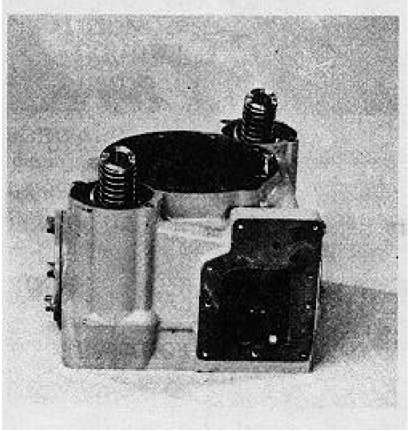


After removing the retainers, scribe a line to mark the height of the servo housing in relation to the pump housing.

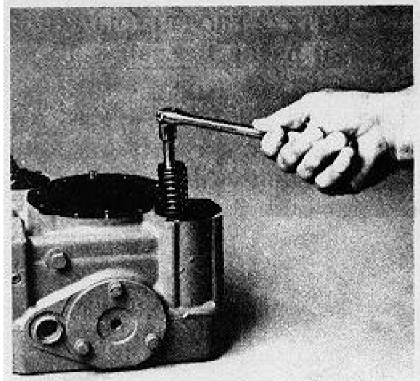


Unscrew the servo housings using channellock pliers to grip the flats on top of the housings.

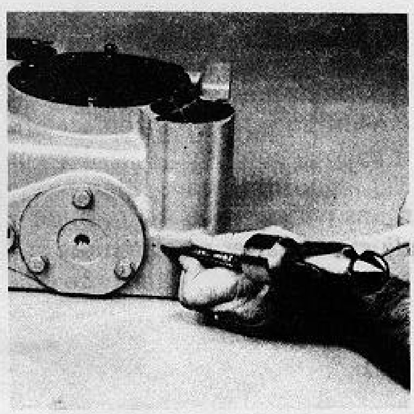




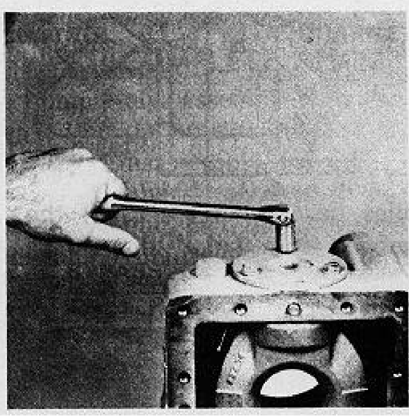
At this time the servo springs should be removed of replacement is necessary as the pump housing will provide a means of leverage when breaking the breaking the screws loose.



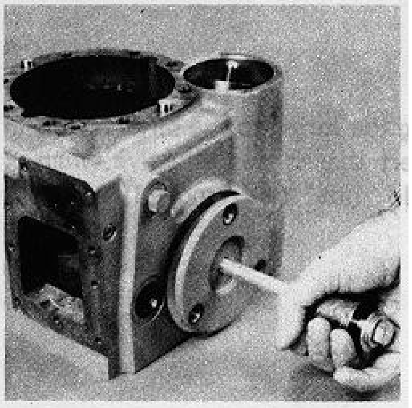
Do not reuse the screw holding the spring to the servo piston as it has a nylon locking insert that is not effective when reused. These springs should not be removed unless necessary.



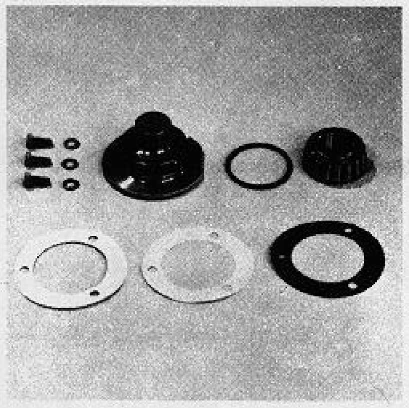
The trunnions should be marked to insure reassembly to the correct side of the housing.



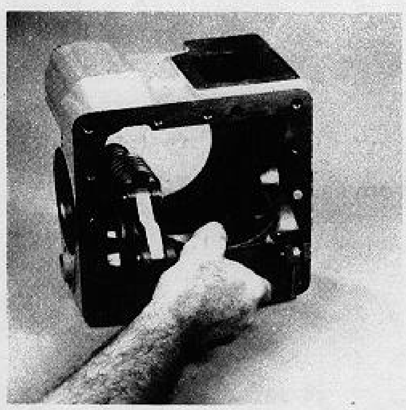
Remove the hex, head screws form each trunnion.



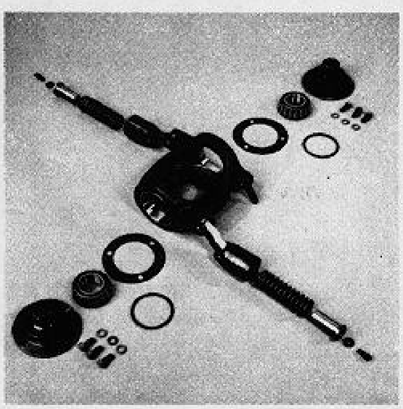
Friction caused by the O-ring on the trunnion may make it necessary to use a slide hammer to pull the trunnion assembly.



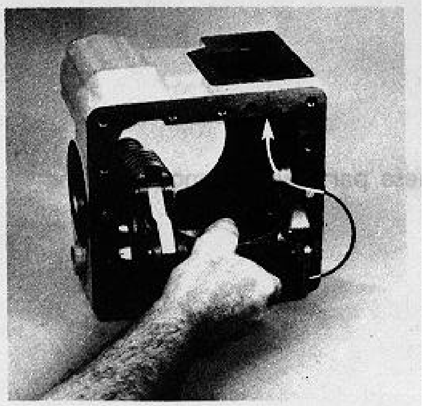
Be certain to keep the plastic shims with the proper trunnion to insure satisfactory bearing adjustment after reassembly.



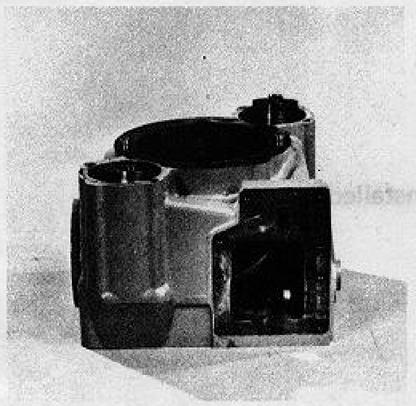
After both trunnion assemblies have been removed, the swashplate assembly can be removed form the pump housing.



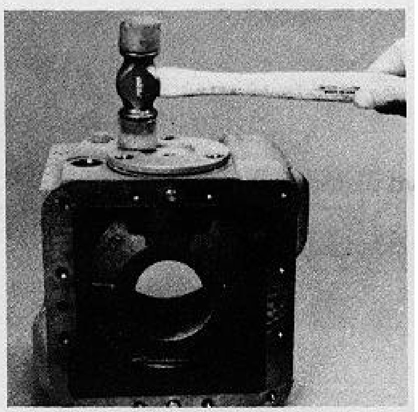
Layout of parts showing swashplate, servo pistons and springs, feedback link and trunnions.



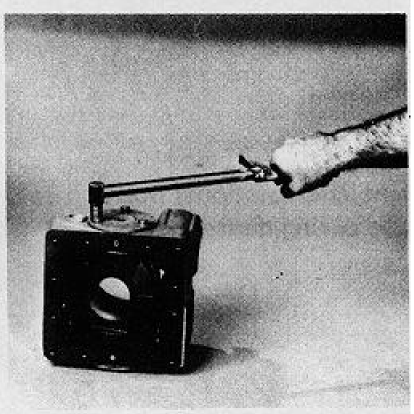
When installing the swashplate assembly into the housing, the feedback link must be laid back along the top of the swashplate so it can be reached through the opening for the control valve.



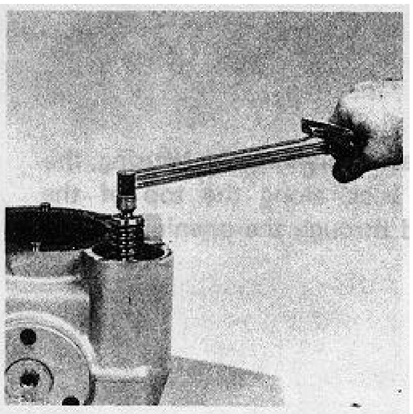
After installing swashplate be certain feedback link is accessible.



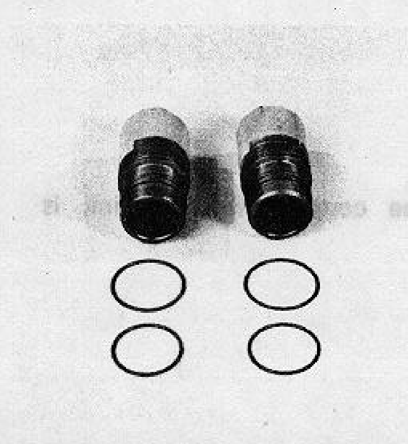
Install the trunnions, checking for proper orientation with the housing and tighten the cap screws. The swashplate should have no side play yet rotate freely. If necessary, alter the plastic shims to obtain the proper adjustment.



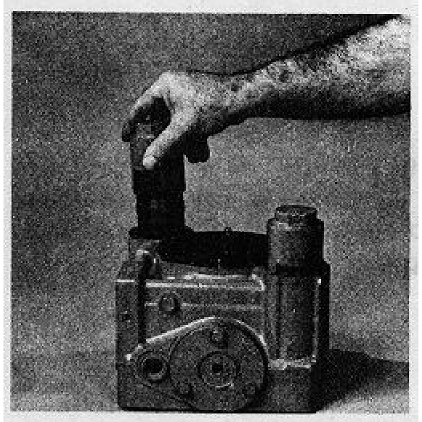
Install and tighten the trunnion cap screws.



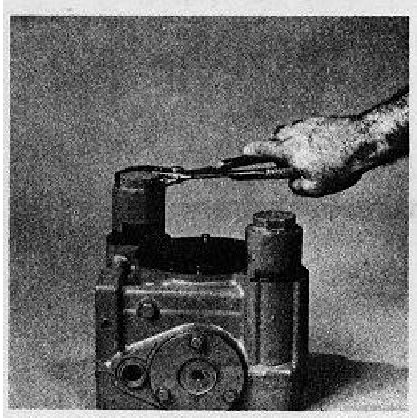
Install the servo springs, if these parts were removed, using new screws.



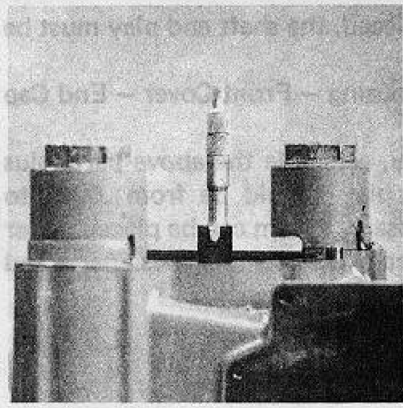
The servo housings should be installed next.



Slide the housing over the servo piston and thread it into the pump housing.

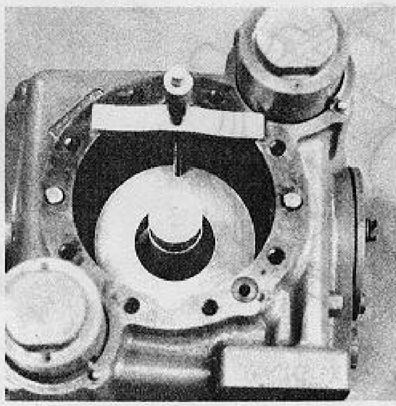


Adjust the housing to the height and rotational position as determined by the markings made during disassembly.



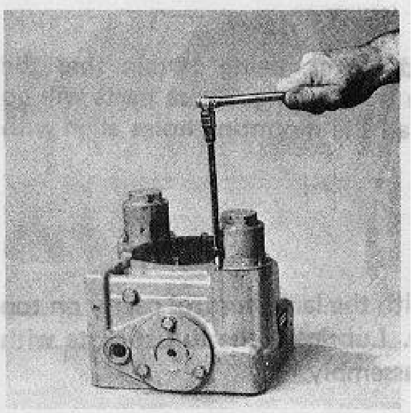
The neutral (zero angle) position of the swashplate must now be checked using a depth micrometer.

The thrust plate must be installed on the swashplate for this measurement. Measure the distance from the end cap mounting face of the pump housing to the face of the thrust plate 900 to the trunnions, at the outer edge of the thrust plate. Take the same measurement at a point 1800 (opposite edge of the thrust plate) from the first. These measurements must not vary more than .001" from each other.

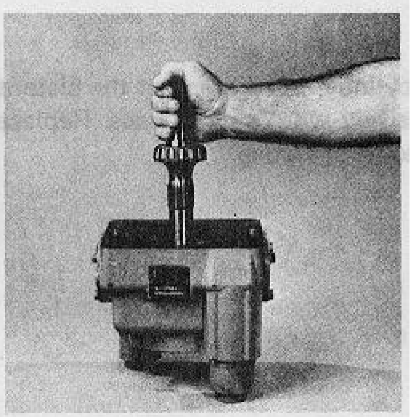


If adjustment is required follow these steps.

a. Back out both servo housings until the spring load is released on the swashplate (check by rocking swashplate).
b. Thread in each housing until spring load just starts to be felt on the swashplate.
c. Check measurements as described previously.
d. Thread each housing farther in until the measurements are within .001" of each other.

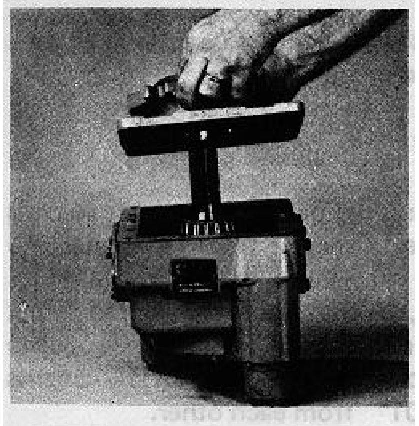


After adjustment has been completed, the retainers can be installed and peened into the locking slot on the housing.



Remove the thrust plate and set the pump on the servo housings.

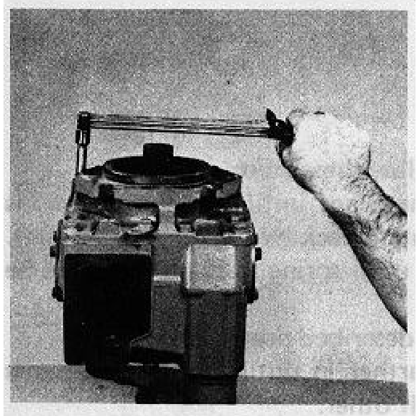
Insert the shaft and bearing assembly through the cast hole in the swashplate, allowing the bearing to rest on the cast leveled edge.

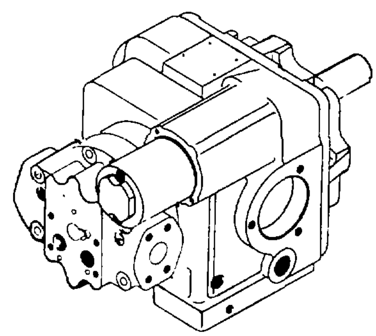


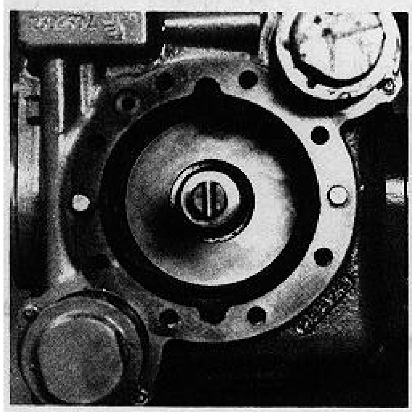
If any of those parts are replaced, the shaft end play must be checked.

Drive Shaft Bearings Housing Front Cover End Cap

To check the shaft end play, assemble the above parts plus the gaskets. The shaft end play should be from .006" to .016". If adjustment is necessary, a shim can be placed under the bearing race in the end cap. Disassemble these parts and resume reassembly procedure.

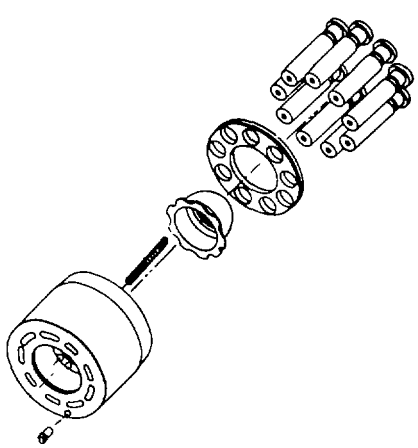




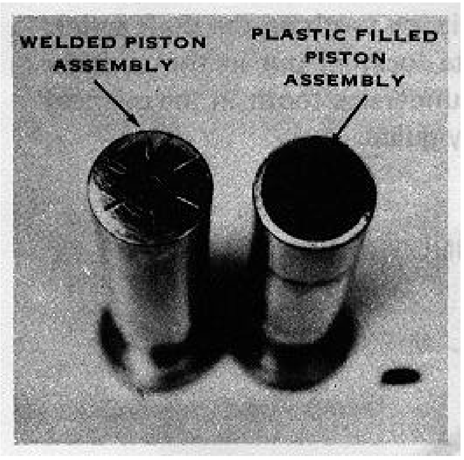


Install the front cover and gasket, being certain that the locating pins are in place in the housing. These parts will go on only one way and have all the mounting holes align with the housing.

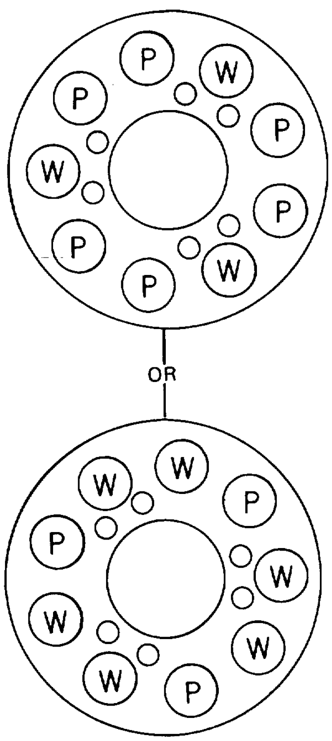
Turn the unit on its side with the large control cavity on top and install the thrust plate. Lubricate the thrust plate with clean hydraulic oil prior to assembly.



Prior to reassembly of the cylinder block, inspect the pistons for contamination or excessively worn slipper pads. Replace any pistons that are found to be defective.



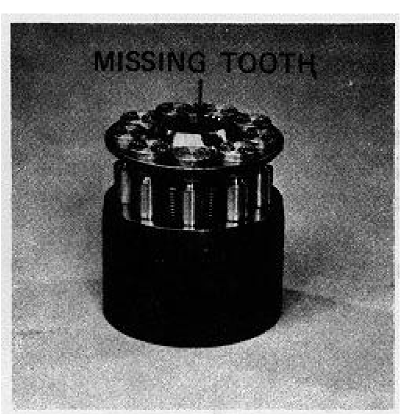
Two types of pistons have been used in 20 Series pumps and motors. Prior to any piston replacement it is necessary to check the construction of all pistons in the cylinder to determine if they are the welded steel or plastic filled type. Replacement of plastic filled pistons with welded pistons may be accomplished by following the procedure outlined below. Plastic filled pistons may not be used to replace welded piston assemblies.



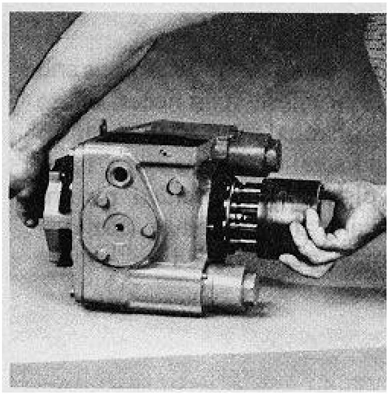
When replacing plastic filled pistons with welded pistons during overhaul or repair of a unit, it is mandatory that the welded pistons be incorporated symmetrically in multiples of three (either three, six, or all nine). See illustrations.

P = Plastic Filled
W = Welded

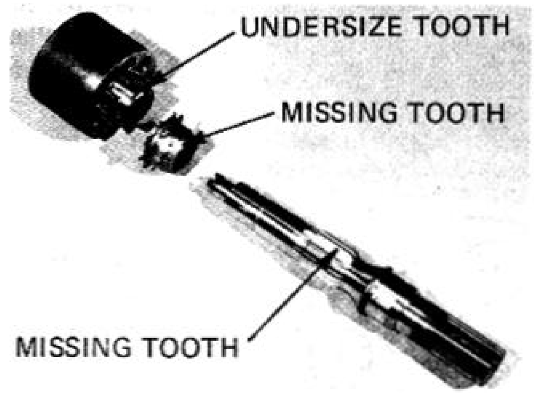
Do not replace welded piston assemblies with plastic filled piston assemblies; however, any plastic filled piston assemblies that you have in inventory can be used to replace existing plastic filled pistons that you may encounter.

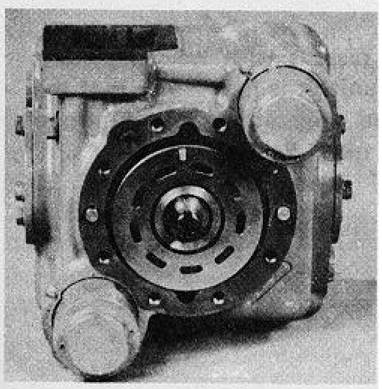


To install the cylinder block assembly, it is necessary to check the alignment of certain parts. There is no special relationship of pistons to bores, springs, etc.. However, the alignment of the ball guide and cylinder block splines is critical. The undersized tooth in the spline of the cylinder block must line up with the missing tooth in the ball guide spline.

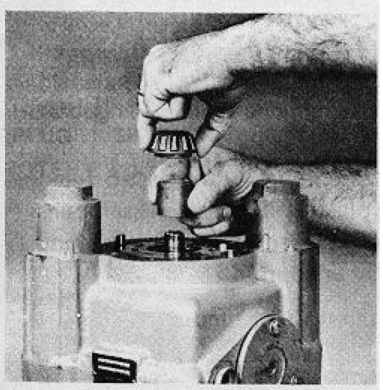


These in turn line up with a missing tooth on the shaft spline. The hole for the bearing plate locating pin in the cylinder block face is in line with the undersize tooth in the cylinder block and provides an assembly guide.

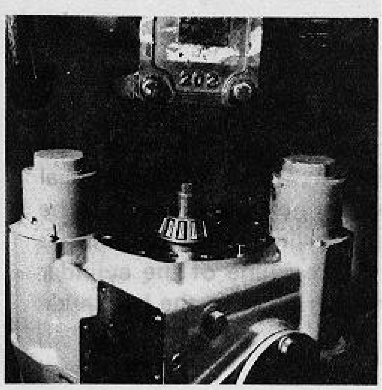




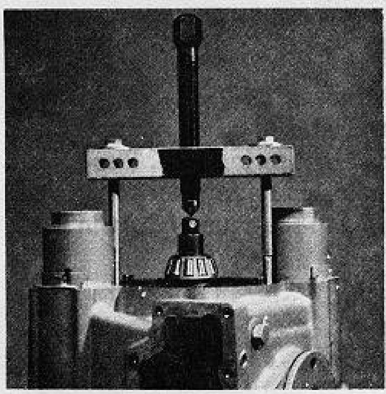
Lubricate the thrust plate, slippers, pistons, and bores with clean hydraulic oil. While holding the shaft on the external end, align the missing tooth of the shaft and ball guide by sighting through the control cavity. Using the locating pin hole as a guide, slide the cylinder block assembly onto the shaft and against the thrust plate. When properly installed a spring load can be felt when pushing against the cylinder block.



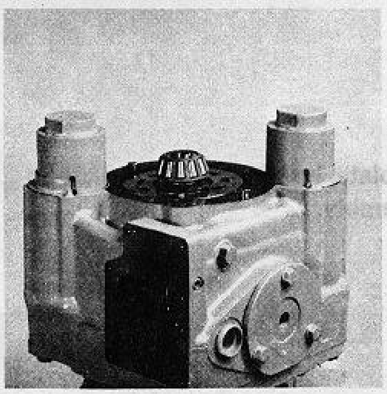
Set the pump vertically and install the spacer into the center bore of the cylinder block.



The tapered bearing should be installed with an arbor type press for the most satisfactory results. This bearing can not be driven onto the shaft due to the internal spring loading of the cylinder block and shaft. Press on the inner race of the bearing and use care not to damage roller cage.

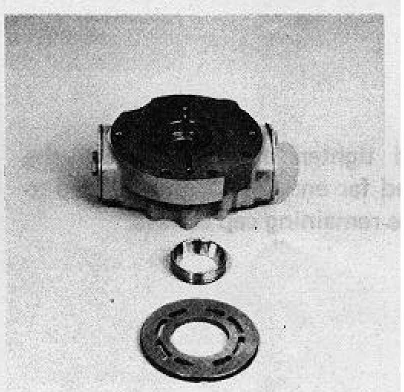


An alternate method of installing this bearing is to use the bearing puller bar and press the bearing onto the shaft with the center screw of the puller bar. A spacer must be used between the center screw and the bearing.

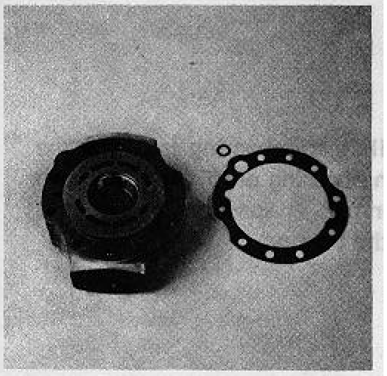


The bearing must be pressed on until it rests on the shoulder of the shaft to insure adequate bearing clearance.

Install the pilot ring in the bearing plate and the locating pin in the cylinder block. Install the bearing plate so that the milled slot locates over the pin and the pilot ring fits in the center bore of the cylinder block. After installation, lubricate the exposed surfaces with clean hydraulic oil.

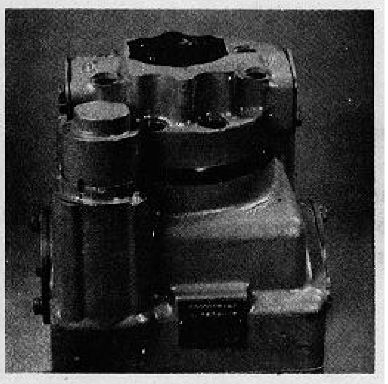


Assemble the bearing race, shim (if required) and locating pin in the end cap. Check the valve plate to be certain it is a pump valve plate (has 2 tapered slots) and that it is for correct rotation (slots point away from direction of rotation).

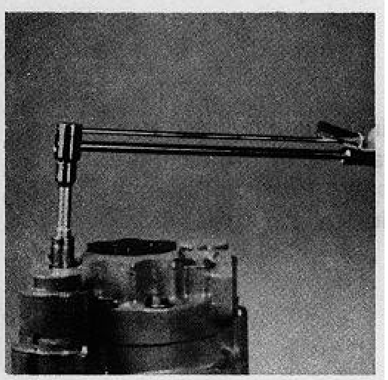


Lubricate the end cap face with clean hydraulic oil. Install the valve plate so that the slot locates over the pin and the center bore fits over the protruding bearing race. Place the end cap gasket on the housing, being certain the locating pins are in place, then install the O-ring in the counter bore in the housing.

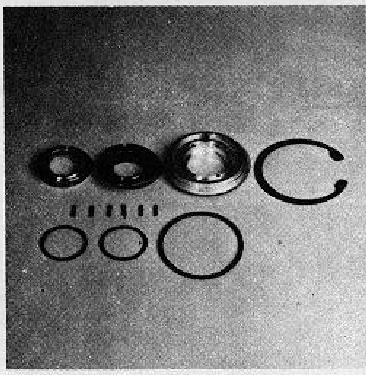
Install the end cap and valve plate, holding the valve plate so it does not drop off during assembly.



The end cap will align with the housing mounting holes in one position only.



Install two (2) screws and tighten alternately until the internal spring has compressed far enough for the end cap to rest on the housing. Install the remaining cap screws.



Install the shaft seal as the last step in reassembly of the basic pump.

Install the remaining major assemblies (Control Valve, Check Valves and Charge Pump) as outlined in the Minor repair procedures.

NOTE:
Fill the pump housing with clean hydraulic oil.

INSTALLATION TORQUE VALUES

INSTALLATION TORQUE VALUES (FT. LBS.)

VALVE MANIFOLD	16-21
END CAP	27-37
CHARGE PUMP	10-11
DISP. CONTROL	10-11
CHECK VALVES	30-40
FRONT COVER	27-37
SERVO SPRING	10-11
TRUNNION	27-37
HIGH PRESSURE RELIEF VALVE	20-30

SUBSECTION 7 HYDRAULIC PUMP

GENERAL

The pump supplies oil to actuate the crane cylinder, tailboard cylinder, spray bar ram, pump valve and fifth wheel cylinder.

OPERATION

The oil from the reservoir flows by gravity to prime the oil pump on the engine. With the engine in operation and the control valves in neutral, oil flows under pump displacement from the reservoir, through pump and through open center passages of valve back to the reservoir. When the operator moves the hydraulic crane the pump location. The line is attached to the bottom section of reservoir, so the reservoir content will run out this line due to the pump being located lower than the reservoir, for self-priming purposes.

a. Remove supply and pressure lines from fittings on hydraulic pump.

b. Remove the nuts and washers from pump casting base on diesel engine. Slide pump out of mount. The connecting drive sleeve coupling may slide out with pump gear. This coupling can be slid back into mesh with drive plate, before reinstallation.

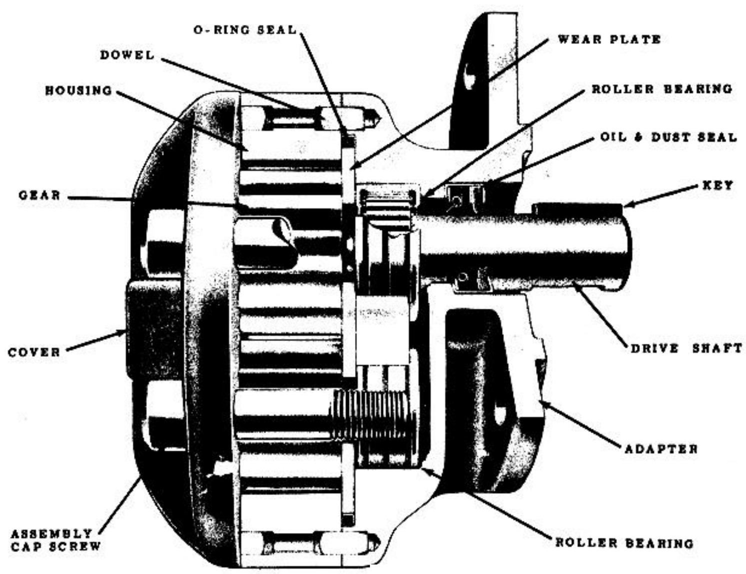


FIGURE 1

valve handle to raise or lower the crane, oil flows from the reservoir to the pump, into the control valve, to "up" or "down" side of hydraulic ram and exerts pressure on ram piston to "raise" or "lower" the crane. The hydraulic hose attached to the ram on the opposite side of piston from where hydraulic pressure is being applied returns oil to the valve and back into the reservoir.

a. The hydraulic pump is mounted on the rear of the diesel engine. The pump is a positive displacement gear type unit. The pump is capable of running at speeds of 2500-3000 RPM and pressures to 2000 P.S.I. It will put out the system required pressure at 500 RPM (1200 P.S.I., 2.2 Gals. per minute).

PUMP REMOVAL

The pump is mounted onto an adapter plate at the rear accessory drive section of the diesel engine. Before removing the pump, prepare to catch the hydraulic oil from the supply line to the pump, at

c. Place pump assembly in a vise or fixture, after cleaning externally with cleaning solvent. Grip by mounting flange. Protect flange with copper or wood guard in vise jaws. Mark cover housing and adapter with a prick punch for proper assembly reference.

d. Remove the four cover cap screws. Remove the cover which may come off separately or with the housing.

e. To prevent possible leakage, avoid scoring or nicking machine surfaces of pump sections. Do not use a screw driver to pry the sections apart. Tap with a fibre hammer if necessary to loosen.

f. Note position of relief pocket and drilled holes in the wear plates for proper reassembly. Mark the drive and driven pump gears with an india stone. See Figure 4 for proper reassembly. Note the location and number of gaskets, when disassembling.

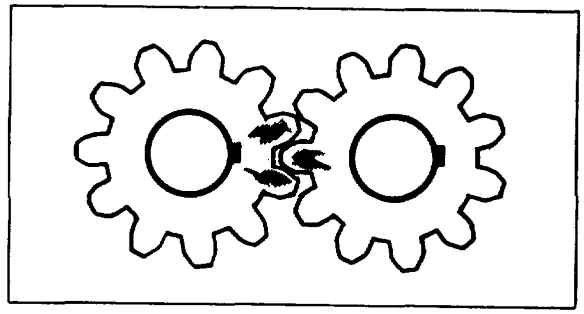


FIGURE 4 Marking of the Gears for Location

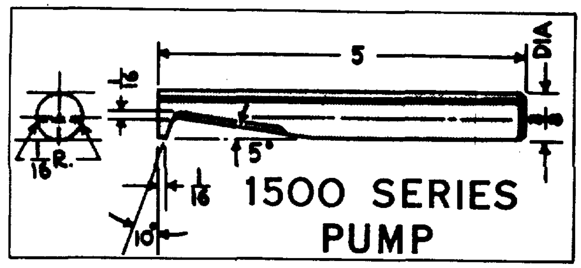


FIGURE 5 Tool Dimensions

g. Remove cotter pin and drive gear from shaft.

h. Remove key from shaft. Remove snap ring adjacent to gear.

i. Remove driven gear and shaft. Remove flange and adapter from vise or fixture and by pressing on drive gear end of shaft, press out the bearing. Be sure to coat drive shaft with white lead, on area where pumps drive gear was removed, to aid in sliding through the outboard bearing.

j. Remove seal assembly and locating snap ring and washer from pump drive shaft.

k. Remove dowel pins from cover and adapter castings, with a pliers or a lever jaw wrench.

NOTE:
Replace roller bearings only if necessary and then only with the same make and type as originally installed.

l. Check bearings for freeness of rollers, pitted, broken or excessively worn rollers. Replace bearing, if it is possible to insert a feeler of 0.020" between rollers. More gap indicates rollers are worn excessively.

m. Remove roller bearings by starting them with tool shown in Figure 5. Insert tool under the bearing and into the cored hole, behind bearing bores, Figure 6.

n. Complete removal of the bearing, using tool Figures 7 and 8 as shown. Tap out with suitable bar.

o. Remove outboard bearing retaining snap ring with ring pliers.

p. Reach down through the drive shaft bearing bore with a brass drift punch and tap out the outboard bearing. Tap opposite side alternately.

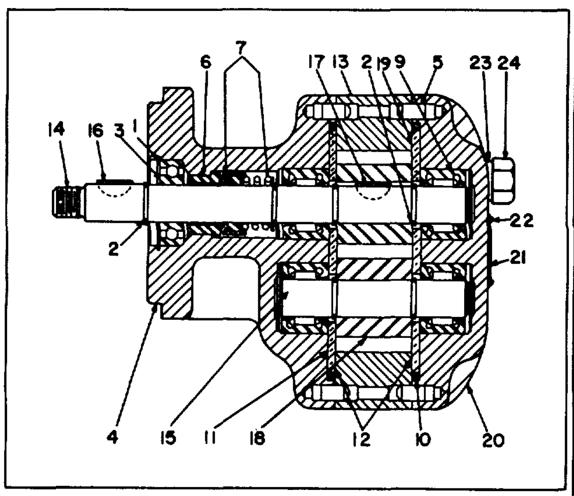


FIGURE 2

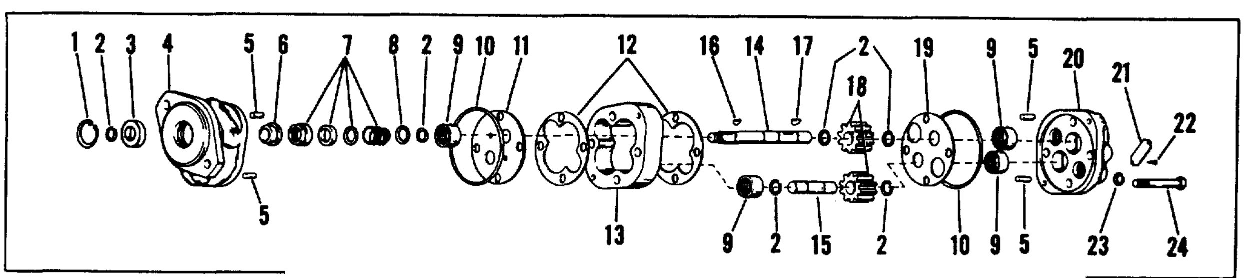


FIGURE 3 Exploded View of Hydraulic Pump

1. Snap Ring
2. Snap Ring
3. Bearing
4. Front Housing
5. Dowel Pin
6. Seal Seat
7. Seal Assembly
8. Washer
9. Bearing
10. "O" Ring Seal
11. Wear Plate
12. Shim Gasket
13. Housing
14. Drive Shaft
15. Driven Shaft
16. Woodruff Key
17. Woodruff Key
18. Gear
19. Rear Plate
20. Rear Housing
21. Name Plate
22. Drive Screw
23. Lockwasher
24. Capscrew

q. The seal seat should not be removed unless the seal face is excessively worn or damaged. To remove the seal seat, invert the adapter and drive out the seat with a hard wood block. If a new seat is required, press into adapter, using seat driver shown in Figure 9.

r. If gears or shafts must be replaced, remove snap rings and press off gears in an arbor press.

PUMP ASSEMBLY

Clean and inspect all components.

a. To reassemble gears to shafts, coat gear

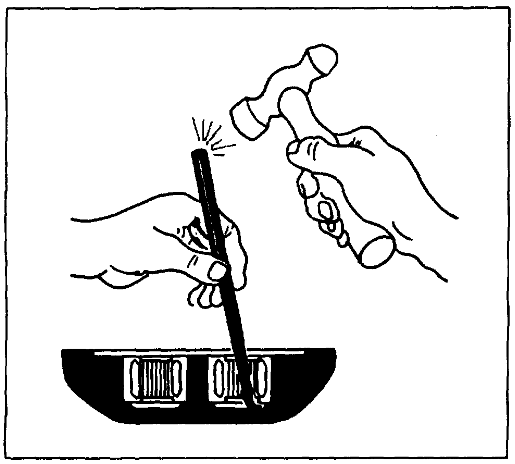


FIGURE 6 Use of Tool Shown in Figure 39

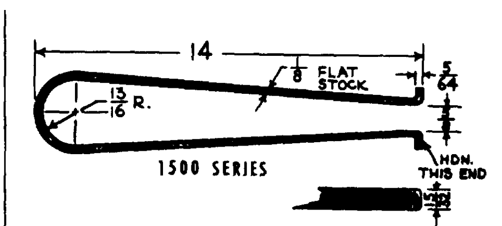


FIGURE 7 Bearing Removal Tool

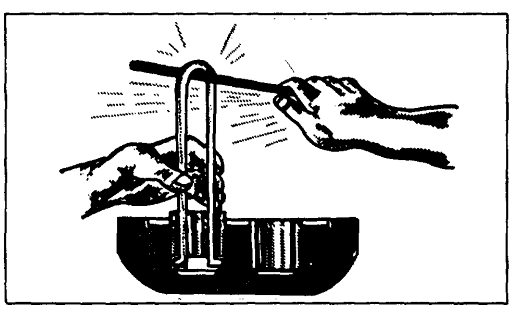


FIGURE 8 Bearing Removal Tool being Used

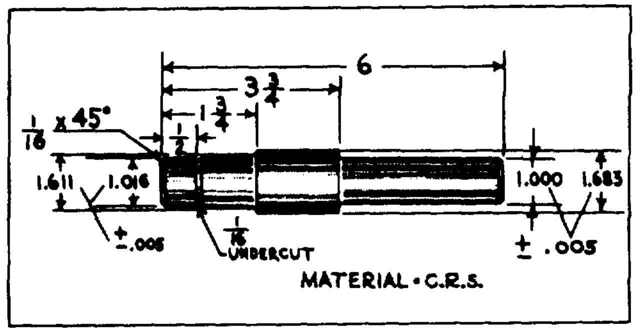


FIGURE 9 Seal Seat Tool

bore with white lead, and after installing one snap ring, press onto shaft, until the gear covers approximately /4 of key slot. Hold key in place and press gear onto shaft, until it contacts the snap ring. Install second snap ring. The same procedure is used for driven shaft except no key is required.

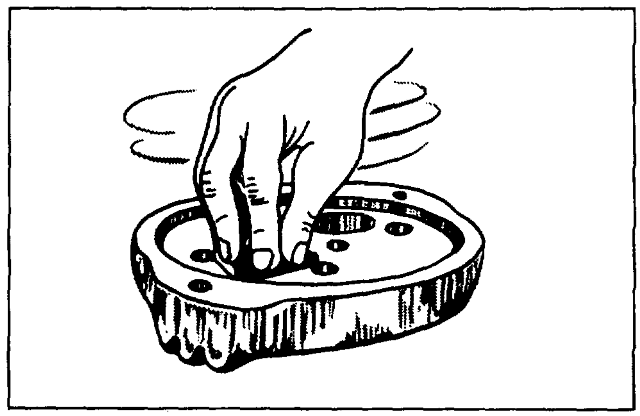


FIGURE 10 Use of Small File Piece to Remove Burrs and Nicks

CAUTION:
To prevent bending of drive shaft push drive or keyed end of shaft through the gear and press on straight end of the shaft

FIGURE 11 De-burring of Machined Surfaces

b. With a flat file (small piece of normal metal file) remove nicks and burrs from around bearing bores and holes of adapter and cover. (Figure 10).

c. Clean up burrs and nicks on machine, mating surfaces of housing, cover and adapter with india stone and fine mill file. Rewash before assembly.

d. Inspect shafts at bearing points and seal areas for rough surfaces and excessive wear.

e. Inspect edges of gear teeth and gear face for scoring. Stone the face of gears and edge of teeth before reassembly. (Figure 12).

f. Inspect roller bearings as outlined for wear, etc.

g. Gaskets should be replaced. Seal rings should be replaced.

h. Replace worn or scored wear plates. Inspect for erosion near the relief hole on bronzed side of gear. Slight gear pattern wear is permissible. Plates showing erosion path should be replaced. (Figure 13).

i. Check for proper seating of wear plates in

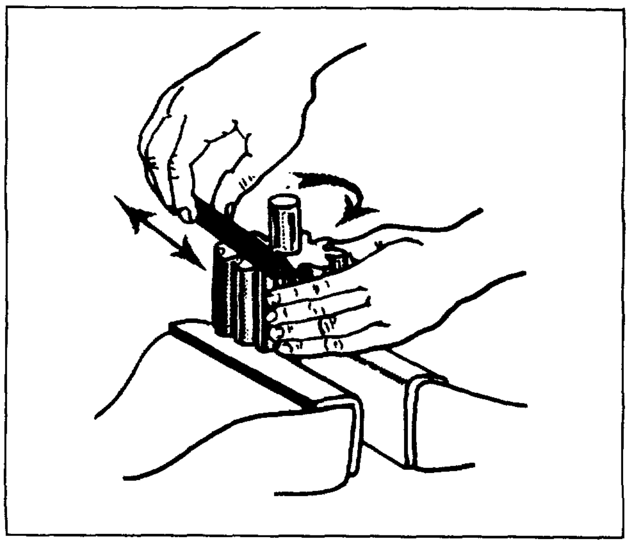


FIGURE 12 Use of India Stone on Gears

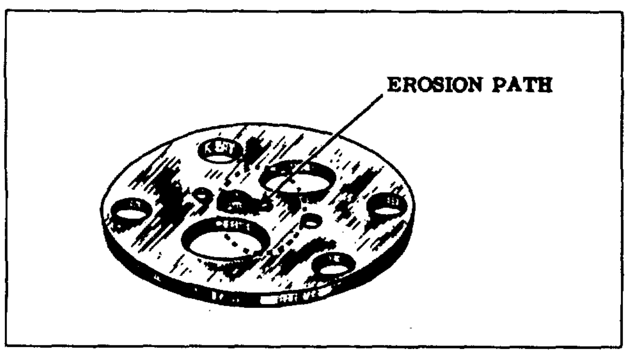


FIGURE 13 Erosion

cover and in adapter. A rocking motion indicates either a burr or nick on adapter or cover.

j. Lubricate roller bearings with light grease. Coat I.D. of bearing bore with white lead. Press bearing assembly into bearing bore of adapter and cover with tool shown in Figure 15.

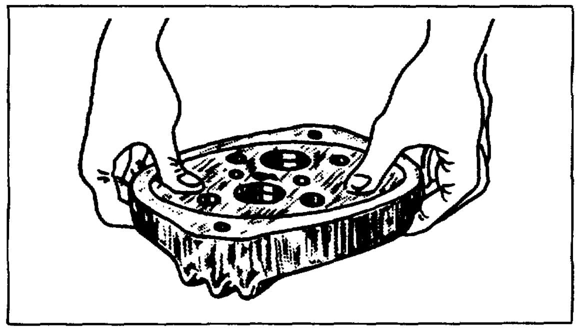


FIGURE 14 Wear Plate Seating Check

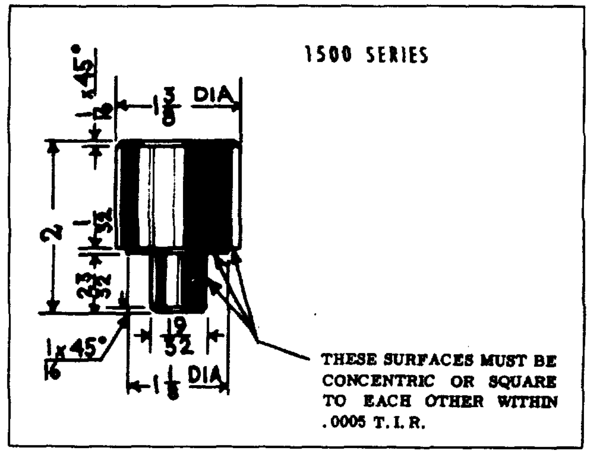


FIGURE 15 Tool Dimensions for Pressing Bearings

k. Install dowel pins in adapter and cover.

l. Support adapter in vise or fixture. Insert

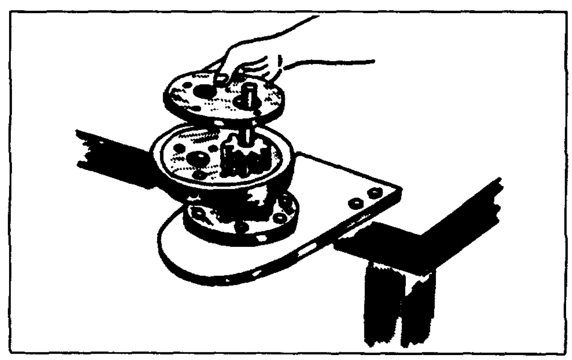


FIGURE 16 Assembly of Drive Shaft and Wear Plate Inner

drive shaft in driven gear shaft bearing with long (drive end) up.

m. Place inner wear plate over drive shaft, making sure the bronzed surface with relief hole is facing gear. (Figure 16).

n. Place roller bearing on the drive shaft. Now assemble the oil seal parts in the following order: lock washer, back up washer, coil spring, back up washer, synthetic rubber ring.

(Lubricate this ring with light oil or grease.) Install the lapped seal cup with lapped surface up. Make sure rubber ring is seated in cup. *Make certain the rubber ring is not cut when placing it on the shaft and when passing it over the key slot.*

o. Press the entire seat assembly down against the spring compressing it. When released, the spring should return the seal cup to original position. If it sticks on the shaft, replace the oil seal assembly.

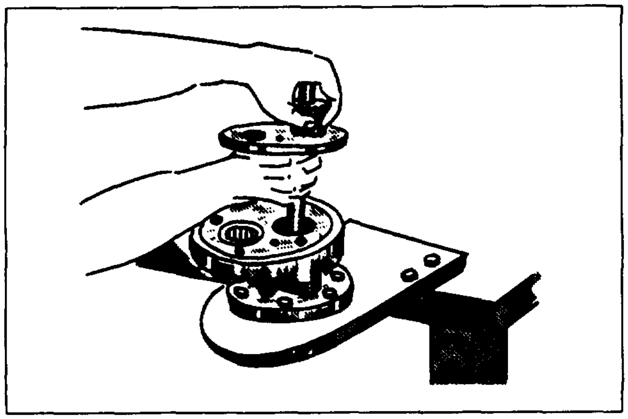


FIGURE 17 Drive Shaft, Inner Wear Plate and Seal Assembly being Installed in Adapter

p. Wipe off any foreign matter from seal seat. Lubricate surfaces of steel seat and seal cup with light oil.

q. Turn the entire drive shaft assembly over and install it in adapter as shown in Figure 17. Use a composition (fibre or plastic) hammer to drive entire assembly into adapter forcing bearing into bearing bore.

r. Place "0" ring seal around wear plate and gear. Lubricate contact surfaces of seal and wear plate.

s. Clearance between gear faces and wear plates is provided by the plastic shim gaskets between housing, inner wear plate and outer wear plate.

t. Measure the width of gear housing and gears with an outside caliper micrometer.

u. The following chart indicates location and number of shims to use. If gears are so worn that housing width becomes more than 0.002" greater than gear width, both gears should be replaced.

v. Insert driven assembled gear and shaft into adapter end. Line up marks previously made on gear faces if original gears are used. Keep keyways 180 degrees apart if new gears are used. Lubricate faces of gears with light oil.

w. Install proper gaskets as selected by chart, Gear width greater (plus) or less (minus) than housing width. Install shim gaskets as indicated below.

SHIM GASKETS SIZE CHART

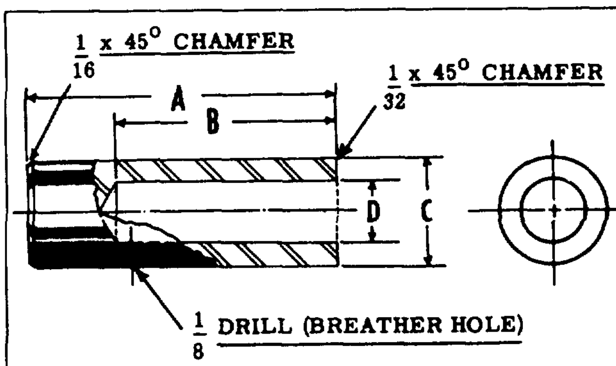
		Inner wear plate	Outer wear plate
Plus	0.002"	0.002"	0.002"
Plus	0.001"	0.001"	0.002"
	0.000"	0.001"	0.001"
Minus	0.001"	- - -	0.001"
Minus	0.002"	- - -	- - -

over gears and on face of wear plate. If it is not practical to use a micrometer to measure gears and housing, use a gasket that measures 0.001" thickness on both sides of gear housing.

x. Line up punch marks and place pump housing over gears and gasket. Tap into position with fibre hammer. Add selected gasket to face of gear housing. Install wear plate (outer) with bronzed surface against gears and relief hole 180 degrees from inner wear plate relief hole.

y. Install wear plate (outer) "O" ring seal and install cover, lining up punch marks. Tap onto housing assembly with fibre hammer.

z. Install four pump cap screws. With a torque wrench, tighten gradually, opposite screws to 60 ft. lbs. torque. Be sure original cap screws or exact replacement are used. Use washers, if used originally. Seating of washers or cap screw head shoulder is important to prevent leakage.



DRIVER FOR OIL SEAL AND OUTBOARD BEARING					
TOOL NO.	PUMP SERIES	A	B	C	D
98064-1	1500	4	2 1/2	1.118 1.116	.6345 .6340

FIGURE 18 Special Bearing Driving Tool and Dimensions

aa. After assembly, turn pump shaft with a six inch adjustable wrench. If shaft turns with a slight drag and not too freely, add or remove as many (0.001") or(0.002") gaskets as necessary to obtain proper clearance.

bb. Install outboard bearing assembly. Coat the I.D. of bearing bore with white lead. Lubricate the bearing with light grease. Drive the bearing down over the drive shaft with special tool, Figure 9 until it bottoms.

cc. Insert snap ring in bearing bore.

BREAK-IN OF REPAIRED PUMPS

1. If a shop test stand is available on which a pump can be mounted and operated. against full pressure and at maximum speed, the following procedure is recommended for a break-in test.

a. Start pump and run for two minutes at zero pressure. Be sure the test stand reservoir is full and that all inlet and outlet lines are open. By restricting pump discharge line with needle or Globe valve, raise discharge pressure to 500 P.S.I. for 10 seconds and lower to zero pressure for 10 seconds. Continue this procedure for five minutes.

CAUTION:
Do not apply pressure /or more than 10 second intervals.

b. Stop pump and rotate drive shaft coupling by hand, to determine, if drive shaft is free. If drive shaft cannot be turned freely, remove and rebuild pump.

c. Resume test and apply 1000 P.S.I. for 10 second periods as done above for 500 P.S.I.

d. Stop pump and check freeness as in (b) above.

e. Check closely for leaks at adapter, housing, and cap screws and around seal assembly.

f. Be sure oil level is up to normal in reservoir and make a capacity test on pumps. Run pressure to 1000 P.S.I. and run flow test for 2.5 gals./min. at 500 RPM, 5.6 gals./min. at 1000 RPM and 1.12 gals./min. at 1800 RPM.

2. If a shop test stand is not available, the following alternate break-in and test procedure may be used.

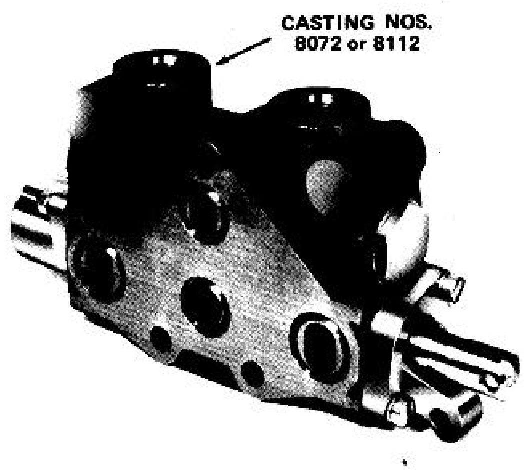
a. Mount repaired pump in place on equipment and run at zero pressure and at slowest engine speed for one-half hour. Increase engine speed gradually, until normal operating speed is obtained with hydraulic control valve in neutral position. With engine at normal speed, increase line pressure with control valve.

b. Check for possible leaks at mating surfaces of adapter, housing and cover and around seal assembly. Check for leakage around the four assembly cap screws.

SUBSECTION 8 HYDRAULIC CONTROL VALVES

GENERAL DESCRIPTION

The hydraulic control valves consist of 4-way 3-position valve sections (Gresen Model V20P) Fig. 1. The valve spool will return to neutral position from A or B power position when the handle is released. The cylinder port is blocked in the neutral position. The sections are ganged together as an assembly. Fig. 2. The main relief valve is non adjustable and factory set for 1200 P.S.I.



Model V20P

FIGURE 1 Valve Section

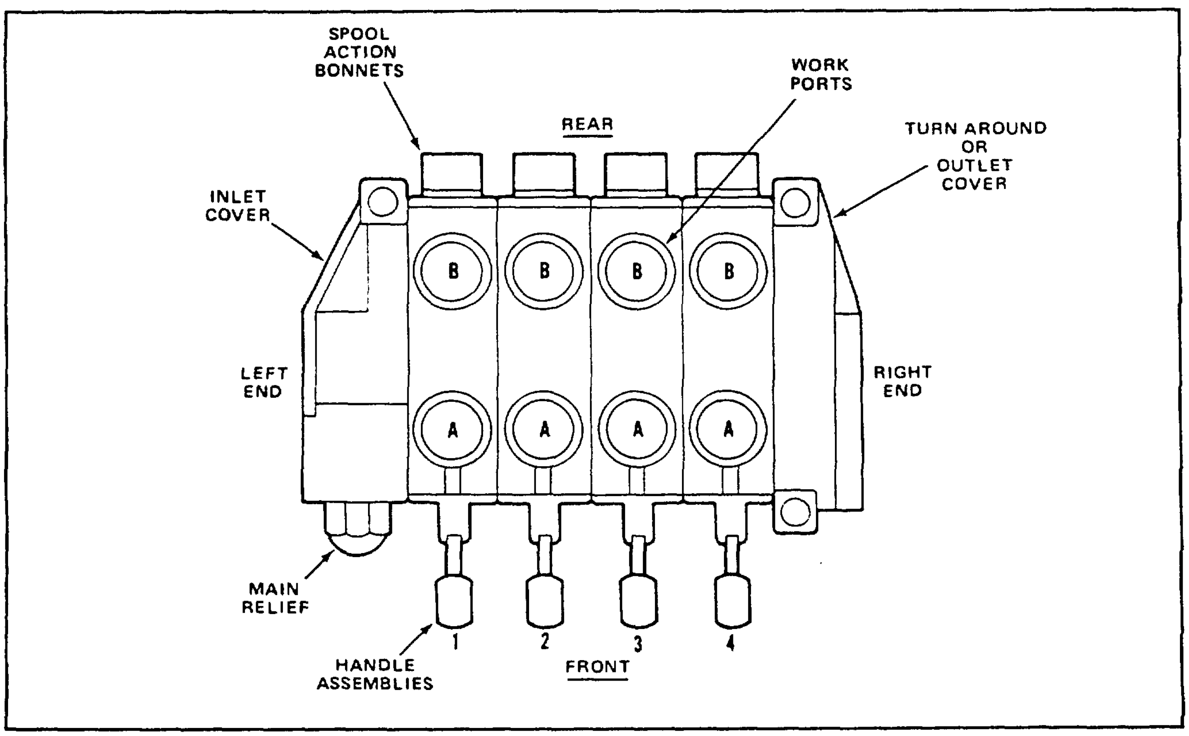


FIGURE 2 Schematic-View of Typical Control Valve Assembly

REPLACING SPOOL SEALS IN CONTROL VALVE (Fig. 3)

For the purpose of these instructions, we shall consider the control handle side of the valve as the front end, and the opposite end as the back end.

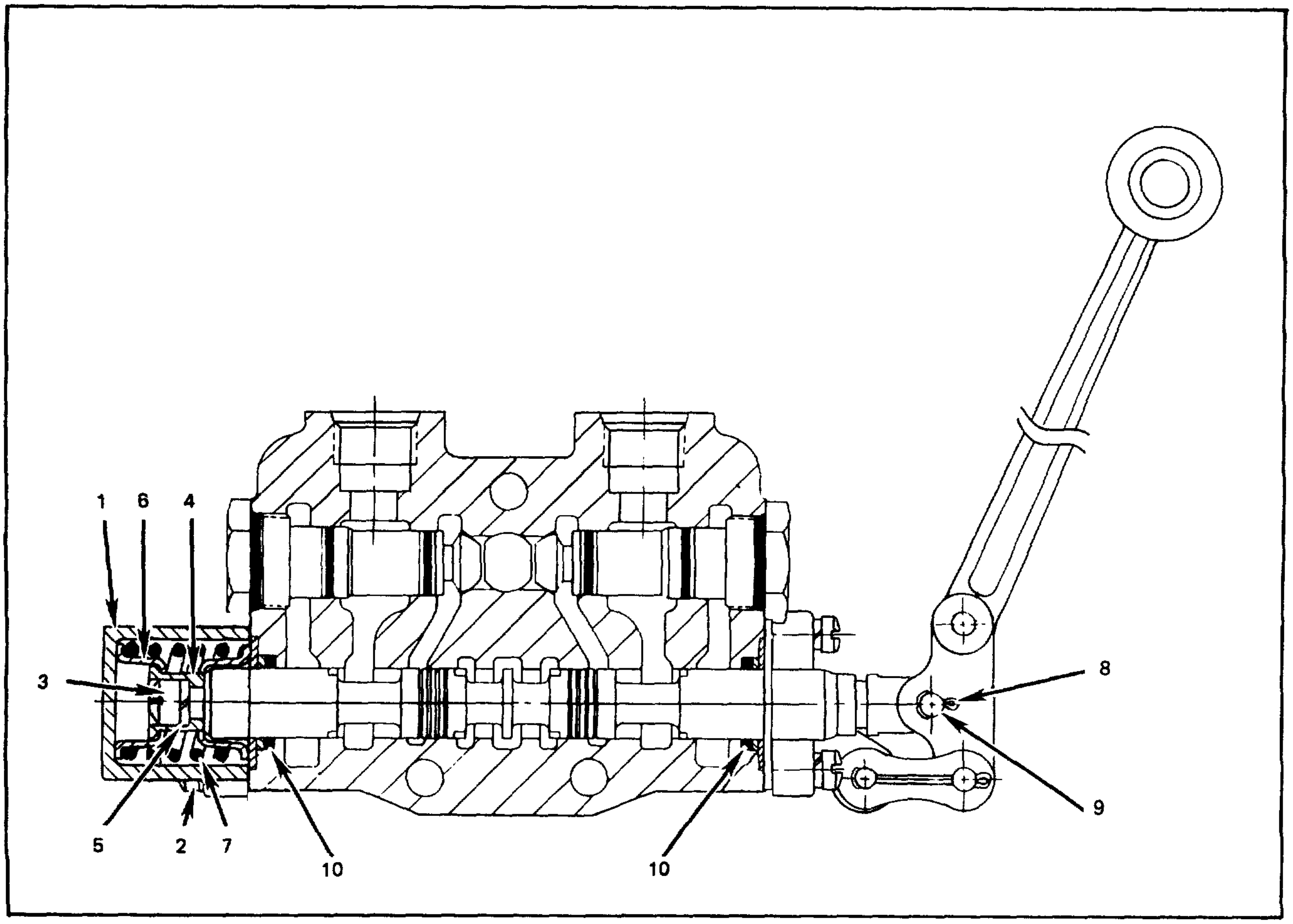


FIGURE 3

1. Remove the bonnet assembly (1) by removing fillister head screws (2).
2. Remove spool assembly screw (3), spool collar (4), lockwasher (5), collar (6) and spring (7). Be sure to observe the order in which these parts are removed to insure proper reinstallation.
3. Disconnect handle from spool by removing cotter pin (8) and handle pin (9). Let handle swing free of spool.

NOTE:

DO NOT REMOVE the spool as the seals can be replaced externally. Prevent spool from turning or moving by inserting a screw driver through clevis slot, or ruling a rod through the pin hole and using as a handle. DO NOT hold the spool with a wrench. This will destroy the finish.

4. Pull spool towards front end of valve just far enough to expose the back seal (10) in housing.
5. Remove back seal (10).
6. Push spool in opposite direction (towards back end) until front seal (10) is fully exposed.
7. Remove front seal (10) from housing.
8. Be sure that body seal grooves are thoroughly and carefully cleaned.
9. Insert new seal (10) in front groove, being very careful that the open end (end with wiping edges) of the seal is placed towards the center of the valve body. It will be very helpful to pinch one side of the seal, causing the seal to bend into a shape slightly smaller than the seal groove in the valve. When the seal has been properly placed in seal groove, straighten the seal by running a smooth rod around the exposed surface of the seal until you have it well seated. To check this, run your finger around the exposed edge of the seal. You should have a smooth perfect ridge with no kinks.
10. Apply a small amount of grease or heavy oil on seal (10) to prevent it from tearing during assembly.
11. Insert the internal-chamfered end of the T-273 special tool into the spool bore of the valve housing from the front side of the valve and through the new seal. Push spool forward until the spool and tool make contact. Push spool further forward against tool until rear seal groove is completely exposed, but no further.
12. Install new seal (10) in back groove and apply grease or heavy oil. Insert T-273 special tool (internal-chamfered end first) carefully into back bore through seal until it makes contact with spool. From front side, push spool back approximately 3/4".
13. Reinstall complete handle assembly, installing handle pin (9) and cotter pin (8).
14. Reinstall the complete spring assembly on back of spool, spring (7), collar (6), lockwasher (5), spool collar (4), and spool assembly screw (3). Be sure the spool assembly screw (3) is securely tightened (6 ft; lbs. torque).
15. Install bonnet assembly (1) and secure with screws (2).

REPLACING CENTER SECTION ASSEMBLIES IN THE VALVE (Fig. 4)

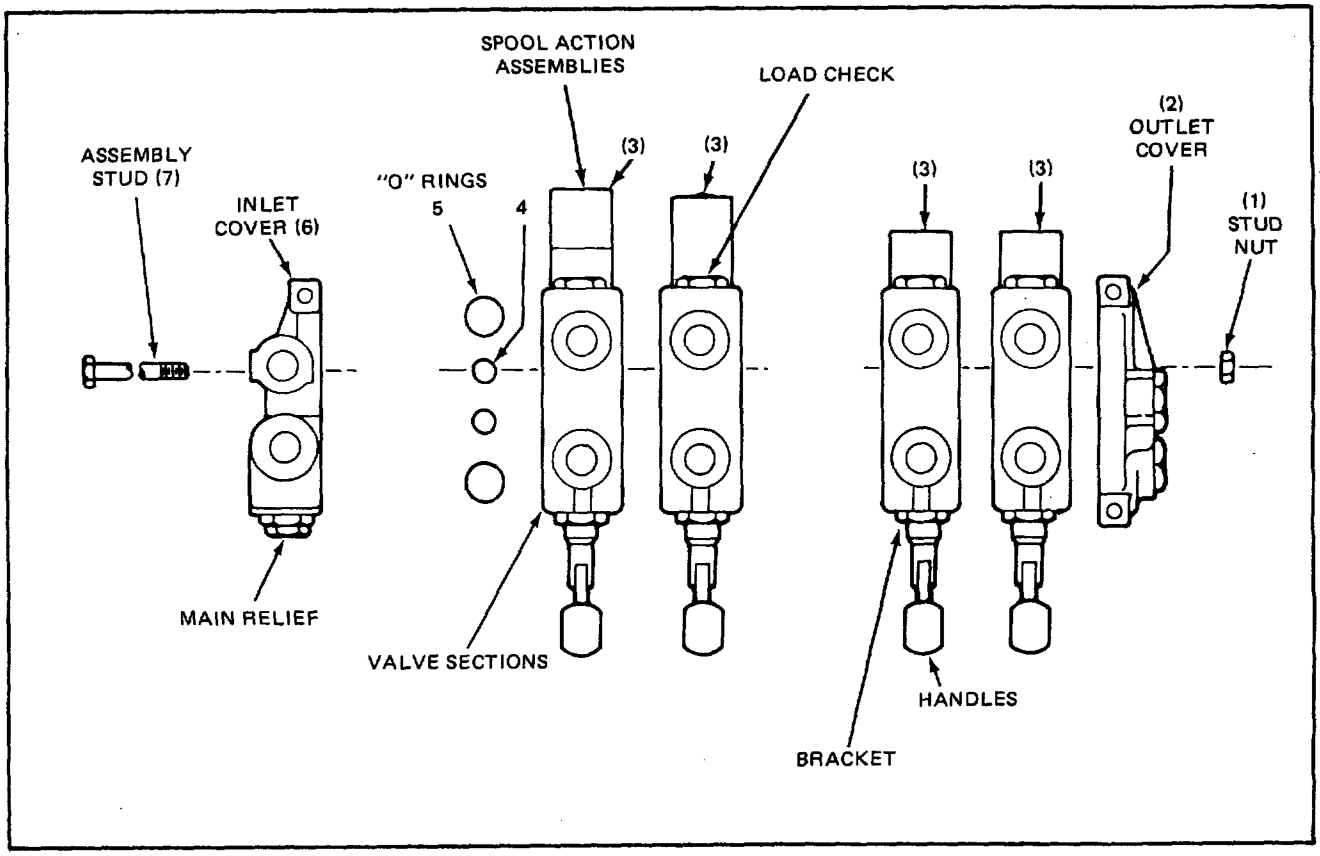


FIGURE 4 Model V20 Directional Control Valve, Typical Main Assembly

For the purpose of these instructions, we shall consider the section containing the main relief valve the left side of the valve.

1. If the valve is to be reassembled in the same order, it is suggested that before disassembling, each section be marked numerically so that they may be returned to the same sequence when reassembled.
2. If valve has been removed from equipment, it is advisable to mount valve vertically in a vise to facilitate disassembly and assembly.
3. On the right end of the valve there may be a power beyond sleeve, conversion plug or closed center plug installed. These must be removed before the valve can be disassembled.
4. Remove the three assembly stud nuts (1) from right end section.
5. Next, valve sections may be disassembled by sliding the sections (2), (3), (6) along the assembly studs.
6. Thoroughly clean the "0" ring counterbores and the ground surface of each section. Place new "O" ring seals (4), (5) in proper counterbores. For better sealing, it is suggested that all "O" rings used in the counterbores be replaced with new parts.
7. Replace the sections on assembly studs with the "O" ring counterbores facing right end of valve. Use care in replacing sections so the section "O" rings are not dislodged from the counterbores.
8. When all sections are assembled on assembly studs, tighten the assembly stud nuts or bolts evenly to 32 ft. lbs. torque, NO MORE, NO LESS, otherwise spools may bind or stick.

SUBSECTION 9 HYDRAULIC CYLINDERS

CRANE LIFT HYDRAULIC CYLINDER (Fig. 1)

The hydraulic ram is assembled to the machine frame and crane with two pins. Lower the rotor and hood assembly and block crane in this position.

1. Remove hydraulic hoses from cylinder. Plug or cap hoses.

2. Remove the ram pins and dismount ram for bench work.

3. Clean ram externally and hold in vise at the base end.

4. Remove snap ring (A) from rod end of cylinder.

Piston assembly (B) may now be forced from cylinder (C) along with gland bushing (D).

5. Unthread packing adapter (E) from rod (F). Packings (H), piston (G), "O" ring (J) and packing adapter (K) may now be removed.

6. Slide gland bushing (D) off rod and remove "O" rings (L) and (M) and dirt seal (N).

7. Clean and inspect all parts for scoring and corrosion. All packings and "O" rings should be replaced. If inside cylinder is scratched, it may be honed to 0.040" oversize. If unable to clean up at this dimension, replace cylinder.

8. Lubricate all parts before reassembly.

9. Assembly Replace "O" ring (M). Slide gland bushing (D) on rod (F). Follow with packing adapter (K), "O" ring (J), first packing (K), piston (G), second packing (H) and thread on packing adapter (E). Tighten and prick punch to rod (F).

10. Replace "O" ring (L) in gland bushing (D). Slide piston assembly (B) into cylinder. Tap gland bushing (D) into cylinder until it bottoms. Replace snap ring (A) and dirt seal (N).

11. Reassemble on machine. Connect hoses. Check for leakage and operation. Air is purged from cylinder by operation. Add fresh oil to hydraulic tank to level mark.

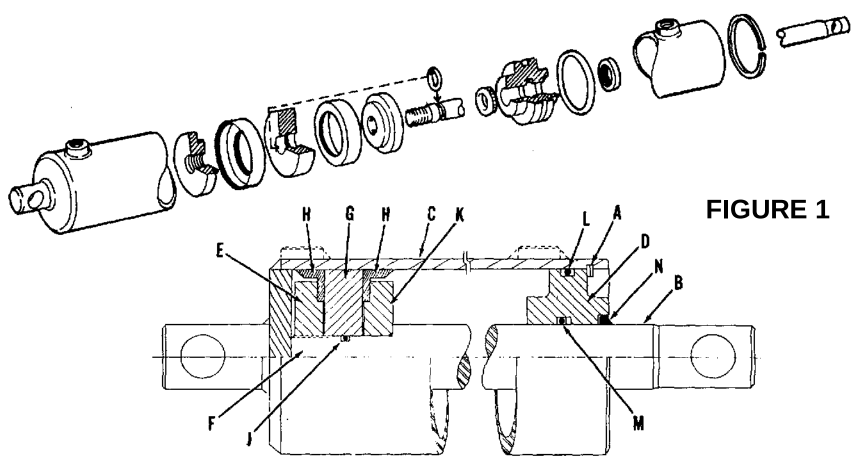


FIGURE 1

TAILBOARD HYDRAULIC CYLINDER (Fig. 2)

Each end of the double acting cylinder is pinned to a non-adjustable base. No adjustment is required. A self-aligning bushing in each rod end allows the cylinder to pivot with the movement of the tailboard.

In the event the cylinder is in need of repair, a repair kit is available from the factory. Refer to Parts Book for parts kit number.

Overhaul of the cylinder is as follows: (Fig. 2)

1. Make sure the cylinder is not under pressure before removing.

2. Clean hydraulic hose couplings at cylinder before unthreading hoses. Disconnect hydraulic hoses from cylinder. Remove bolts or pins at base and rod end of cylinder and remove cylinder.

3. Hold cylinder in a vise, gripped lightly at the base end.

4. Remove snap ring (A), pull piston and rod assembly (B) out against the cylinder head (C) by tapping against shoulder of rod base (D), this will free the cylinder head (C) from cylinder (E).

5. Remove nut (F) from shaft (G). The piston (H) and cylinder head (C) may now be slid off shaft (G).

Pry seal (J) out from cylinder head. Remove "O" rings (K), (L), (M) and (N) and leather ring (P).

6. Clean all parts in solvent SD-2 or kerosene and soak seal and leather ring in oil before assembly. Coat "O" rings with oil before assembly. Inspect shaft, piston and inside of cylinder for score marks. If worn, they should be replaced.

WARNING

Solvent SD-2 is potentially dangerous. Do not use near open flame or heat.

7. Assembly Press new seal U) into cylinder head (C) with lip of seal facing the outside. Install "0" ring (K), leather seal (P) and "O" ring (L). Slide cylinder head on shaft being careful not to damage the seal lip and leather seal (P).

8. Install "O" rings (M) and (N) on piston and reassemble piston on shaft securing with nut (E).

9. Slide piston and rod assembly into cylinder. It may be necessary to tap the cylinder head in place to bottom on shoulder in cylinder. Replace snap ring "A".

10. Reinstall cylinder on machine. Hydraulic oil may be added to cylinder thru the cylinder connections since they are facing up. This will help relieve the air. Connect the hoses and fill hydraulic tank to level plug. Run hydraulic system a few minutes, work cylinder and recheck hydraulic oil tank. Add oil if necessary.

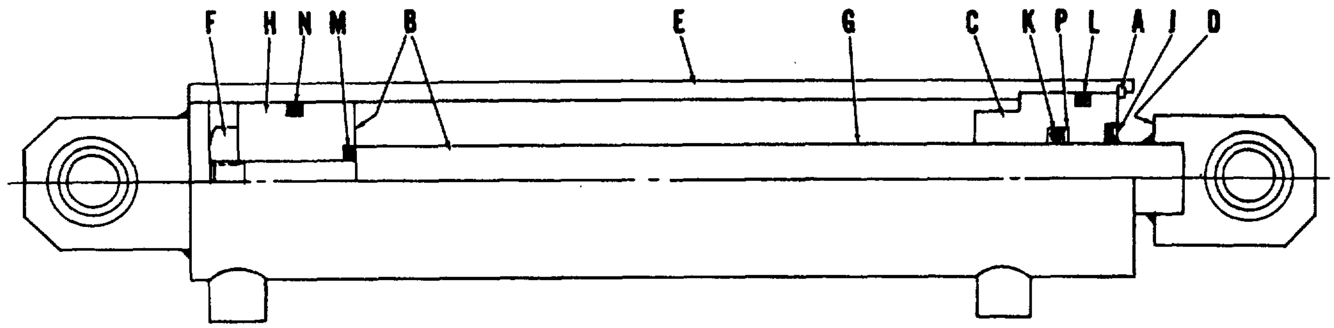


FIGURE 2

SPRAY BAR HYDRAULIC CYLINDER (Fig. 3)

Ram removal from machine With the spray bar actuating rod in the vertical position, disconnect hoses from ram ports. Disconnect ram at the base and rod ends. Loosen clamps and remove protective boot.

Loosen lock nut and thread off the rod end plus the lock nut.

Ram may be held in a lead or brass jawed vise gripped at the base end.

With the use of a drift pin and hammer, tapping stuffing box (A) counterclockwise, remove stuffing box. Piston rod assembly can now be pulled out of cylinder (B).

Using a small spanner wrench, back off on the packing gland (C). Stuffing box and packing gland can now be removed from rod (D). Pull out packing (E)from stuffing box. Remove wiper (F) from packing gland. Remove "O" ring (G) from stuffing box.

The piston end parts may be disassembled by removing nut (M). The followers U(), piston cups (K), and piston (L) may be removed. Remove "O" ring (H) from follower U)

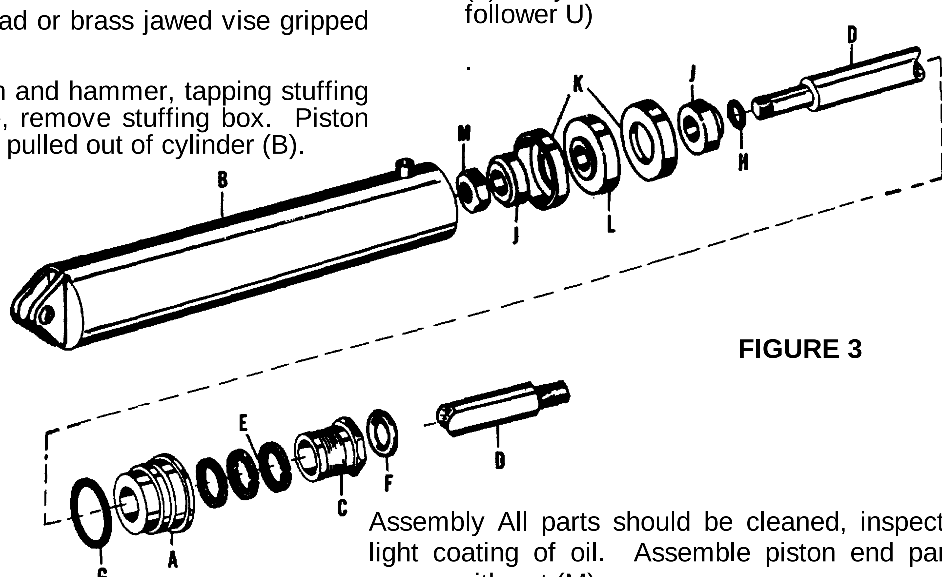


FIGURE 3

Assembly All parts should be cleaned, inspected and given a light coating of oil. Assemble piston end parts in order and secure with nut (M).

Slip new "0O" ring (G) on stuffing box. Slide stuffing box on shaft. Insert this partial assembly into cylinder and tighten. Install new packing (E) and follow with packing gland. Tighten packing gland. Install wiper. Reinstall nut and rod end. Replace clamps and boot.

Reinstall ram on machine. Connect hoses. Run system for a few minutes to relieve. Recheck oil level and add oil if necessary.

SUBSECTION 10 - DIESEL ENGINE

GENERAL INFORMATION **CHAPTER 1**

SCOPE AND USE OF THE MANUAL

This section covers the basic Series 71 In-line diesel engines built by the Detroit Diesel Allison Division of General Motors Corporation. Multiple engine units are available in various combinations such as side-by-side twins, tandem twins and quads. Complete instructions on operation, adjustment (tune-up), preventive maintenance and lubrication, and repair (including complete overhaul) are covered. The manual was written primarily for persons servicing and overhauling the engine and, in addition, contains all of the instructions essential to the operators and users. Basic maintenance and overhaul procedures are common to all Series 71 In-line engines and therefore apply to all engine models.

This section is divided into numbered chapters. The first chapter covers the engine (less major assemblies). The following chapters cover a complete system such as the fuel system, lubrication system or air system. Each chapter is divided into sub-sections which contain complete maintenance and operating instructions for a specific sub-assembly on the engine. For example, Chapter 1, which covers the basic engine, contains a sub-section pertaining to the cylinder block, another sub-section covering the cylinder head, etc. The subjects and chapters are listed in the Table of Contents on the preceding page. Pages are numbered consecutively, starting with a new Page 1 at the beginning of each sub-section. The illustrations are also numbered consecutively. beginning with a new Figure 1 at the start of each chapter.

Information regarding a general subject, such as the lubrication system, can best be located by using the Table of Contents. Opposite each subject in the Table of Contents is a chapter number. Information on a specific sub-assembly or accessory can then be found by consulting the list of contents on the first page of the chapter. For example, the cylinder liner is part of the basic engine, therefore, it will be found in Chapter 2. Looking down the list of contents on the first page of Chapter 2, the cylinder liner is found on page 10-2-92. Figure numbers are found in numerical order beginning with Fig. 1 at the start of each new sub-heading. For instance, in Chapter 2, the first sub-heading is "Cylinder Block" and Figure I is an illustration of a typical cylinder block. The second sub-heading in Chapter 2 is "Cylinder Block End Plates," with Figure 1 being an illustration of the drain passages in the cylinder block.

SERVICE PARTS AVAILABILITY

Genuine Detroit Diesel Allison service parts are available from authorized Detroit Diesel Allison distributors and service dealers throughout the world. A complete list of all distributors and dealers is available in the World Wide Parts and Service Directory, 6SE280. This publication can be ordered from any authorized distributor.

CLEARANCES AND TORQUE SPECIFICATIONS

Clearances of new parts and wear limits on used parts are listed in tabular form at the end of each section throughout the manual. It should be specifically noted that the "New Parts" clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still assure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the paragraph entitled *Inspection* under *General Procedures* in this chapter.

Bolt, nut and stud torque specifications are also listed in tabular form at the end of each chapter.

GENERAL PROCEDURES

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 a customer 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 desirable 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 sub-assemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, water and fuel.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be mounted on an engine overhaul stand; then the various sub-assemblies 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 having 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

Before removing any of the sub-assemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each sub-assembly 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 in Chapter 2; any special cleaning procedures will be mentioned in the 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 sub-assemblies.

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 temperature. 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 repair 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 gages, such as dial bore gages, 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 the 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 sub-assemblies, 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 chapter 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 intersects 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 available from the Parts Depot already have a sealer applied to the threads. This pre-coating will not be affected when the pipe sealer with teflon is also applied.

IMPORTANT: The sealer information above 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 engine firing by accidentally turning the fan or, in the case of vehicle application, by being bumped by another vehicle 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 manual. 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 tetrachloride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichlorethylene. However, while less toxic than other chlorinated 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 on the container or by the manufacturer 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.

IMPORTANT SAFETY NOTICE

Proper service and repair is important to the safe, reliable operation of all motor vehicles. The service procedures recommended by Detroit Diesel Allison and described in this service manual are effective methods for performing service operations. Some of these service operations require the use of tools specially designed for the purpose. The special tools should be used when and as recommended.

It is important to note that some warnings against the use of specific service methods that can damage the vehicle or render it unsafe are stated in this service manual. It is also important to understand these warnings are not exhaustive. Detroit Diesel Allison could not possibly know, evaluate and advise the service trade of all conceivable ways in which service might be done or of the possible hazardous consequences of each way. Consequently, Detroit Diesel Allison has not undertaken any such broad evaluation. Accordingly, anyone who uses a service procedure or tool which is not recommended by Detroit Diesel Allison must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects.

ENGINE **CHAPTER 2**

CONTENTS

CYLINDER BLOCK

The cylinder block (Figs. 1 and 2) serves as the main structural part of the engine. Transverse members, cast integrally, provide rigidity and strength and ensure alignment of the block bores and bearings under load. Cylinder blocks for the three, four and six-cylinder engines are identical in design and dimensions except for length. The two ends of the block are similar, so the flywheel housing and the gear train can be assembled to either end.

The block is bored to receive replaceable cylinder liners. Water jackets, which extend the full length of the bores, are divided into upper and lower sections which are connected by hollow struts (Fig. 2). Coolant from the pump enters at the bottom of each water jacket and leaves at the top of the block through holes which register with corresponding openings in the cylinder head.

An air box (Fig. 2) surrounding the water jackets conducts the air from the blower to the air inlet ports in the cylinder liners. Air box openings (Fig. 3) on the side of the block opposite to the blower provide access to the air box and permit inspection of the pistons and compression rings through the air inlet ports in the cylinder walls.

The camshaft and balance shaft bores are located on opposite sides near the top of the block.

The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping.

The perimeter of the top surface of the cylinder block is grooved, outside of the cam pockets, to accommodate a block-to-head oil seal ring. The top surface of the block is also counterbored at each water or oil passage to accommodate individual seal rings (Fig. 4).

Each cylinder liner is retained in the block by a flange at its upper end. The liner flange rests on a cast iron insert located in the counterbore in the block bore. An individual compression gasket is used at each cylinder.

When the cylinder head is installed, the gaskets and seal rings compress sufficiently to form a tight metal-to-metal contact between the head and block.

New service replacement cylinder block assemblies include the main bearing caps and bolts, dowels and the necessary plugs.

Since the cylinder block is the main structural part of the engine, the various sub-assemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand (Fig. 5) provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction 90 ° or 180 ° c where it is locked in place and then, if desired, tipped back with either end or the oil pan side up.

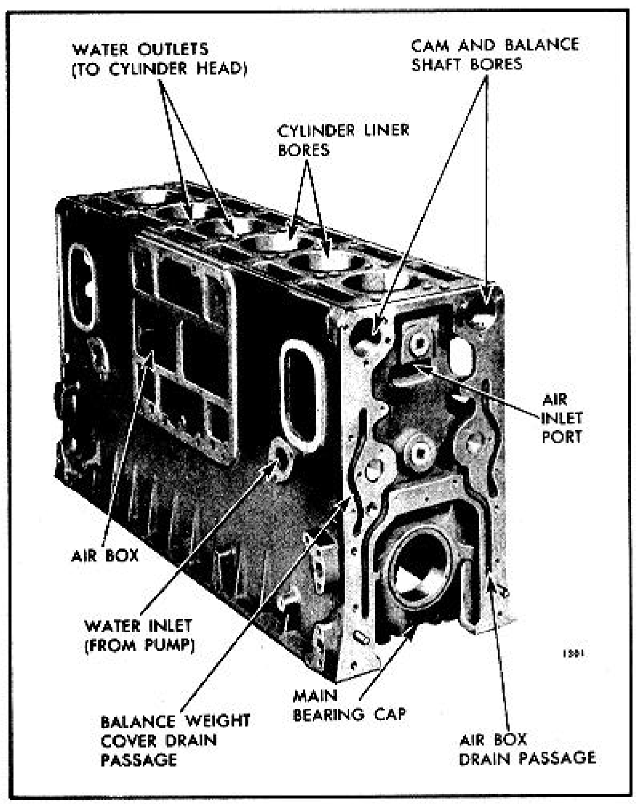


Fig. 1 - Typical Cylinder Block

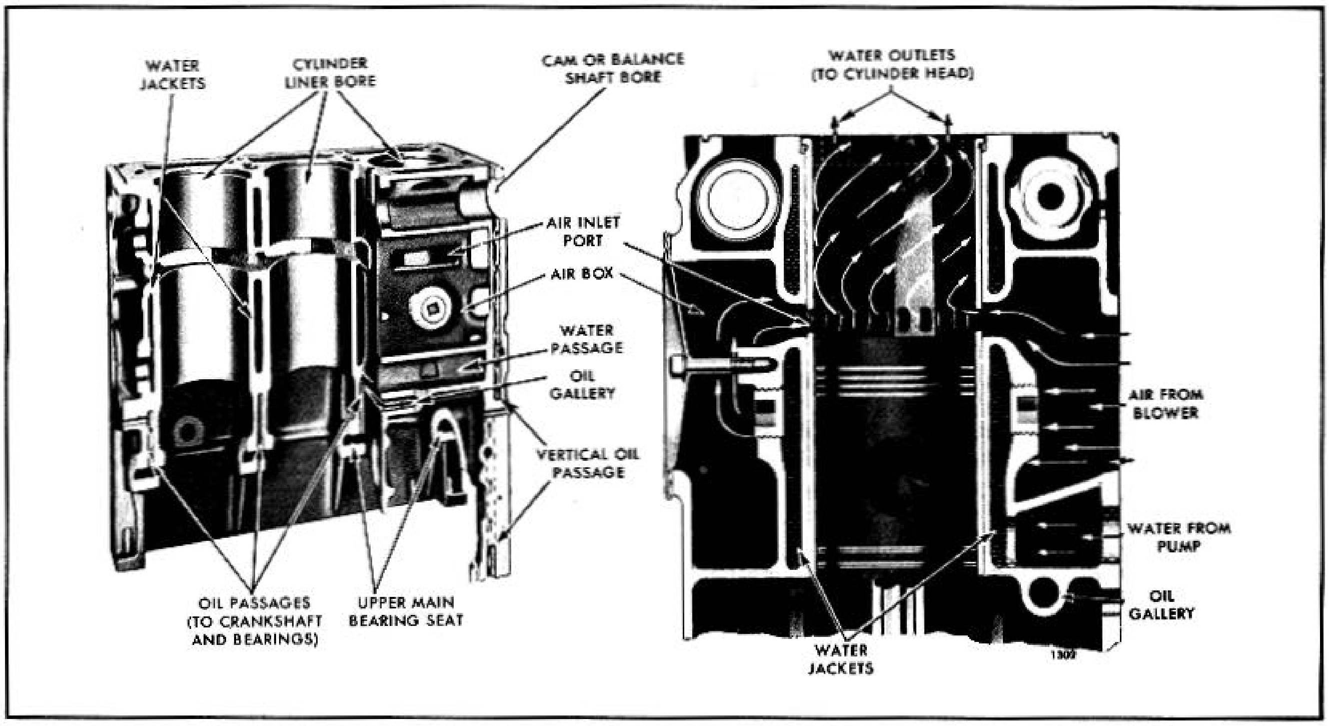


Fig. 2 - Cutaway View of Cylinder Block Showing Air and Water Passages

ENGINE AND ROTOR TRANSMISSION REMOVAL

The engine and rotor transmission should be removed from the vehicle as a unit.

Removal

1. Drain the cooling system.
2. Drain the lubricating oil.
3. Disconnect the fuel lines.

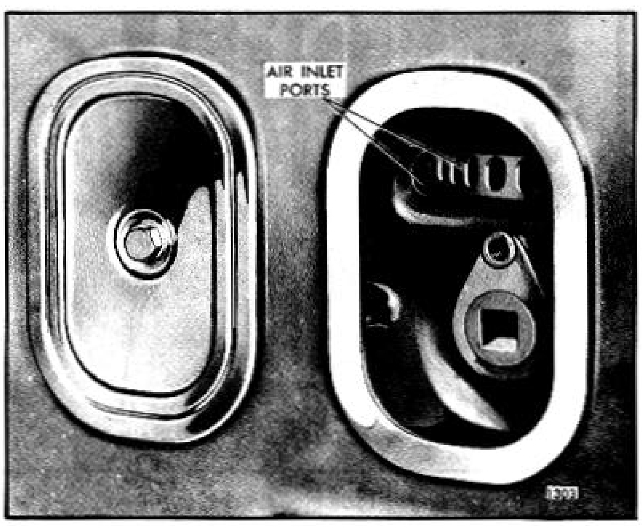


Fig. 3 - Air Box Covers and Air Inlet Ports

4. Remove the air cleaner tubes.
5. Disconnect the exhaust pipe and muffler.
6. Disconnect the throttle controls.
7. Remove engine hood and side covers.
8. Remove radiator and shroud as a unit after removing radiator hoses from radiator.
9. Remove drive line to traction pump.

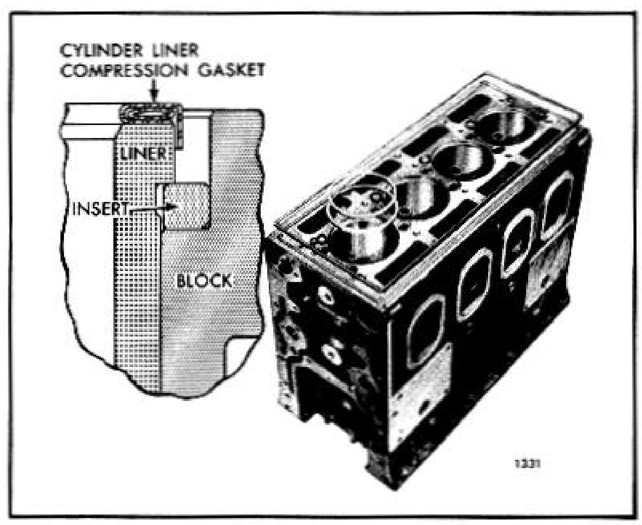


Fig. 4 - Sealing Arrangement of Cylinder Block

10. Remove rotor drive line.

11. Remove clutch linkage.

12. Disconnect batteries and remove cables from starter.

13. Loosen fan belts.

14. Remove power steering pump and lines as a unit by removing pump mounting bracket from engine and swing free from engine.

15. Label and disconnect alternator wires.

16. Disconnect neutral start switch wires on traction pump.

17. Disconnect wires from ignition switch.

18. Label and remove or unclamp any wires that are attached to engine or rotor transmission.

19. Remove the air box covers.

20. Attach a spreader bar with a suitable sling and adequate chain hoist to the front and rear engine lifter brackets. To prevent bending of the engine lifter brackets, the lifting device should be adjusted so the lifting hooks are vertical. (Fig. 6).

21. Remove front and rear engine mounting bolts.

IMPORTANT: Do not lift an engine by the webs in the air inlet opening of the cylinder block.

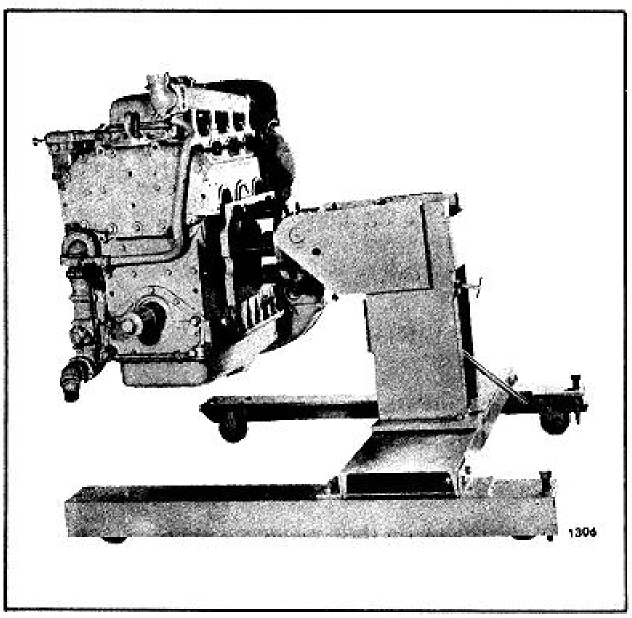


Fig. 5 - Engine Mounted on Overhaul Stand

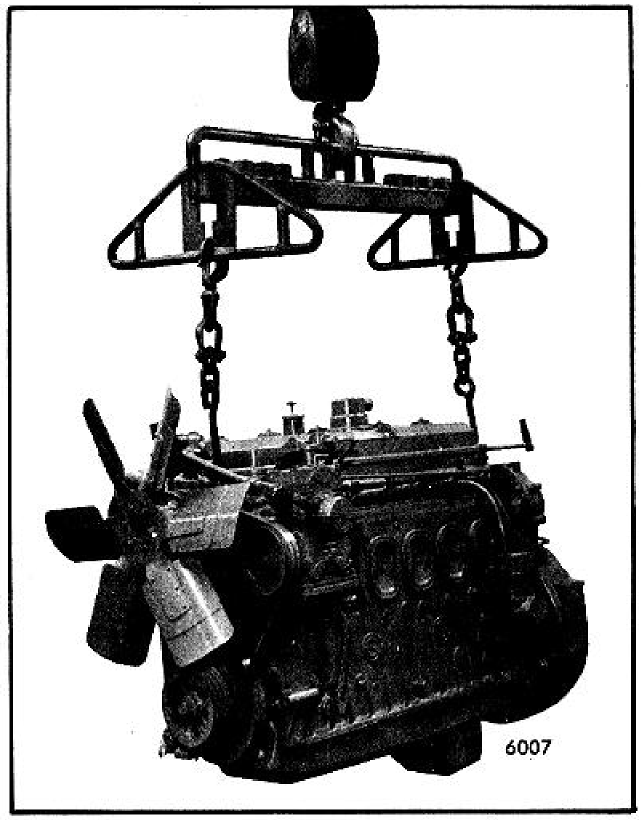


Fig. 6 - Lifting Engine with Spreader and Sling

22. Lift out engine-transmission assembly from vehicle.

Installation of the engine and rotor transmission is of the reverse procedure. The following is removal of sub assemblies.

23. 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 of the engine.

The adaptor plate, used with the hydraulic engine overhaul stand must be attached to the mounting plate on the overhaul stand with six spacers and bolts (Fig. 5). Long spacers and bolts are used with 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.

24. Loosen the lock nuts on the two holding lugs on the adaptor plate and lower the engine while guiding the lugs into the air box openings.

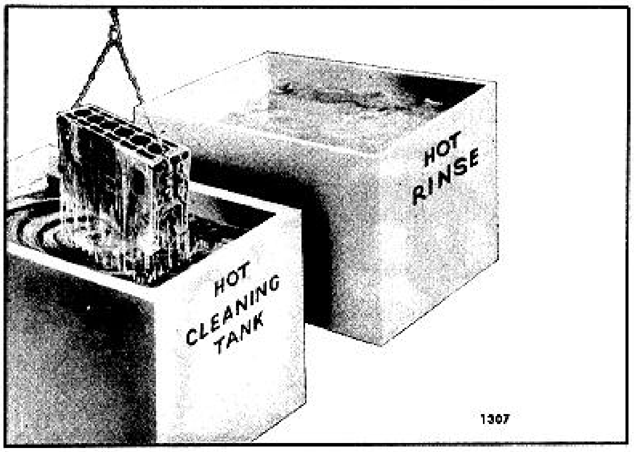


Fig. 7 - Cleaning Cylinder Block

25. Turn the holding lugs crosswise in the air box openings and tighten the lock nuts, drawing the engine tight against the adaptor plate.

26. To be sure the engine does not shift on or break away from the overhaul stand, insert a 7/16"-14 x 2" bolt, with a plain washer under the head of the bolt, through the hole in the adaptor plate and into the pad on the cylinder block.

WARNING

Be sure the engine is securely mounted to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the overhaul stand.

27. Place suitable jack under rotor transmission, remove transmission mounting bolts and remove transmission from engine.

28. Remove clutch pressure plate mounting bolts and remove clutch assembly from engine flywheel.

29. Remove cylinder block sub assemblies.

The procedure for removing each sub-assembly from the cylinder block, together with disassembly, inspection, repair and re-assembly of each, will be found in the various chapters of this manual.

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 hole plugs (except cup plugs) to allow the cleaning solution to contact the inside of the oil and water passages. This permits more efficient cleaning and eliminates the possibility of the cleaning solution attacking the aluminum core hole plug gaskets.

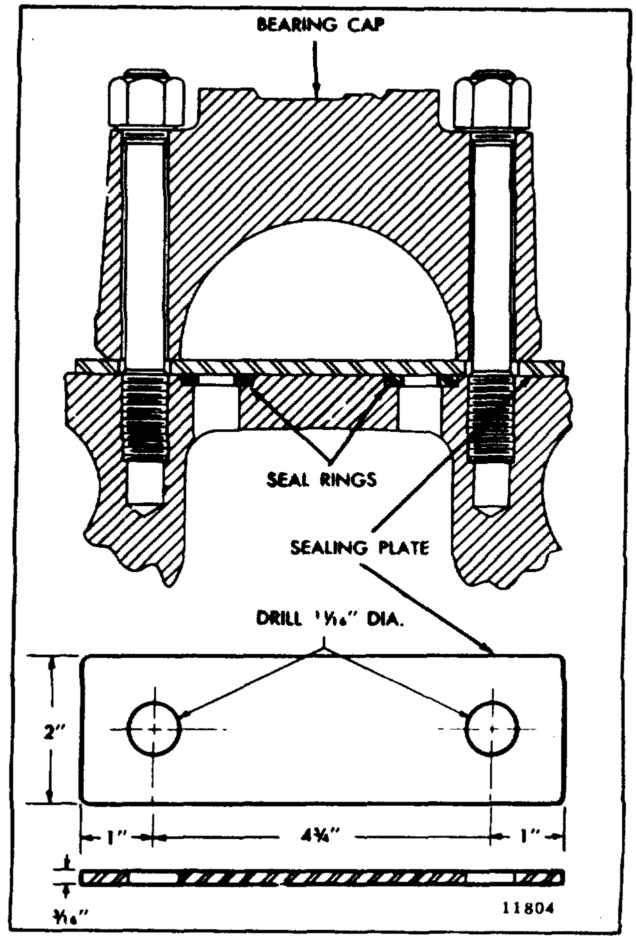


Fig. 8 Sealing Plate Details for Pressure Testing Cylinder Block

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 l/2 " flexible handle and a short extension placed in the countersunk hole in the plug, turn the plug slightly in the direction of tightening. Then turn it in the opposite direction and back the plug out.

Clean the cylinder block as follows:

1. Remove the grease by agitating the cylinder block in a hot bath of commercial heavy-duty alkaline solution (Fig. 7).

2. Wash the block in hot water or steam clean it to remove the alkaline solution.

3. If the water jackets are heavily scaled. proceed as follows:

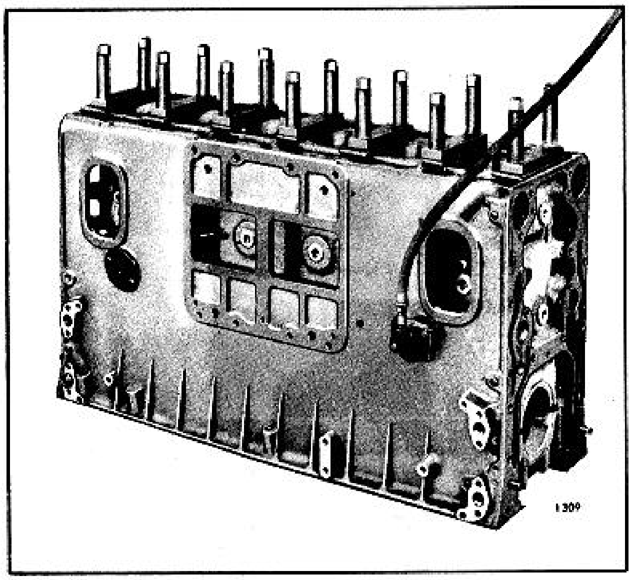


Fig. 9 - Cylinder Block Prepared for Pressure Test

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.

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.

After the cylinder block has been thoroughly cleaned and dried, re-install the core hole plugs. Coat the threads of the plugs with sealant. Install the core hole plugs in the sides of the block from 2 " to 2-1/4" below the machined surface of the block. They must be water tight. The core hole plugs in the ends of the block are flanged to provide a positive stop against the counterbore of the hole, thus preventing the plugs from entering the water jacket and restricting the flow of water. Soft aluminum gaskets are used with the plugs. Coat the threads of the end plugs with sealant and, using new gaskets, re-install the plugs and tighten them to 150-180 lb-ft (204-244 Nm) torque.

CAUTION:
Excessive torque applied to the core hole plugs may result in cracks in the water jacket.

Pressure Test

Cylinder Block Extremely tight fitting cylinder liners, severe scoring of the liners and overheating of the engine may result in cracks in the cylinder bores. Overheating of the engine may also result in cracks between the water jackets and the oil passages.

The cylinder block may be pressure tested for cracks or leaks by either one of two methods. In either method, it will be necessary to make plates (Fig. 8) to seal the water openings in the top of the block. Main bearing caps may be used to secure the plates to the block with the cylinder head bolts or studs and nuts. Cylinder head seal rings may be used as gaskets between the plates and the block. It will also be necessary to use water hole cover plates and gaskets to cover the water pump inlet openings in the block. Drill and tap one cover plate to provide a connection for an air line (Fig. 9).

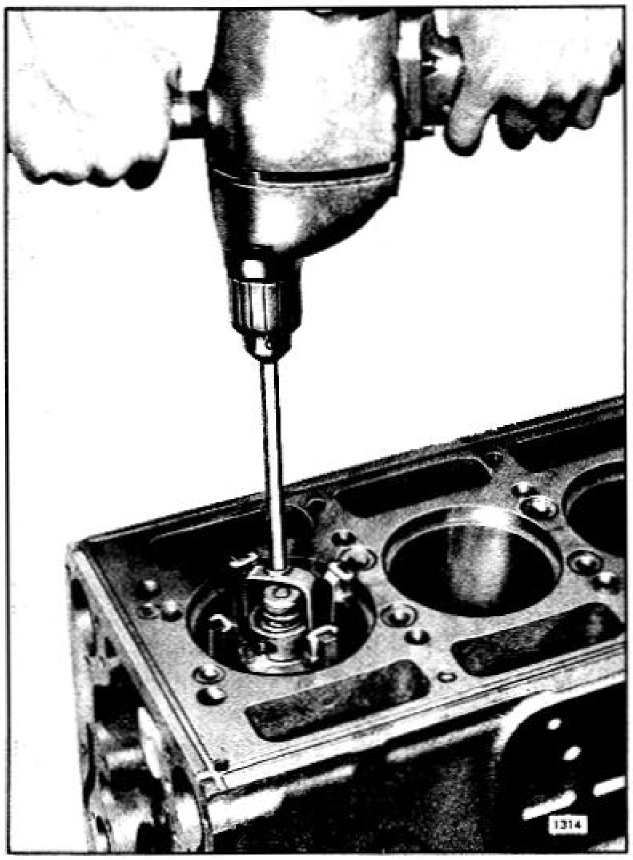


Fig. 10 - Honing Bore of Cylinder Block

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).

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.

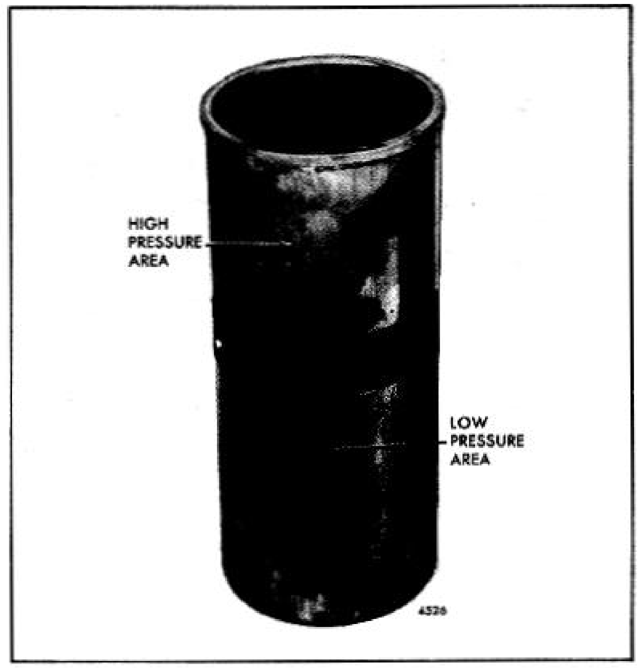


Fig. 11 - High Pressure Areas on Cylinder Liner

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 replaced by a new block.

5. After the test is completed, remove the plates, drain

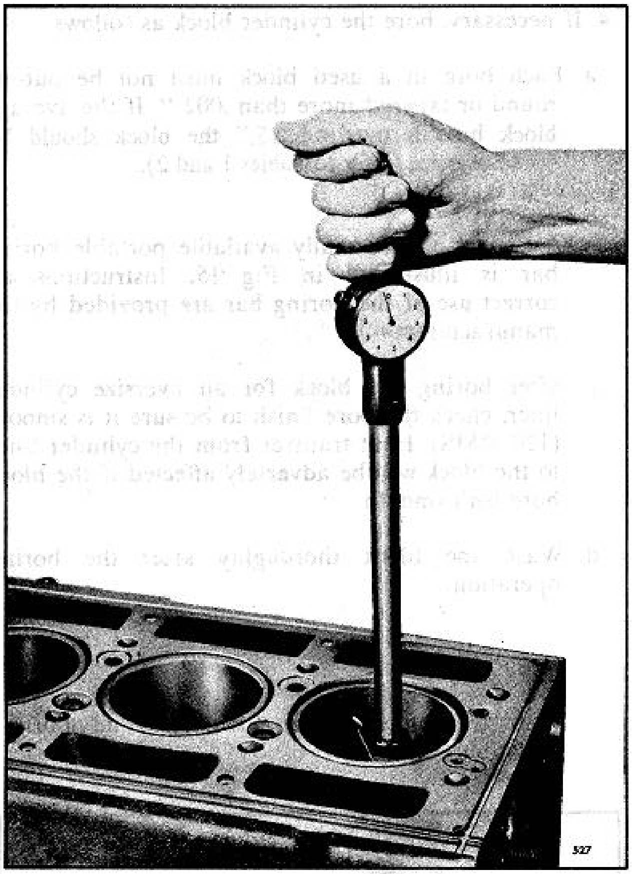


Fig. 12. Checking Bore of Cylinder Block

the water jacket and blow out all of the passages in the block with compressed air.

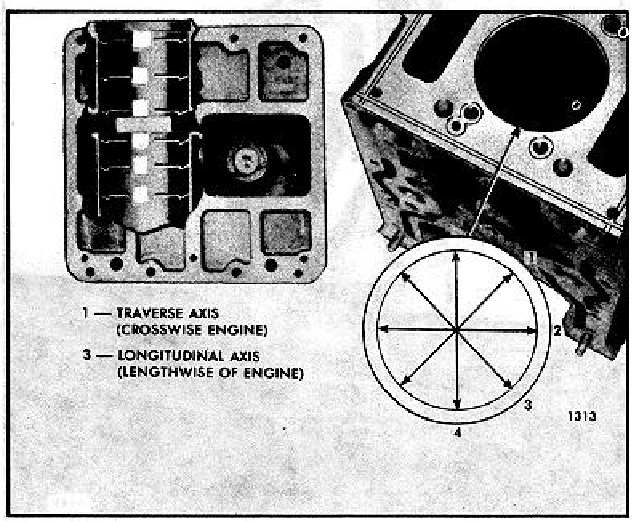


Fig. 13. Cylinder Bore Measurement Diagram

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 bores, hone them throughout their entire length until about 75% of the area above the ports has been "cleaned-up"

1. Hone the block bores as follows:
   a. Use a hone in which the cutting radius of the stones can be set in a fixed position to remove irregularities in the bore rather than following the irregularities as with a spring-loaded hone. Clean the stones frequently with a wire brush to prevent stone loading. Follow the hone manufacturer's instructions regarding the use of oil or kerosene on the stones. Do not use such cutting agents with a dry hone. Use 120 grit stones J 5902-14.
   b. Insert the hone in the bore (Fig. 10) 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 I " 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 (Fig. 11). A slight increase in block bore size is normal with high mileage or long period: o)I engine operation.

a. Visually check the contact area as revealed by the honed surface. There must not be any low spots which are larger in area than a half dollar.

b. Measure the entire bore of each cylinder with cylinder bore gage J 5347-01 (Fig. 12) which has a dial indicator calibrated in .0001 " increments. The standard block bore is 4.6260" to 4.6275." Place the bore gage in the master ring gage J 8386-01 which has an I.D. of 4.6270" and set the dial to zero. Take measurements on the cleaned-up surface only at positions A, B, C, D, E and F in the bore on axes 45° apart (Fig. 13). Read the measurements from the zero mark on the gage. The readings may be recorded on a form similar to the one illustrated in Fig. 14.

NOTE: Dial bore gage setting master tool J 23059-01 may be used in place of the master ring gage.

3. The liner-to-block clearance with new parts is zero to .0015." With used parts, the maximum clearance is .0025." After measuring the bores, measure the outside diameter of the cylinder liners (Page 10-2-94). Then determine the block-to-liner clearances (refer to Page 10-2-96 for the specified clearances) and whether it will be necessary to bore the block for oversize cylinder liners.

	Trans.	45°	Long.	45°
	1	2	3	4
A				
B				
C				
Port Belt				
D				
E				
F				

Fig. 14. Block Bore Measurement Record 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 .002 ". If the average block bore is over 4.6285," the block should be bored oversize (refer to Tables 1 and 2).

b. A typical commercially available portable boring bar is illustrated in Fig. 15. Instructions on correct use of the boring bar are provided by the manufacturer.

c. After boring the block 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 isn't smooth.

d. Wash the block thoroughly after the boring operation.

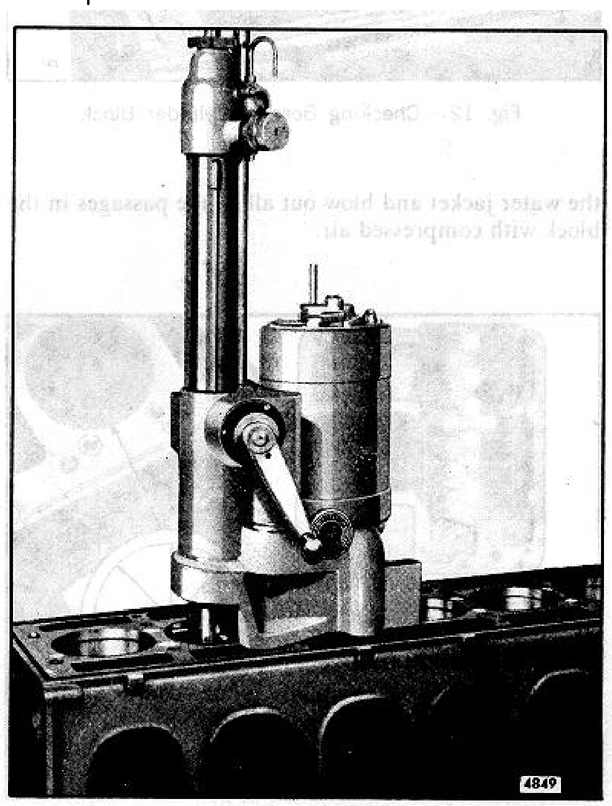


Fig. 15. Boring Cylinder Block with Portable Boring Bar

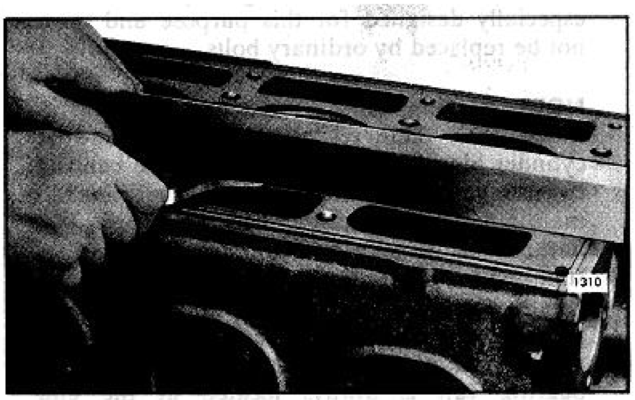


Fig. 16. Checking Top Face of Cylinder Block

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 (Page 10-2-97).

5. Check the top of the block for flatness with an accurate straight edge and a feeler gage (Fig. 16).

a. The top surface of the block must not vary more than .003" transversely and not over .007" longitudinally. It will be difficult to prevent water, oil and compression leaks if the top surface of the block exceeds these tolerances.

b. If it is necessary to machine the top surface of the block to correct for the above conditions, do not remove more than .008 " of metal. Stamp the amount of stock removed on the face of the block. The distance from the centerline of the crankshaft to the top of the block must not be less than 16.176 " (Fig. 17).

For Average Block Bore I.D. Size	Use Liner O.D. Size	For Liner-to-Block Clearance
4.6260" / 4.6275"	Standard	.000 to .0025"
4.6270" / 4.6285"	.001" Oversize	.000" to .0025"

TABLE 1

Block Boring Dimensions	Liner O.D. Size	Max. Block Bore I.D. on Used Block
4.63120" / 4.6320"	.005" Oversize	4.6325"
4.6360" / 4.6370"	.010" Oversize	4.6375"
4.6460" / 4.6470"	.020" Oversize	4.6475"
4.6560" / 4.6570"	.030" Oversize	4.6575"

TABLE 2

c. If stock is removed from the top surface of the block, check the depth of the seal ring grooves and counterbores. The cylinder head seal strip grooves must be .092 "-.107 " deep. The large water hole counterbores (between the cylinders) must be .109 "-.120 " deep, and the combination water and oil hole counterbores and small water hole counterbores must be .087 "-.098 " deep. If necessary, deepen the grooves or counterbores to the specified limits to retain the proper "crush" on the seal rings. It is not necessary to deepen the counterbores for the cylinder liners since .004" and .008 " undersize thickness inserts are available for adjusting the liner position as outlined on Page 10-2-97, *Fitting Cylinder Liner in Block Bore.*

6. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth (Fig. 18). The depth must be .4770 " to .4795 " 'and must not vary more than .0015 " throughout the entire circumference. The counterbored surfaces must be smooth and square with the cylinder bore within .001 " total indicator reading. There must not be over .001 " difference between any two adjacent cylinder counterbores when measured along the cylinder longitudinal centerline of the cylinder block.

7. Check the main bearing bores as follows:

a. Check the bore diameters with the main bearing caps in their original positions. Apply a small

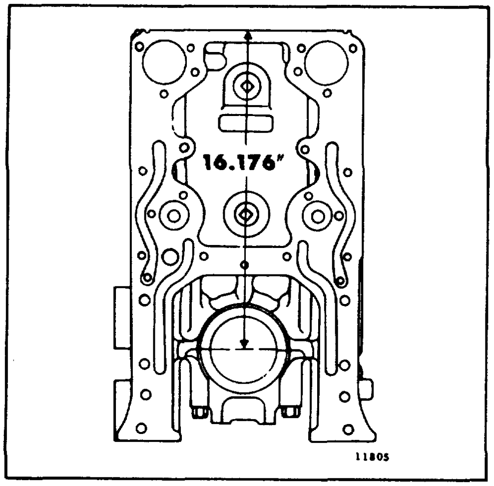


Fig. 17. Minimum Distance from Center Line of Crankshaft to Top of Cylinder Block

quantity of International Compound No. 2 or equivalent, to the threads on the bolts and to the bolt head contact area. Then install and tighten the bolts to 165-175 lb-ft (224238 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.

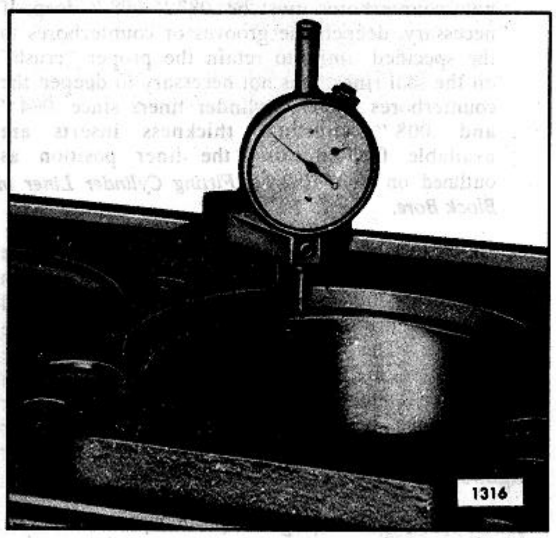


Fig. 18. Checking Depth of Counterbore for Cylinder Liner with Tool J 22273

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

NOTE: Bearing caps are numbered to correspond with their respective positions in the cylinder block. It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The number of the front main bearing cap is 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. I main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 19), regardless of engine rotation or accessory arrangement. As originally manufactured, the main bearing caps are installed with the numbered side facing the blower side of the engine. Machining of the cylinder block and main bearing caps is such that the mating parts are "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.

b. Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a finished replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. If a replacement bearing cap

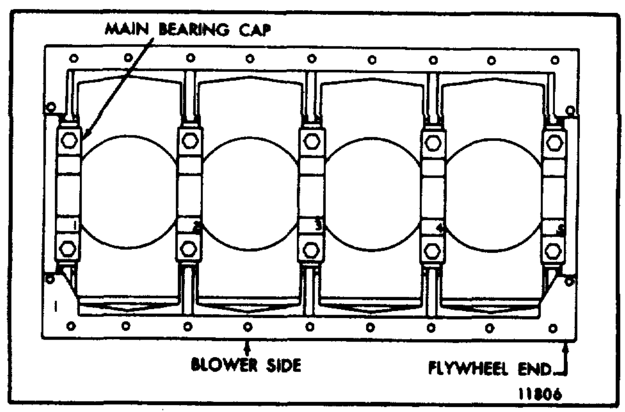


Fig. 19. Cylinder Block Markings

is installed, be sure to stamp the correct bearing position number on the cap.

NOTE: Use the unfinished bearing caps for the front and intermediate bearing positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the rear bearing position.

c. Main bearing bores are line-bored with the bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured in place and the bolts tightened as specified on Page 10-2-62. If a main bearing bore is more than .001" out of alignment, the block must be linebored or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat or other damage.

d. If the main bearing bores are not in alignment when a replacement bearing cap is used, the block must be line-bored. 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 than .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 section and install the necessary plugs and dowels.

9. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .625 " from the face of the block.

The dowels used to retain the crankshaft thrust washers on the rear main bearing cap must extend .110 " to .120 " from the surface of the bearing cap.

NOTE: A stepped dowel pin is available to replace loose pins in the rear main bearing cap. Before installing the stepped pins, rebore the dowel holes in the bearing cap with a No. 11 (.1910 ") or No. 12 (.1890 ") drill. After pressing the pins into the bearing cap, remove all burrs from the base of the dowel pins to ensure proper seating of the thrust washers.

10. Examine the tapped bolt holes for the cylinder head or main bearing cap bolts and, if the threads are damaged, "clean-up" the threads or install a helical thread insert. The tapped holes may be tapped with a 5/8 "-II UNC3B tap. All cylinder head bolt or stud holes must have the threads extending 1.84 " below the block surface.

NOTE: The current service replacement cast iron cylinder blocks use a special cylinder head bolt in all positions.

11. 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.

12. Check the remaining cylinder block surfaces and threaded holes. Check all of the mating surfaces, or mounting pads, for flatness, nicks and burrs. The flatness of the blower mounting pad must not vary more than .004 ". Clean-up damaged threads in tapped holes with a tap or install helical thread inserts, if necessary.

13. 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 (Fig. 19) and the position of the No. I bearing on the oil pan mounting flange of the block.

3. Install all of the required cylinder block plugs and drain cocks. Use a good grade of non-hardening sealant on the threads of the plugs and drain cocks. Install the plugs flush with or below the surface of the block.

4. Clean and inspect all engine parts and subassemblies and, using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. The procedures for inspecting and installing the various parts and sub-assemblies are outlined in the following sections of this manual.

5. Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.

6. Complete the engine build-up by installing all remaining accessories, fuel lines, electrical connections, controls etc.

7. Operate the engine on a dynamometer, following the RUN-IN procedure outline on Page 10-9-2.

8. Reinstall the engine.

CYLINDER BLOCK END PLATES

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. Clean the end plate as outlined under *Clean Cylinder Block* on Page 10-2-6.

Inspect both surfaces of each end plate for nicks, dents, scratches or score marks and check the end plates for warpage. Also check the tapped holes in the end plates at this time. If nicks or scratches on the sealing surfaces of the end plates are too deep to be cleaned up, replace the end plates.

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).

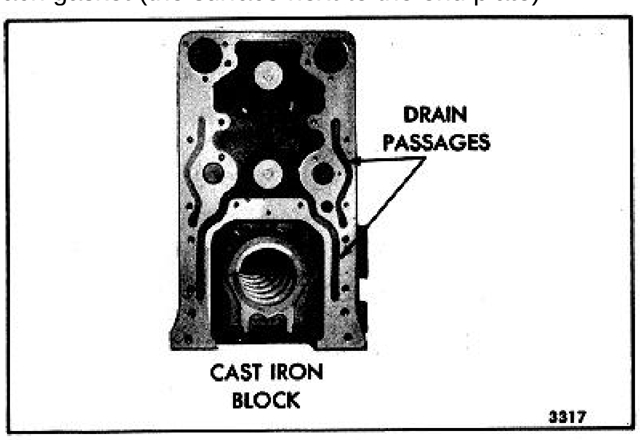


Fig. 1. Drain Passages in Cylinder Block

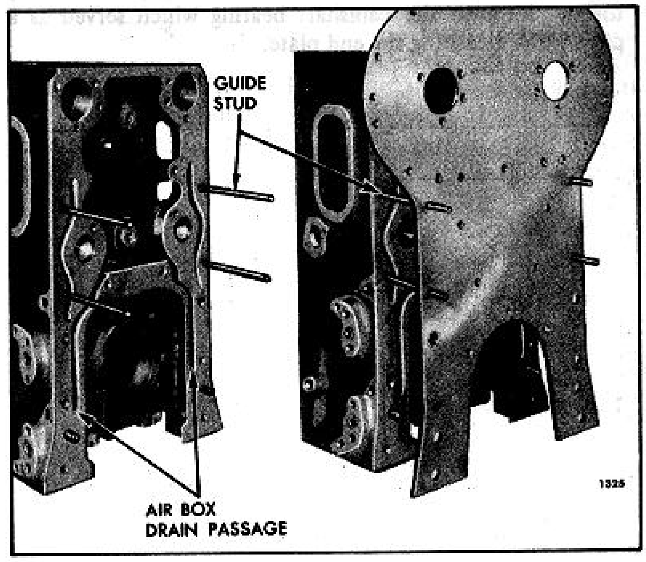


Fig. 2. Installing Front End Plate

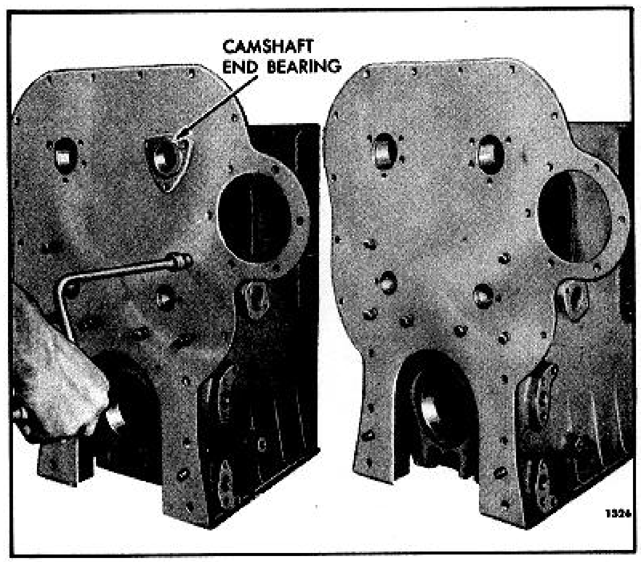


Fig. 3 - Installing Rear End Plate

2. Use guide studs J 1927-01 as shown in Fig. 2 to set the front end plate next to the cylinder block and install the bolts and lock washers. Do not tighten the bolts at this time. Wipe the excess gasket cement from the bores in the end plate and the cylinder block.

3. Insert a camshaft end bearing through the SMALL bearing bore in the end plate and into the bore of the block to accurately align the end plate as shown in Fig. 3.

4. With the bearing in place, tighten the 3/8" -16 end plate retaining bolts 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.

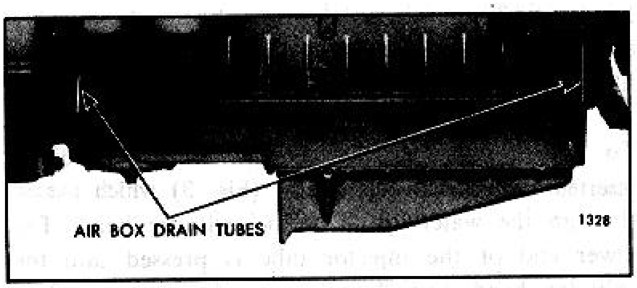


Fig. 1. Air Box Drain Tubes

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 (Fig. 1).

Air box drains must be kept open at all times, otherwise water and oil that may accumulate will be drawn into the cylinders.

Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Page 10-11-6).

CYLINDER HEAD

The cylinder head (Fig. 1 and 2) is a one-piece casting securely held to the top of the cylinder block by special bolts.

The exhaust valves, fuel injectors and the valve and injector operating mechanism are located in the cylinder head.

Two exhaust valves are provided for each cylinder.

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of valves under varying conditions of temperature and materially prolong the life of the cylinder head.

To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube (Fig. 3) which passes through the water space in the cylinder head. The lower end of the injector tube is pressed into the cylinder head and flared over; the upper end is flanged and sealed with a neoprene seal. The sealed

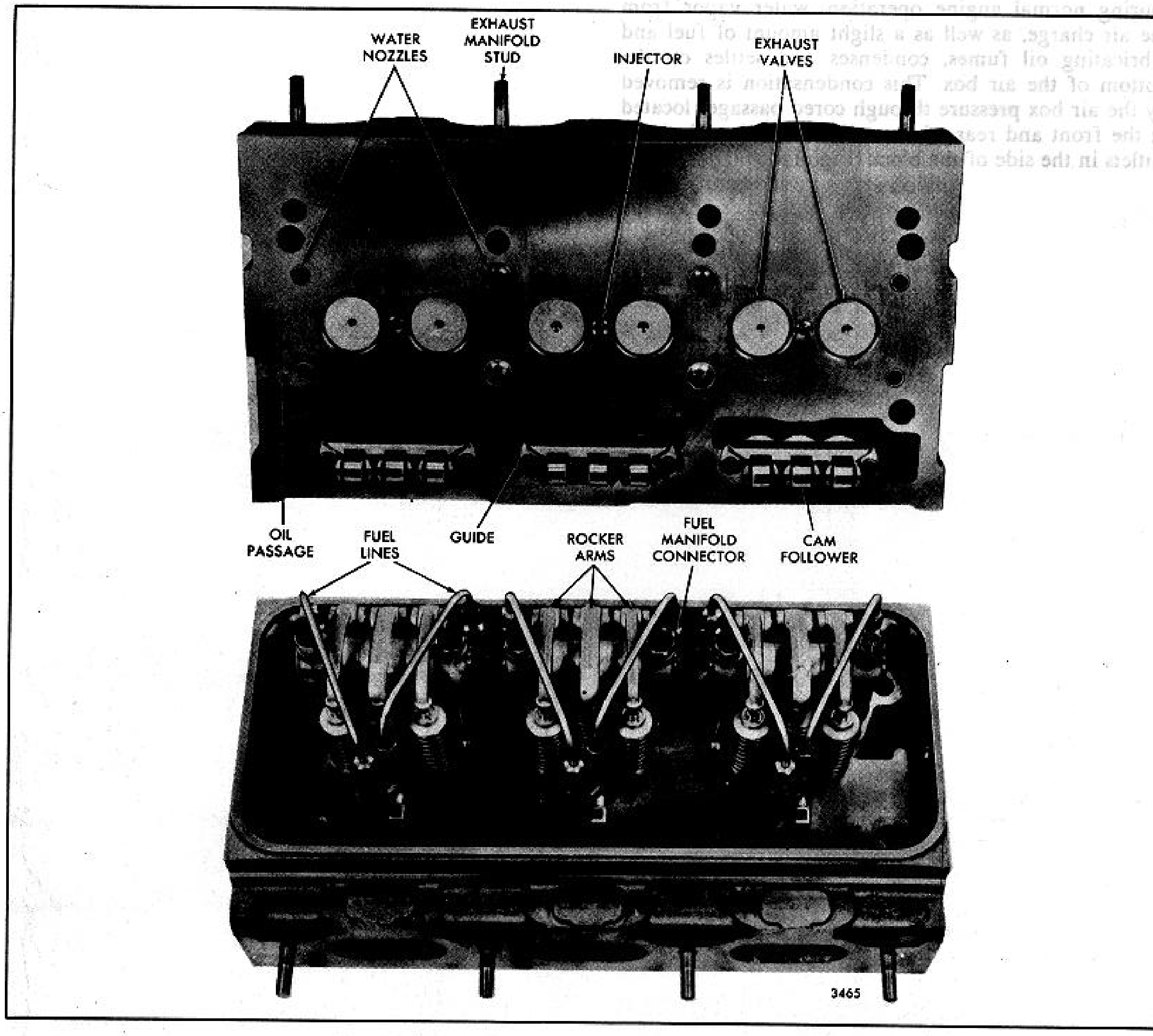


Fig. 1. Typical Cylinder Head Assembly (Two-Valve)

upper end and flared lower end of the injector tube prevent water and compression leaks.

The exhaust passages from the exhaust valves of each cylinder lead through a single port to the exhaust manifold. The exhaust passages and the injector tubes are surrounded by engine coolant.

In addition, cooling of the above areas is further ensured by the use of water nozzles (Fig. 4) pressed into the water inlet ports in the cylinder head. The nozzles direct the comparatively cool engine coolant at high velocity toward the sections of the cylinder head which are subjected to the greatest heat.

The fuel inlet and outlet manifolds are cast as an integral part of the current cylinder heads. Tapped holes are provided for connection of the fuel lines at various points along each manifold.

The water manifold is also cast as an integral part of the cylinder head.

To seal compression between the cylinder head and the cylinder liner, separate laminated metal gaskets are provided at each cylinder. Water and oil passages between the cylinder head and cylinder block are

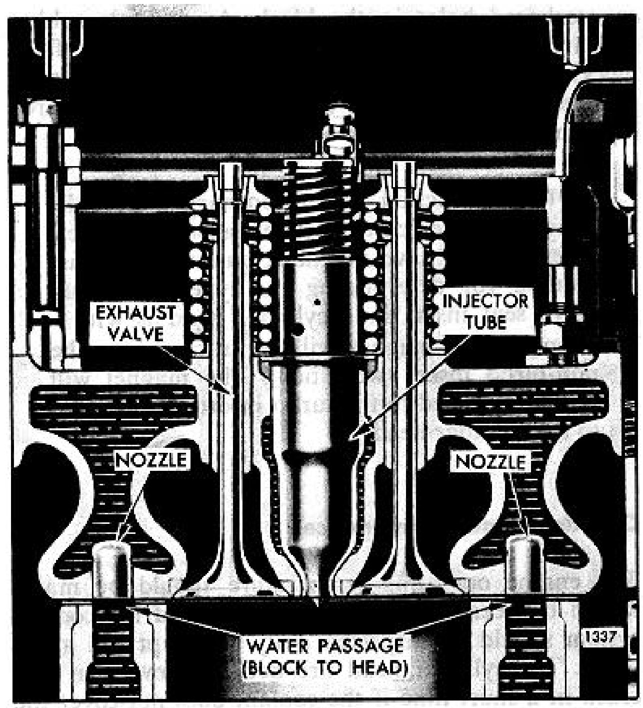


Fig. 2. Typical Mounting of Cylinder Head

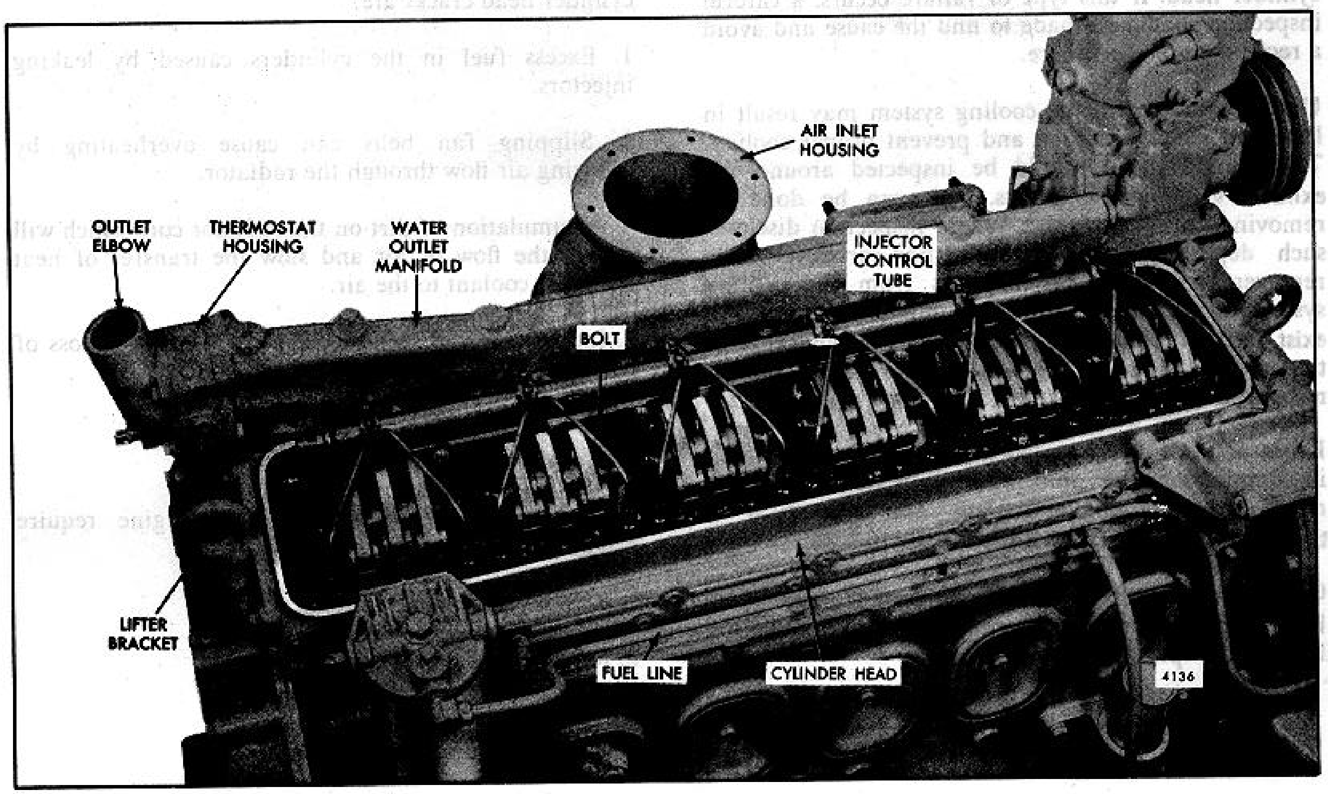


Fig. 3. Typical Mounting of Cylinder Head

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.

> **NOTE**: Production non-turbocharged cylinder heads include cast steel exhaust valve seat inserts which have magnetic qualities. An easy method for determining the type of exhaust valve seat insert in a cylinder head is with a magnet. The magnet will be attracted to the non-turbo insert (will stick). The magnet will not be attracted to the turbo insert, it will jump to the cylinder head.

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. Refer to Page 10-9-13 for engine coolant recommendations.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and also result in loss of engine coolant. The tubes must be tight to be properly seated. Refer to Page 10-3-25.

Overtightened injector clamp bolts may also cause head cracks. Always use a torque wrench to tighten the bolts to the specified torque.

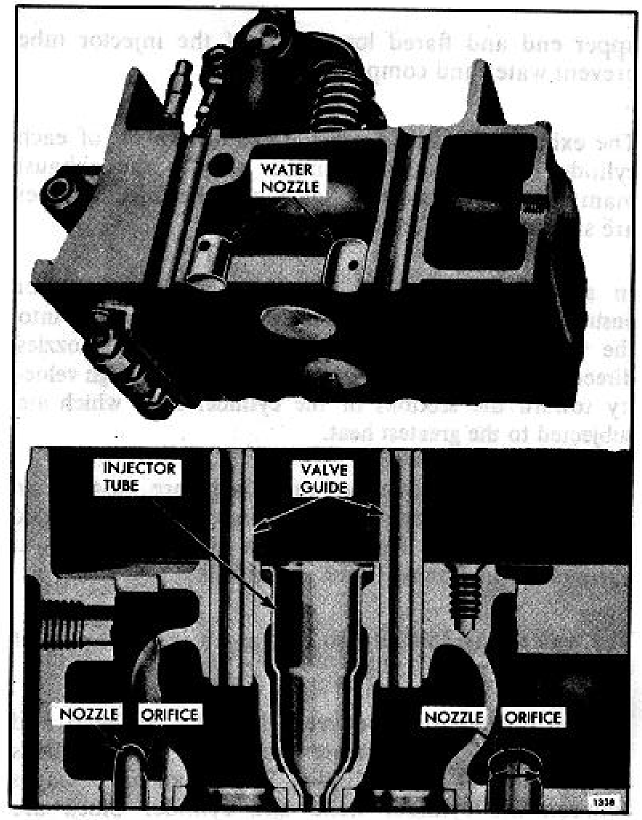


Fig. 4. Water Nozzle in Two-Valve Cylinder Head

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.
8. Remove and install camshaft.

Due to the various optional and accessory equipment used, only the general steps for removal of the cylinder head are covered. If the engine is equipped with accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to ensure correct reinstallation. Then refer to Fig. 2 and remove the cylinder head as follows.

1. Drain the cooling system.
2. Disconnect the exhaust piping at the exhaust manifold.
3. Remove the air 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 (Fig. 2).
6. Remove the thermostat housing assembly.
7. Remove the water manifold.

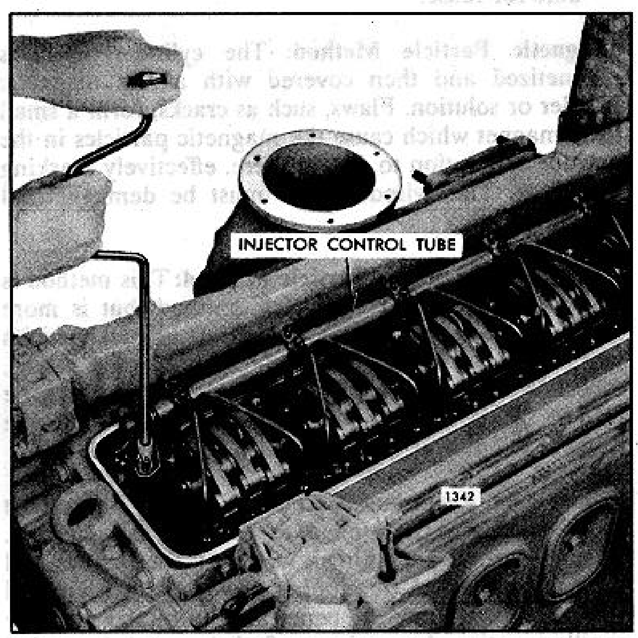


Fig. 5. Removing or Installing Injector Control Tube

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 (Fig. 5).
11. If the cylinder head is to be disassembled for reconditioning of the exhaust valves and valve seat inserts or for a complete overhaul, remove the fuel pipes and injectors at this time. Refer to Page 10-3-25 for removal of the injectors.
12. Loosen (three or four turns) the two bolts directly below each lifter bracket which attach the balance weight cover and flywheel housing to the front and rear end plates. Otherwise, the threaded ends of the bolts may interfere with removal of the cylinder head.
13. Remove the two bolts which secure the front lifter bracket to the balance weight cover and the two bolts attaching the rear lifter bracket to the flywheel housing.
14. Check the torque on the cylinder head bolts before removing the head. Then remove the bolts and, using lifting hooks and a chain hoist, lift the cylinder head from the cylinder block. Checking the torque before removing the head bolts and examining the condition of the compression gaskets and seals after the head is removed may reveal the causes of any cylinder head problems.

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 lifter brackets and gaskets. Then attach the cylinder head holding plates J 3087-01 to raise the head above the work bench (Fig. 6).

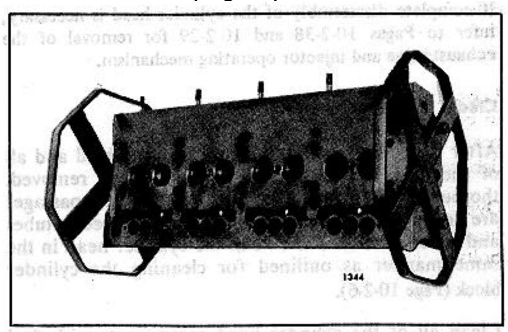


Fig. 6. Cylinder Head Mounted on Holding Plates (J 3087-01)

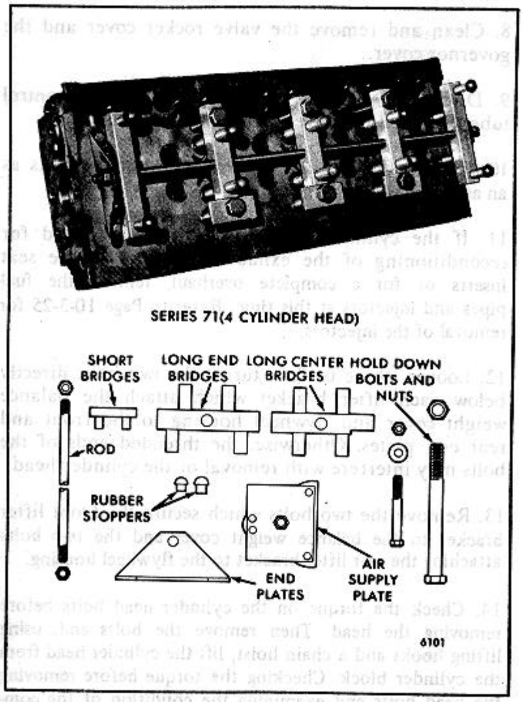


Fig. 7. Cylinder Head Prepared for Pressure Test using Tool J 28454

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 head is necessary, refer to Pages 10-2-38 and 10-2-29 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 been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tubes and water nozzles. Then clean the cylinder head in the same manner as outlined for cleaning the cylinder block (Page 10-2-6).

Clean all of the cylinder head components with fuel oil and dry them with compressed air.

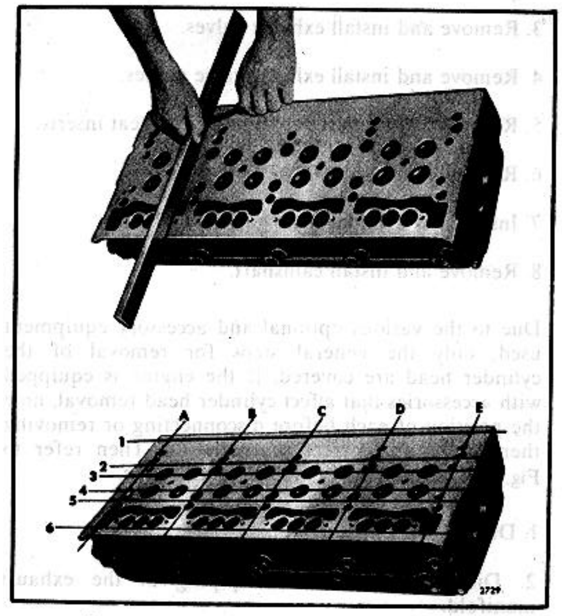


Fig. 8. Checking Bottom Face of Cylinder Head

Inspect Cylinder Head

1. Before a cylinder head 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.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it uses fluorescent magnetic particles which glow under a "Black Light". Very fine cracks, especially on discolored or dark surfaces, that may be missed using the Magnetic Particle Method will be disclosed under the "Black Light".

Fluorescent Penetrant Method: A highly fluorescent liquid penetrant is applied to the area in question. Then the excess penetrant is wiped off the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection to find the crack is carried out using a "Black Light".

Non-Fluorescent Penetrant Method: The test area being inspected is sprayed with "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 agaitator 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 (Fig. 7):
   1. Install the rubber stoppers on the bridges.
      a. Large stoppers are installed on the long center bridge feet opposite the notch and on the long 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 stopper could distort enough to seal both the inner and outer diameter of the water nozzles. If the outer diameter is sealed, a leak from the outer diameter would not be detected.

   4. Install the air supply plate.

   CAUTION: Do not hook onto the pressure checking tool, or any part of it, to move the cylinder head from one location to another. If this is done it could result in permanent damage to the tool.

b. Install scrap or dummy injectors to ensure proper seating of the injector tubes. Dummy injectors may be made from old injector nuts and bodies -the injector spray tips are not necessary. Tighten the injector clamp bolts to 20-25 lb-ft (27-34 Nm) torque.

c. Apply 40 psi (276 kPa) air pressure to the water jacket. Then immerse the cylinder head in a tank of water, previously heated to 180-200°F (8293 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.

d. Relieve the air pressure and remove the cylinder head from the water tank. Then remove the plates, gaskets and injectors and dry the head with compressed air.

2. Check the bottom (fire deck) of the cylinder head for flatness:

a. Use a heavy, accurate straight-edge and feeler gages, tool J 3172, to check for transverse warpage at each end and between all cylinders. Also check for longitudinal warpage in six places as shown in Fig. 8. Refer to Table 1 for maximum allowable warpage.

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
4-71	.008"	.004"

TABLE 1

b. Use the measurements obtained and the limits given in Table I 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 3.536" (Fig. 9).

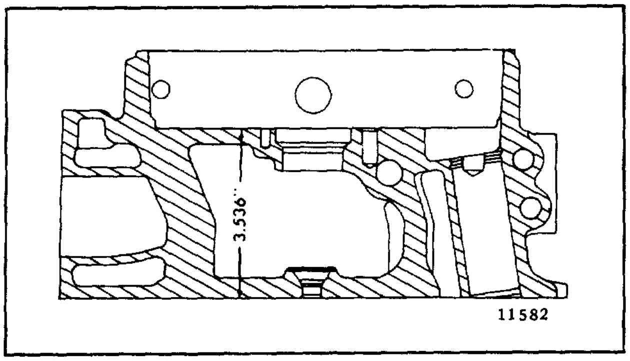


Fig. 9- Minimum Distance Between Top and Bottom Faces of Cylinder Head

> **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 in the engine.

3. Install new injector tubes (Page 10-3-25) if the old tubes leaked or the cylinder head was refaced.

4. Inspect the exhaust valve seat inserts and valve guides (refer to Page 10-2-40).

5. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. Measure the bore diameters with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record and compare the readings of the followers and bores to determine the cam followers-to-bore clearances. The clearance must not exceed .006" with used parts (refer to Page 10-2-136 for specifications). If the bores are excessively scored or worn, replace the cylinder head.

6. Check the water hole nozzles to be sure they are not loose. If necessary, replace the nozzles as follows:

a. Remove the old nozzles.

b. Make sure the water inlet ports in the cylinder head are clean and free of scale. The water holes at each end of the head may be cleaned up with a 1/2" drill and the intermediate holes may be cleaned up with a 13/16" drill. Break the edges of the holes slightly.

c. Press the nozzles in place with the nozzle openings parallel to the longitudinal center line of the two valve cylinder head (Fig. 10). Install the 1/2" diameter nozzles at the ends of the cylinder head with their openings toward the center of the engine. Press the nozzles flush to .0312" recessed below the surface of the cylinder head.

d. Check to make sure the nozzles fit tight. If necessary. use a wood plug or other suitable tool to expand the nozzles, or tin the outside diameter with solder to provide a tight fit. If solder is used, make sure the orifices in the nozzles are not closed with solder.

7. Replace broken or damaged studs. Apply sealant to the threads of new studs and drive them to 10-25 lb-ft (14-34 Nm) torque (water manifold cover studs) or to 25-40 lb-ft (34-54 Nm) torque (exhaust manifold studs).

8. Inspect all other components removed from the cylinder head.

If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of all rust preventive compound, particularly inside the integral fuel manifolds, before installing the plugs. A simple method of removing the rust preventive compound is to immerse the head in 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.

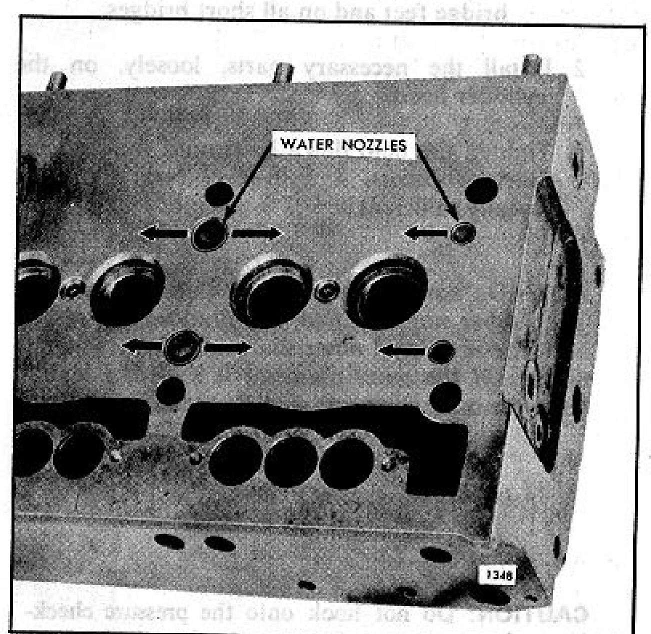


Fig. 10. Correct Installation of Water Nozzles in Two-Valve Cylinder Head

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, lock washers 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 (Page 10-2-141). Drive headless plugs flush to .0625" below the surface of the cylinder head. The 3/8" socket head oil gallery plug, at each end of the head, must not protrude more than .0625", and a .2187" diameter rod placed in the vertical oil feed hole must pass the inner face of the plug. Refer to the Cylinder Head Plugging Charts 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 (Page 102-43).
   b. Cam followers, guides, push rods, springs, retainers, rocker arms, shafts, brackets and other related parts (Page 10-2-33).
   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 (Page 10-2-97).

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 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.

Install Cylinder Head

1. Refer to Fig. 11 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 (Fig. 12). This is effective with engines built after July, 1979. The new gasket can be identified by GM-MC-H, GM-VG-H or GM-FPH. 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.

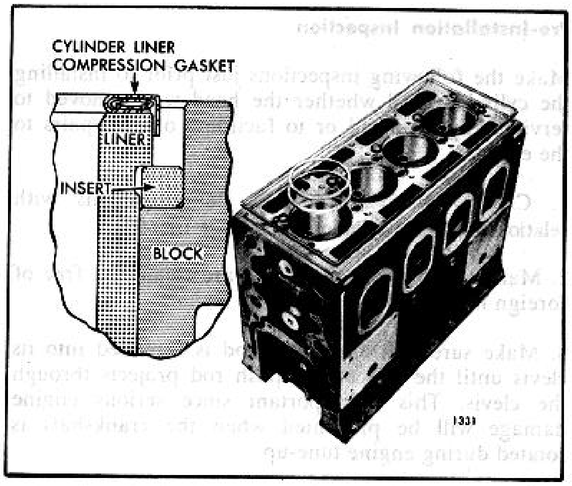


Fig. 11 Cylinder Head Seals and Gaskets

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 tire deck to minimize overspray.

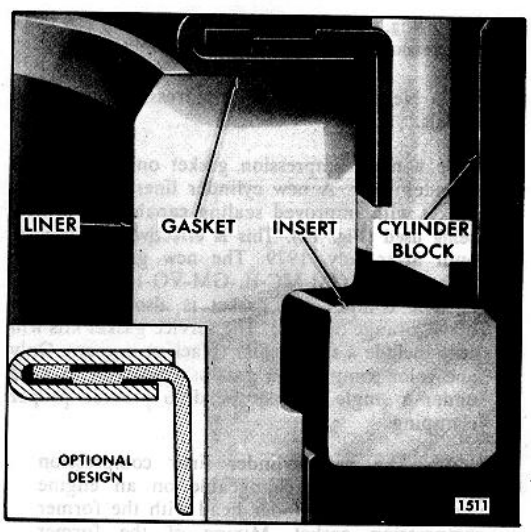


Fig. 12. Compression Gasket Mounting in Cylinder Block

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.
3. Allow the adhesive to dry to a high-tack consistency (stickiness) before installing the seal. This permits the evaporation of the liquid propellant used with the adhesive. 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 stripe facing away from the cylinder bores can improve its sealing capabilities.

NOTE: 3M Company Super-Tack Gasket adhesive #8082 or equivalent may also be used to hold the peripheral head-to-block oil seals in place during engine rebuild.

2. To install the cylinder head on the engine without disturbing the gaskets and seals, install guide studs J 9665 in two corner bolt holes in the cylinder block.

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. Gaskets and seals which are not seated properly will cause leaks and "blow-by" and result in poor engine performance and damage to the engine.

5. Wipe the bottom of the cylinder head clean. Then lower the head until it is about 1/2" from the surface of the cylinder block.

6. Apply a small amount of International Compound No. 2, or equivalent, to the threads and underside of the head of all cylinder head attaching bolts. Then install bolts 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.

NOTE: Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

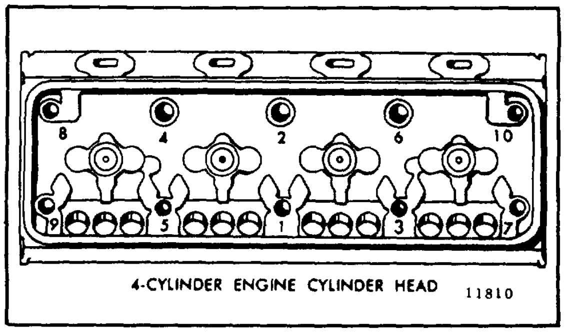


Fig. 13 Cylinder Head Bolt Tightening Sequence

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 handle (15-20 lb-ft or 20-27 Nm torque). However, before tightening the bolts, 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 cylinder head. Clearance must be assured between the exhaust manifold and the bosses on the cylinder block.

8. Tighten the bolts 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 Fig. 13. 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.

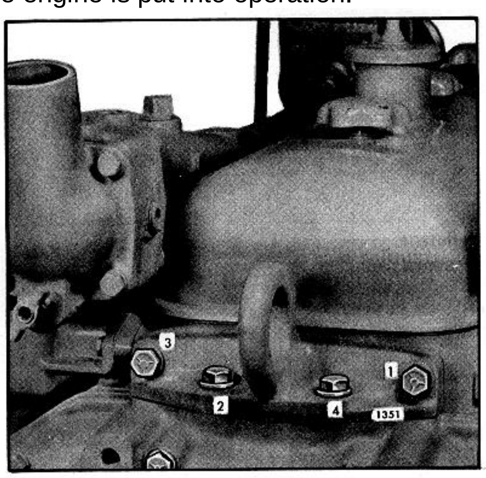


Fig. 14. Lifter Bracket Bolt Tightening Sequence

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. (Fig. 14).

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.

11. If the fuel injectors were not previously installed, refer to Page 10-3-8 or 10-3-23 and install them at this time.

12. Tighten the rocker arm bracket bolts to the specified torque (Page 10-2-140).

13. 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.

CAUTION: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to *Pressurize Fuel System Check for Leaks on Page 10-3-56).*

14. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts linger 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.

15. 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.

16. Attach the fuel rod to the differential lever in the governor housing. Secure the governor to the cylinder head with bolts and lock washers.

17. Connect the governor fuel rod to the injector control tube lever.

18. Install the fuel filter and connect the fuel lines.

19. Install the exhaust manifold.

20. Install the water manifold.

21. Install the temperature gage thermocouple in the adaptor at the rear end of the water manifold.

22. Install the thermostat and secure the thermostat housing to the water manifold with four bolts and lock washers.

23. 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. Fill the cooling system and lubrication system.

26. Before starting the engine, perform an engine tuneup as outlined in Chapter 10.

VALVE AND INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder (Fig. 1); the two outer arms operate the exhaust valves and the center arm operates the fuel injector.

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Removal of the two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and the exhaust valve springs.

The rocker arms are operated by the camshaft through cam followers and short push rods extending through the cylinder head.

Each cam follower operates in a bore in the cylinder head. A guide for each set of three cam followers is attached to the bottom of the cylinder head to retain the cam followers in place and to align the cam follower rollers with the camshaft lobes.

A coil spring, inside of each cam follower, maintains a pre-determined load on the cam follower to ensure contact of the cam roller on the camshaft lobe at all times.

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage on the camshaft side of the cylinder head, which connects with the main oil gallery in the cylinder block. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft to lubricate the rocker arms (Fig. 2).

Overflow oil from the rocker arms lubricates the exhaust valves 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.

Lubrication

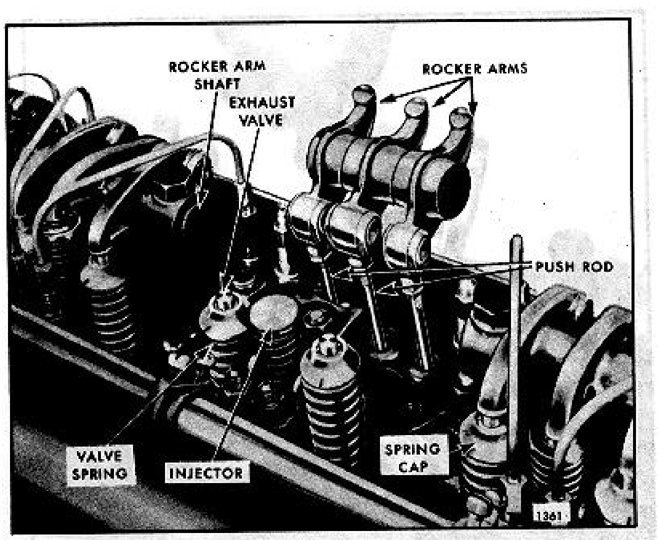


Fig. 1. Valve and Injector Operating Mechanism (Two-Valve Head)

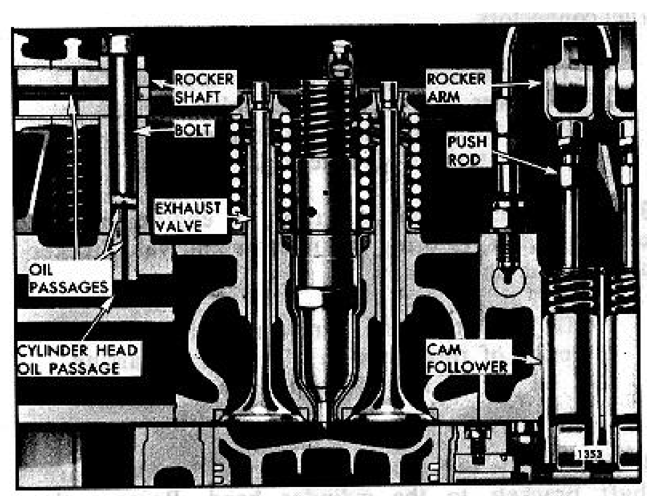


Fig. 2. Lubrication of Valve Operating Mechanism

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 a rocker arm.
4. Replace a rocker arm shaft or bracket.
5. Replace a fuel injector.

It is also possible to replace a push rod. push rod spring, the spring seats or a cam follower without removing the cylinder head. However, these parts are more easily changed from the lower side when the cylinder head is off the engine. Both methods are covered in this section.

To replace the exhaust valves, valve guides and valve seat inserts, the cylinder head must be removed (refer to Page 10-2-20).

Remove Rocker Arms and Shaft

1. Clean and remove the valve rocker cover.
2. Remove the fuel pipes from the injector and the fuel connectors.

> **NOTE**: Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

3. Turn the crankshaft, or crank the engine with the starting motor, to bring the injector and valve rocker arms in line horizontally.

> **NOTE**: Do not bar the crankshaft in a left-hand direction of rotation with a wrench or barring tool on the crankshaft bolt, because 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.

> **CAUTION**: When removing the rocker arm shaft, fold the three rocker arms back just far enough so the shaft can be removed. *Do not force the rocker arms all the way back with the shaft in place as this may impose a load that could bend the push rods.*

5. Loosen the locknuts at the upper ends of the push rods, next to the clevises, and unscrew the rocker arms from the push rods.

> **NOTE**: If the rocker arms and shafts from two or more cylinders are to be removed. tag them so they may be reinstalled in their original positions.

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 .004" is allowable with used parts (refer to Page 10-2-137). 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 .010". However, proceed with caution when surface grinding to avoid overheating the rocker arm. Maintain the

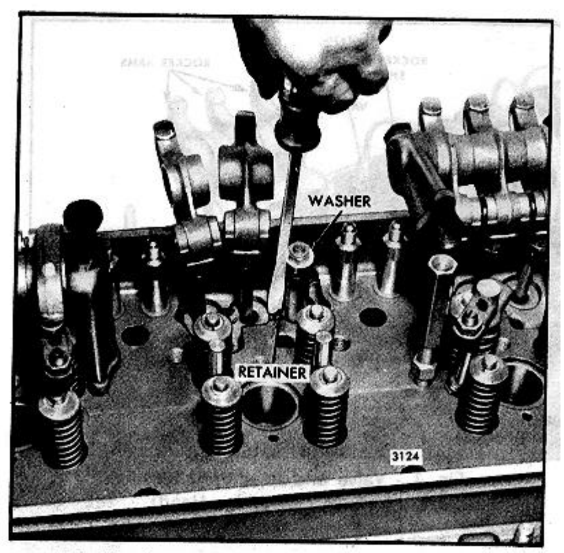


Fig. 3. Removing Push Rod from Upper Side of Cylinder Head using Tool J 3092-01

radius and finish as close to the original surface as possible.

Remove Cam Follower and Push Rod (Cylinder Head on Engine)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

To remove a push rod, spring, spring seats and cam follower from the top of the cylinder head, proceed as follows:

1. Remove the rocker arm shaft and brackets as outlined under Remove Rocker Arms and Shaft.

2. Loosen the locknut and unscrew the rocker arm from the push rod to be removed. Remove the locknut.

3. Install remover J 3092-01, a flat washer and the locknut on the push rod, with the lower end of the tool resting on the upper spring seat.

4. Thread the nut down to compress the spring.

5. Remove the spring seat retainer from the groove in the cylinder head (Fig. 3).

6. Unscrew the locknut to release the spring. Then remove the nut, flat washer and tool from the push rod.

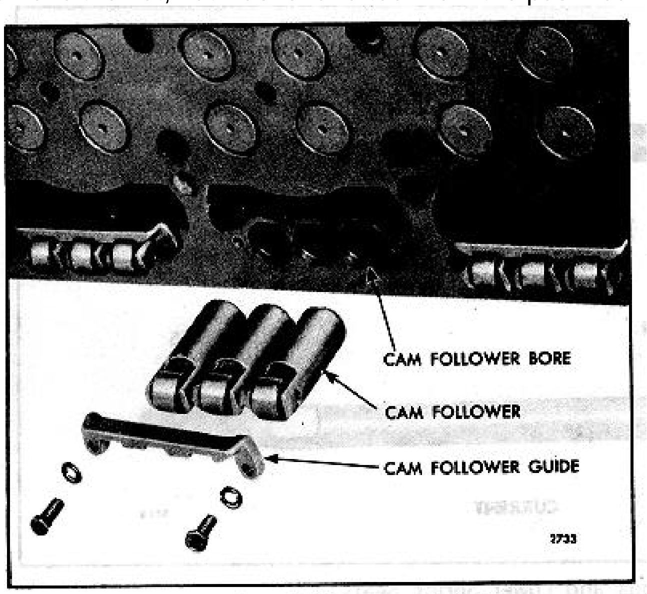


Fig. 4. Cam Followers and Guide

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 location.

1. Rest the cylinder head on its side and remove the cam follower guide (Fig. 4).

2. Pull the cam follower out of the cylinder head.

3. Remove the fuel pipes from the injector and the fuel connectors.

> **NOTE**: Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

4. Loosen the push rod locknut and unscrew the push rod from the rocker arm clevis.

5. Pull the push rod and spring assembly from the bottom of the cylinder head.

6. Remove the push rod locknut, spring and spring seats from the push rod.

If the cylinder head is to be replaced, remove the spring retainers and install them in the new head.

Inspection

Proper inspection and service of the cam follower is very necessary to obtain continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, remove the cam followers and their related parts and inspect them for excessive wear. This change in injector timing or valve clearance can usually be detected by excessive noise at idle speed.

Wash the cam followers with lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil*. Fuel oil working its way in between the cam roller bushing and pin may cause scoring on initial start-up of the engine since fuel oil does not provide adequate lubrication. The push rods, springs and spring seats may be washed with clean fuel oil and dried with compressed air.

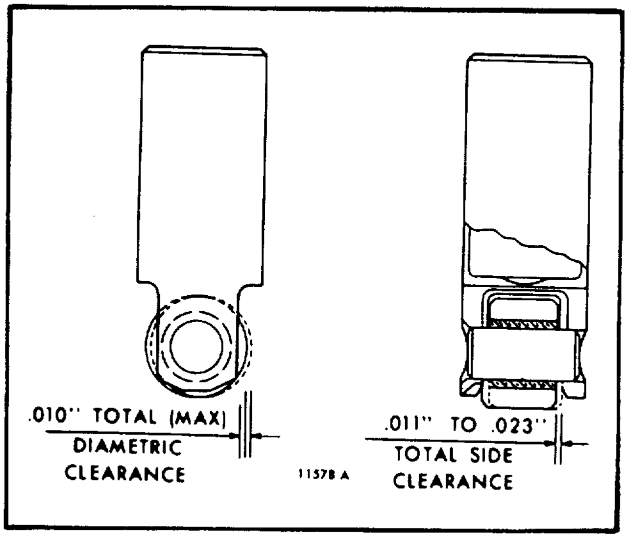


Fig. 5. Cam Roller Clearances

Examine the cam follower rollers for scoring, pitting or flat spots. The rollers must turn freely on their pins. Measure the total diametric clearance and side clearance. Install a new roller and pin if the clearances exceed those specified in Fig. 5. 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 gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record the readings and compare the readings of the followers and bores to determine the cam follower-to-bore clearances (refer to Page 10-2-137 for specifications).

If the push rod breaks or is damaged, the rocker arm should be suspect. Any wear or excessive movement in the rocker arm or clevis can put a side load on the push rod, resulting in fracture or damage. Before replacing the push rod, inspect the rocker arm for signs of wear or cracking. If wear or excessive movement of the rocker arm or clevis is noted, replace the rocker arm.

Inspect the push rods and spring seats for wear. The current push rods have milled wrench flats and a bright "turned" finish and the lower spring seats are serrated along the push rod contact surfaces (Fig. 6).

> **NOTE**: When replacing a push rod or lower spring seat, do not use a plain spring seat (Fig. 6) with a current type push rod. Any other combination of spring seat and push rod may be used.

Examine the cam follower springs for wear or damage and check the spring load. Replace a spring when a load of less than 172 lbs. will compress it to a length of 2.125". Use spring tester J 22738-02 to check the spring load (Fig. 7).

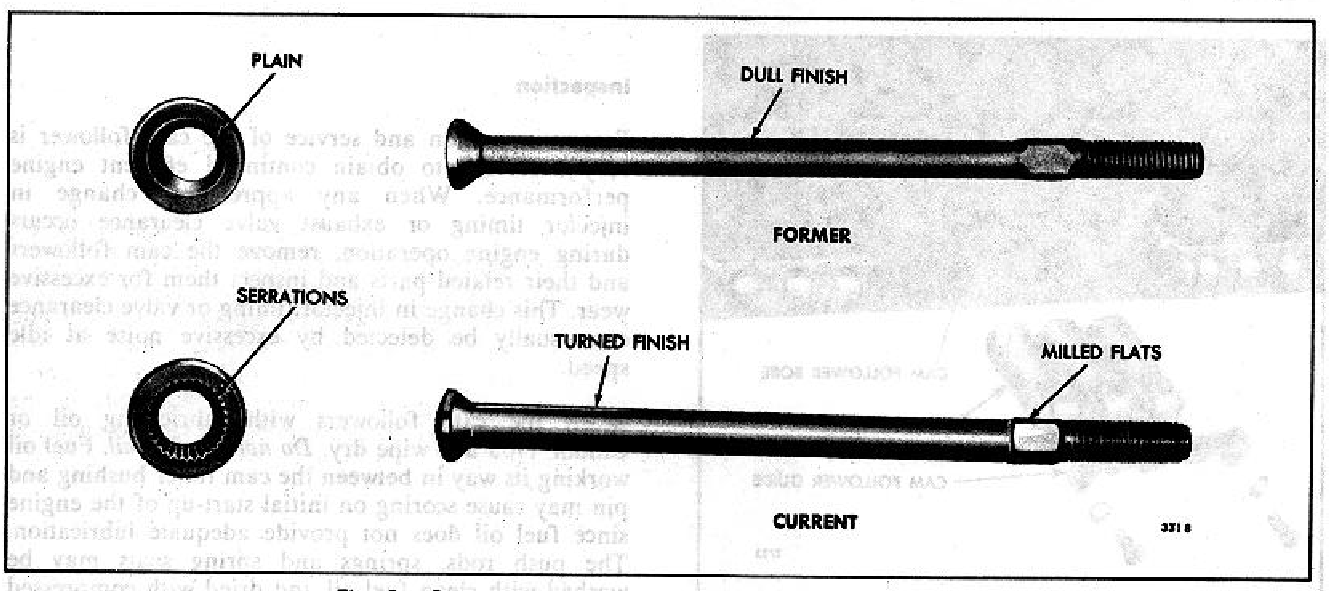


Fig. 6. Comparison of Push Rods and Lower Spring Seats

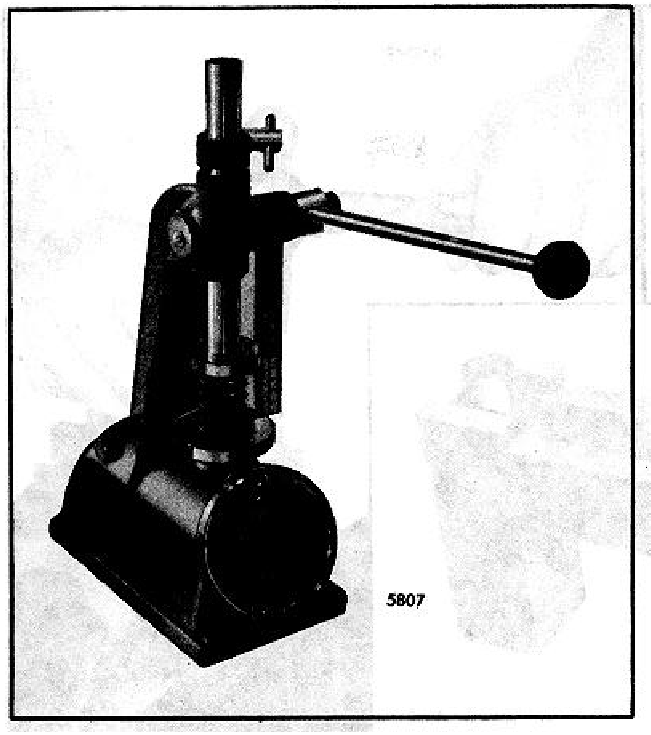


Fig. 7. Testing Cam Follower Spring using Tool J 22738-02

Replace Cam Roller and Pin To replace a cam roller and pin, proceed as follows:

> **NOTE**: Do not attempt to bore out the legs of a standard cam follower for an oversize pin.

1. Clamp fixture J 5840-01 securely in a vise as shown in Fig. 8. Then place the cam follower in the groove in the top of the fixture, with the follower pin resting on top of the corresponding size plunger in the fixture.

2. Drive the pin from the roller with a suitable drift. Exercise caution in removing the cam follower body and roller from the fixture as the roller pin is seated on a spring-loaded plunger in the fixture.

3. Before installing the new roller and pin, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705 and wipe dry. Do not use fuel oil. After washing the parts, lubricate the roller and pin with Cindol 1705.

4. Position the cam follower body in the groove of the fixture, with the small plunger extending through the roller pin hole in the lower leg of the follower body.

5. Position the new cam roller in the cam follower body. When released, the plunger will extend into the roller bushing and align the roller with the cam follower body.

6. Start the new pin in the cam follower body, then carefully tap it in until it is centered in the cam follower body.

7. Remove the cam follower from the fixture and check the side clearance (Fig. 5). The clearance must be .011" to .023".

Install Cam Follower and Push Rod

If new cam follower assemblies are to be installed, remove the preservative by washing with Cindol 1705 and wipe dry. *Do not use fuel oil*.

Before cam followers are installed, immerse them in clean Cindol 1705 (heated to 100-125°F or 38-52°C) for at least one hour to ensure initial lubrication of the cam roller pins and bushings. Rotate the cam rollers during the soaking period to purge any air from the bushing-roller area. The heated Cindol oil results in better penetration as it is less viscous than engine oil and flows more easily between the cam roller bushing and pin. After the cam 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 Fig. 9 and proceed as follows:

<u>CYLINDER HEAD ON ENGINE</u>:

1. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves (Fig. 10), slide the cam follower in position in the cylinder head.

2. Assemble the *serrated* lower spring seat (Fig. 6), spring and upper spring seat on the push rod.

3. Place a flat washer over the upper spring seat and start the locknut on the push rod. Place tool J 3092-01 on the push rod between the washer and the upper spring seat and place the push rod assembly in the cam follower. Then thread the locknut on the push rod until the spring is compressed sufficiently to permit the spring retainer to be installed. Install the retainer with the tangs facing the notch in the cylinder head.

4. Remove the nut, flat washer and tool. Then reinstall the locknut and thread it as far as possible on the push rod.

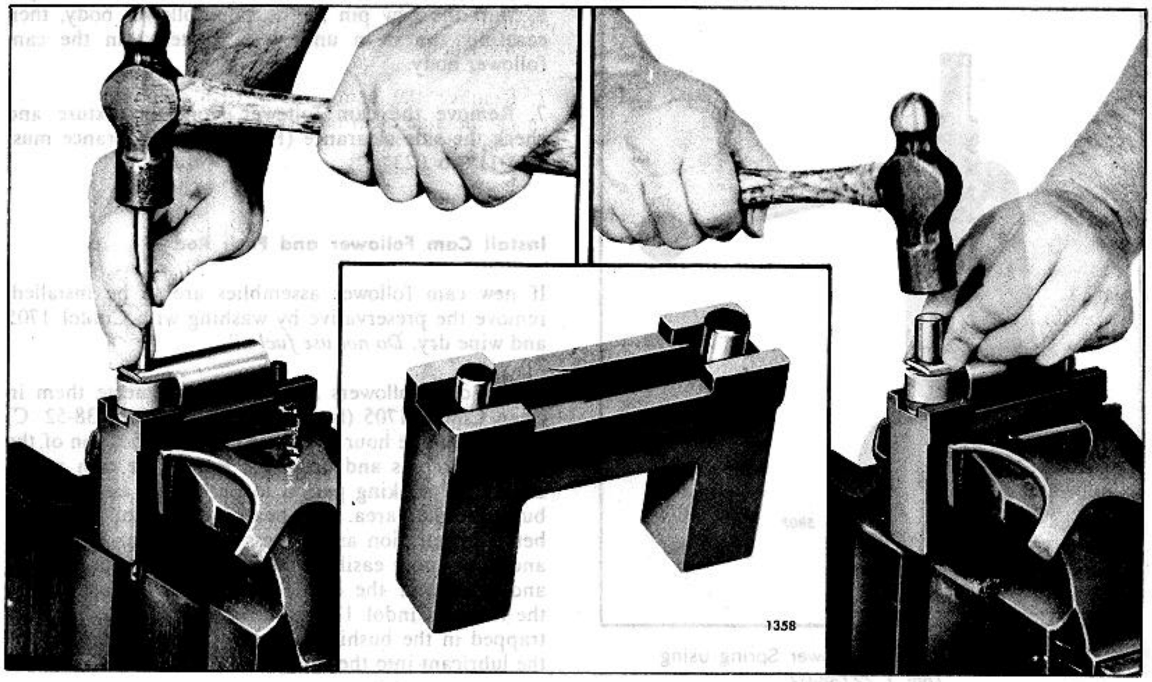


Fig. 8. Removing or Installing Cam Follower Roller using Tool J 5840-01

CYLINDER HEAD REMOVED FROM ENGINE:

Refer to Fig. 9 and install the cam follower and push rod as follows:

1. Assemble the *serrated* lower spring seat (Fig. 6). spring, upper spring seat and locknut on the push rod.

2. With the spring retainer in place in the cylinder head, slide the push rod assembly in position from the bottom of the head.

3. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves (Fig. 10), 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 .005" clearance between the cam follower legs and the cam follower guide (Fig. 11). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Fig. 12). Then retighten the bolts to the specified torque.

> **NOTE**: It is important to use the correct bolts as prescribed in the parts books. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation.

Install Rocker Arms and Shaft

The injector rocker arm (center arm of the group) is slightly different from the exhaust valve rocker arms: the boss for the shaft on the left and right-hand valve rocker arms is longer on one side. The extended boss of each valve rocker arm must face toward the injector rocker arm.

> **NOTE**: If the rocker arm is damaged or breaks, the push rod should always be changed out when the new rocker arm is installed. A damaged rocker arm can cause side loading and weakening of the push rod. If reused, a sideloaded push rod can break.

1. Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. This will provide sufficient initial clearance between the exhaust valve and the piston when the crankshaft is turned during the valve clearance adjustment procedure.

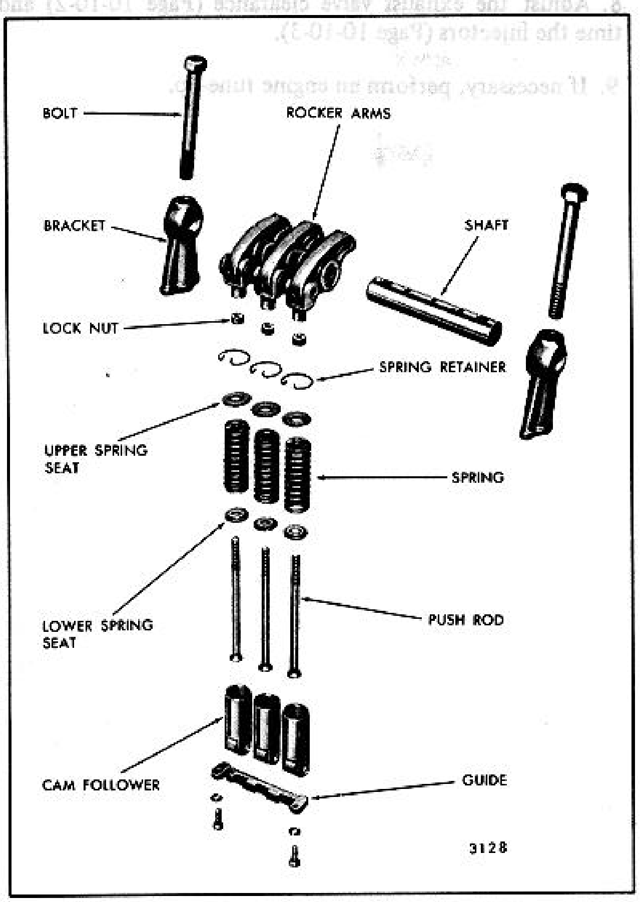


Fig. 9. Valve and Injector Operating Mechanism and Relative Location of Parts

2. If removed, install the cylinder head on the engine (refer to Page 10-2-25).

3. If removed, install the fuel injectors.

4. 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.

5. Insert the rocker arm bracket bolts through the brackets and the shaft. Tighten the bolts to the specified torque (refer to Page 10-2-140).

6. 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.

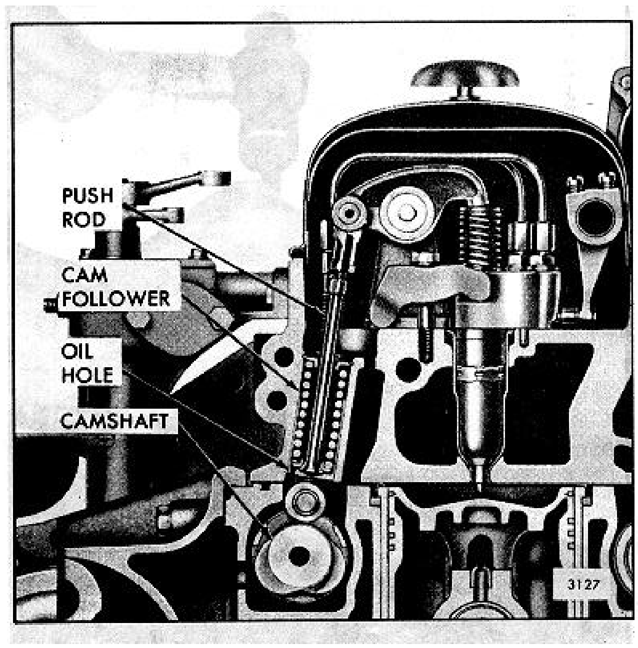


Fig. 10 Installation of Cam Followers

CAUTION: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubrication oil diluted by fuel oil can cause serious damage to the engine bearings.

7. Fill the cooling system.

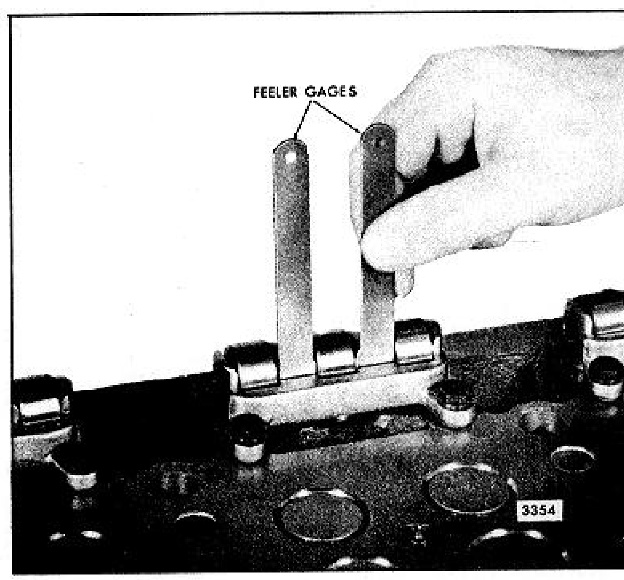


Fig. 11. Checking Cam Follower to Guide Clearance

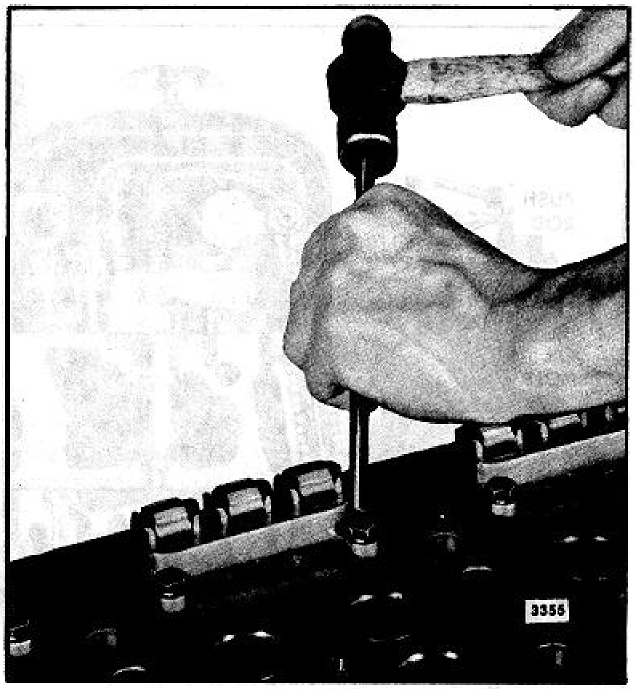


Fig. 12. Adjusting Cam Follower Guide

8. Adjust the exhaust valve clearance (Page 10-10-2) and time the injectors (Page 10-10-3).

9. If necessary, perform an engine tune-up.

EXHAUST VALVES

Two exhaust valves are provided for each cylinder. (Fig. 1). The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the rocker arm.

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head (Fig. 2).

Exhaust valve seat inserts (Fig. 2), pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head. The exhaust valves are ground to a 30° seating angle while the exhaust valve seat inserts are ground to a 31° seating angle.

The exhaust valve springs are held in place by the valve spring caps and tapered two-piece valve locks.

Excess oil from the rocker arms lubricates the exhaust valve stems. The valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

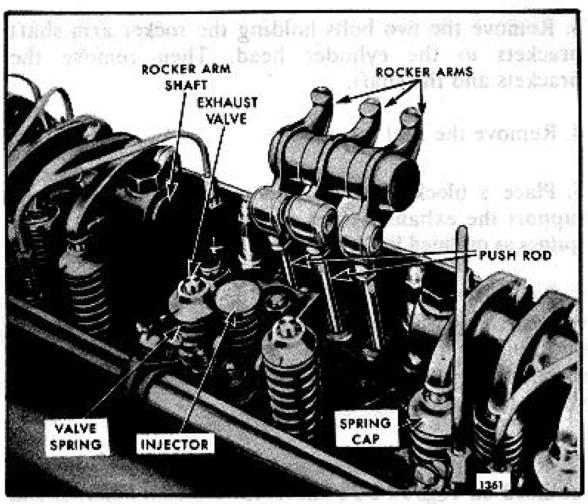


Fig. 1. Location of Exhaust Valves (Two-Valve Cylinder Head)

Exhaust Valve Maintenance

Efficient combustion in the engine requires that the exhaust valves he 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 (Page 10-10-2) 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 valves and valve seats and loss of compression will result.

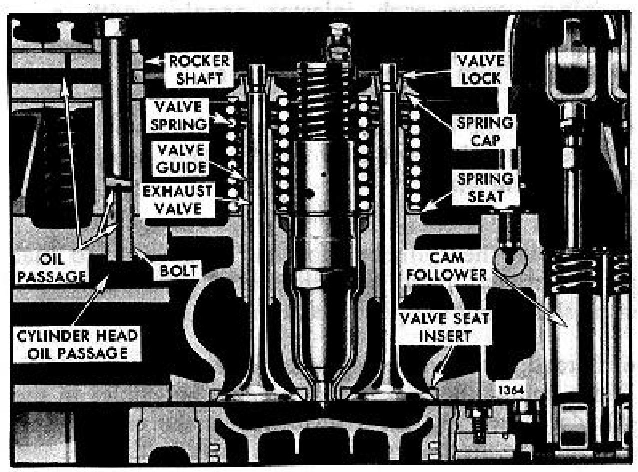


Fig. 2. Assembly of Exhaust Valves and Guides

Lubricating oil and oil filters should be changed periodically to avoid the accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil. leakage of antifreeze (glycol) into the lubricating oil which forms a soft sticky carbon and gums the valve stems, and bent or worn valve guides. Sticking valves may eventually be struck by the piston and become bent or broken.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically. Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion.

Remove Exhaust Valve Spring (Cylinder Head Installed)

An exhaust valve spring may be removed, without removing the cylinder head from the engine, as follows:

1. Clean and remove the valve rocker cover.

2. Crank the engine over to bring the valve and injector rocker arms in line horizontally.

> **NOTE**: When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may loosen.

3. Disconnect and remove the fuel pipes from the injector and the fuel connectors.

> **NOTE**: Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

4. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and shaft.

5. Remove the 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.

6. Thread the valve spring compressor adaptor J 74557 into one of the rocker arm bracket bolt holes in the cylinder head (Fig. 3). Then compress the valve spring and remove the two-piece tapered valve lock.

7. Release the tool and remove the valve spring cap, valve spring and spring seat.

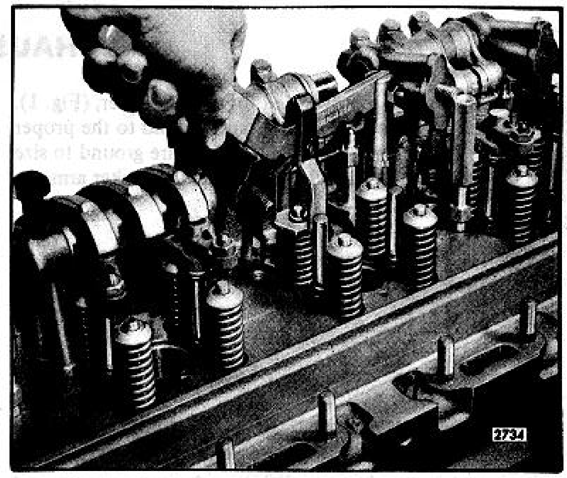


Fig. 3. Removing Exhaust Valve Spring (Four-Valve Head Shown) using Tool J 7455

Remove Exhaust Valves and Valve Springs (Cylinder Head Removed)

With the cylinder head removed from the engine, remove the exhaust valves and springs as follows:

1. Support the cylinder head on 2 " thick wood blocks to keep the cam followers clear of the bench.

2. Remove the fuel pipes from the injectors and the fuel connectors.

> **NOTE**: Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

3. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and the shaft.

4. Remove the fuel injectors.

5. Place a block of wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in Steps 6 and 7 above.

6. 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.

7. Remove the cam followers and push rod assemblies as outlined on Page 10-2-31 under *Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).*

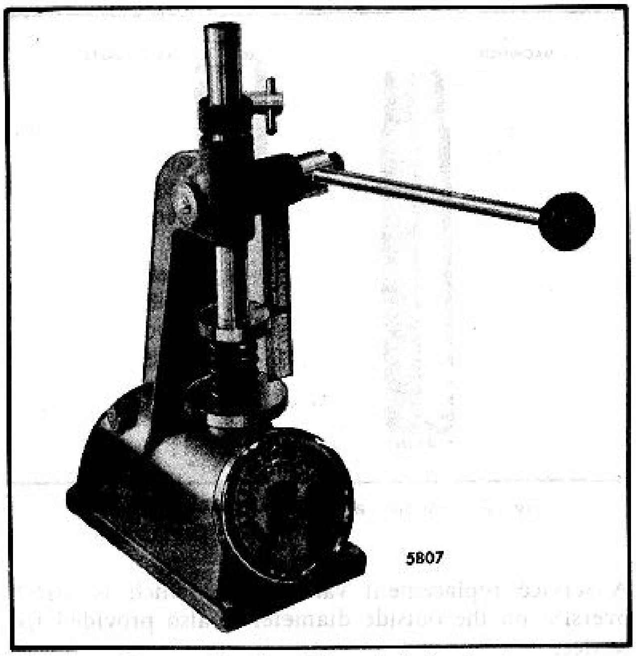


Fig. 4. Testing Exhaust Valve Spring using Tool J 22738-02

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 (Fig. 4). Replace a two-valve cylinder head exhaust valve spring when a load of less than 25 pounds (111 N) will compress it to 2.20 " (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 faulty seat. Black carbon deposits extending from the valve seats to the valve guides may result from cold operation due to light loads or the use of too heavy a grade of fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the valve guides is evidence of high operating temperatures. High operating temperatures are normally due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil.

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges, cracks or pitting. If necessary, reface

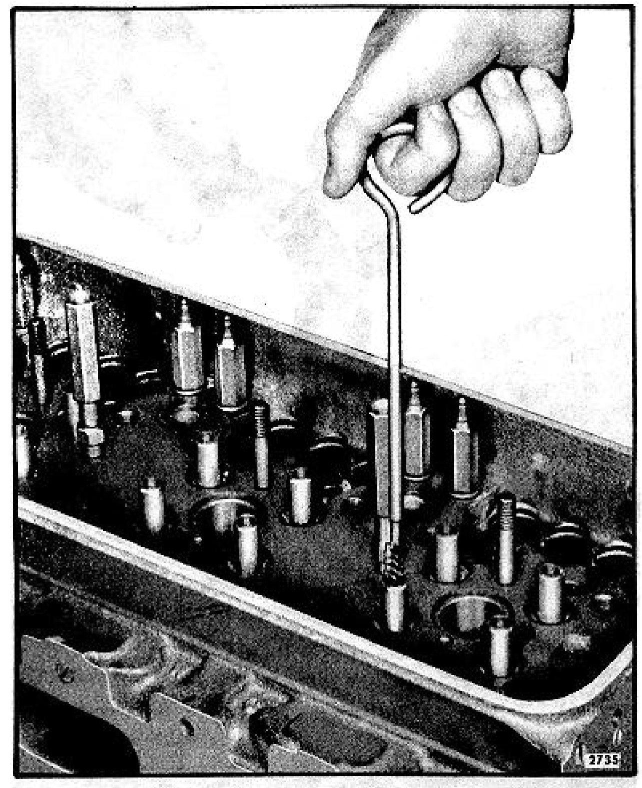


Fig. 5. Cleaning Valve Guide

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.

Clean the inside diameter of the valve guides with brush J 5437 (Fig. 5). 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 gage or inside micrometer and record the readings. After inspecting and cleaning the exhaust valves, measure the outside diameter of the valve stems with a micrometer and record the readings. Compare the readings to obtain the valve-to-guide clearance. If the clearance exceeds .006" replace the valve guides.

Replace Exhaust Valve Guide

Remove an exhaust valve guide as follows:

1. Remove and discard the valve guide oil seal, if used.

Fig. 6. Removing Exhaust Valve Guide

2. Support the cylinder head, bottom side up, on 3" thick wood blocks.

3. Drive the valve guide out of the cylinder head with valve guide remover J 267, as shown in Fig. 6.

Place the cylinder head right side up on the bed of an arbor press and install the valve guide (Fig. 7) as follows:

1. Insert the internally threaded end of the valve guide in the valve guide installing tool J9530, and locate the valve guide to the dimension of 1.530" above the top of the head.

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 (Fig. 8). Then press the guide in until the tool contacts the cylinder head.

NOTE:

Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

Service replacement valve guides are completely finish reamed during manufacture and, therefore, do not require reaming after installation.

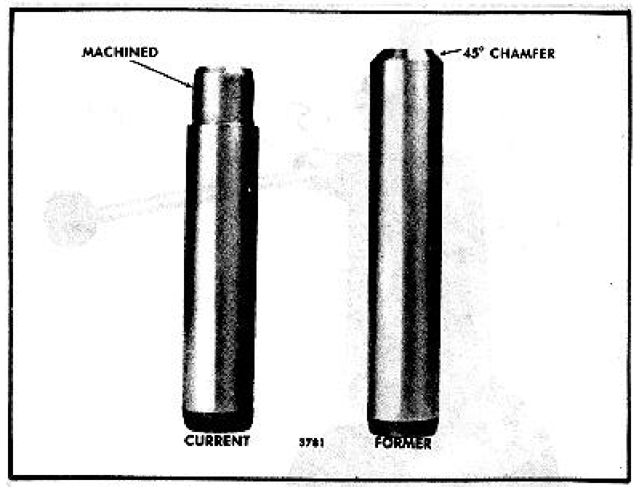


Fig. 7. Former and Current Valve Guides

A service replacement valve guide which is .016" oversize on the outside diameter is also provided for service.

3. Install a new valve guide oil seal, (refer to Item 5 under *Install Exhaust Valves and Springs*).

Inspect Exhaust Valve Seat Insert

A new exhaust valve insert is pre-ground and only needs to be checked for concentricity after installation. Do not grind a new insert unless the runout exceeds .002 ".

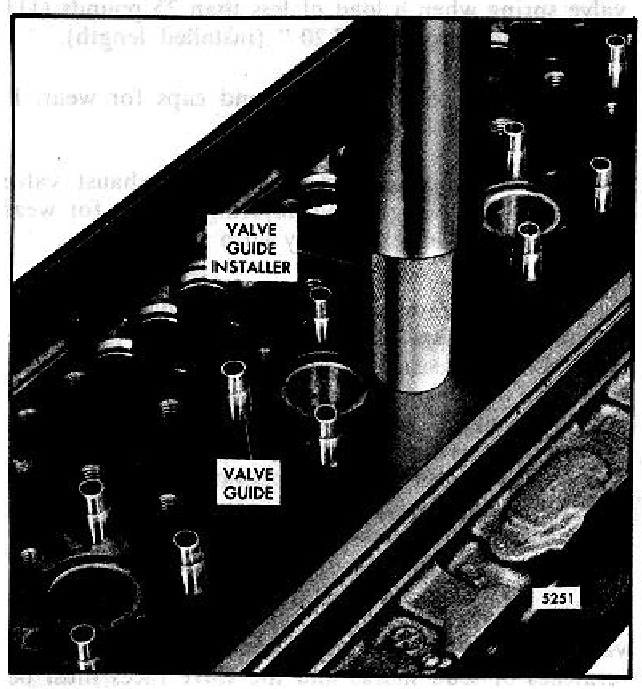


Fig. 8. Installing Valve Guide

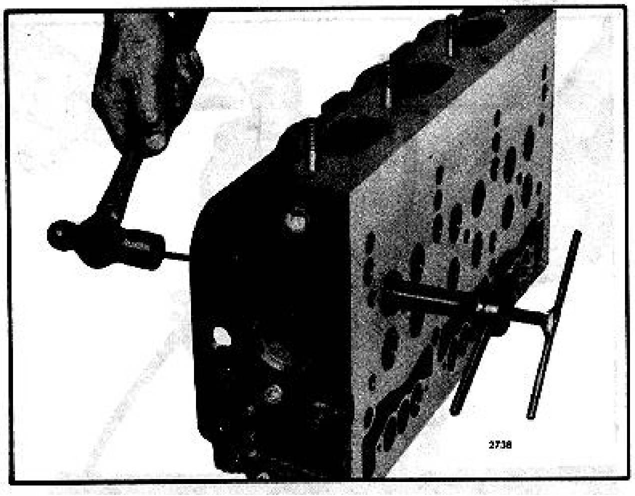


Fig. 9. Removing Valve Seat Insert

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 head and must be removed as outlined in the following procedure to avoid damage to the cylinder head:

1. Place the cylinder head on its side as shown in Fig. 9.

2. Place the collet of tool J 4824-03 inside of the valve seat insert so that the bottom of the collet is flush with the bottom of the insert.

3. Hold the collet handle and turn the T handle to expand the collet cone until the insert is held securely by the tool.

4. Insert the drive bar of the tool through the valve guide.

5. Tap the drive bar once or twice to move the insert about 1/16 " away from its seat in the cylinder head.

6. Turn the T handle to loosen the collet cone and move the tool into the insert slightly so the narrow flange at the bottom of the collet is below the valve seat insert.

7. Tighten the collet cone and continue to drive the insert out of the cylinder head.

NOTE:

In place of the above procedure, a new cam operated insert remover J 23479-15 and collet J 23479-9 can be used to remove the exhaust valve seat insert from the cylinder head.

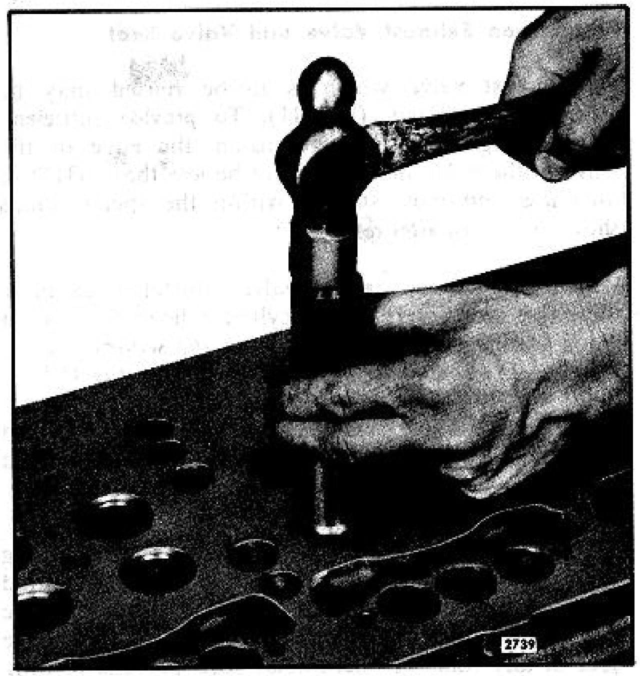


Fig. 10. Installing Valve Seat Insert

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 counterbores in a two-valve cylinder head have a diameter of 1.626 " to 1.627 " and a depth of .3705 " to .3845". The counterbores must be concentric with the valve guides within .003" total indicator reading. Valve seat inserts which are .010" oversize on the outside diameter are available, if required.

3. Immerse the cylinder head for at least thirty minutes in water heated to 180-200 °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 1736 as shown in Fig. 10 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 (Fig. 11). To provide sufficient valve strength and spring tension. the edge of the valve at the valve head must not be less than .031 " in thickness and must still be within the specifications shown in Fig. 14 after refacing.

Before either a new or used valve is installed, examine the valve seat insert in the cylinder head for proper valve seating. *The proper angle for the seating face of the valve is 30 ° and for the valve seat insert it is 31 °.*

When a new valve seat insert is installed or an old insert is reconditioned, the work must be done with a grinding wheel (Fig. 12).

The eccentric grinding method for reconditioning valve seat inserts is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits feeding the grinding wheel into the work .001 " at a time.

Eccentric valve seat grinder set J 7040, which includes the grinder, dress stand and pilot, and dial gage, is used to grind the inserts. An adaptor set which includes the grinding wheels and pilot is used with the grinder.

Adaptor set J 8165-8, used for the two-valve cylinder head, consists of the following:

1. Pilot, tool J 8165-3.

2. Grinding wheel (15 °), tool J 8165-4.

3. Grinding wheel (31 °), tool J 8165-5.

4. Grinding wheel (60 °), tool J 8165-7.

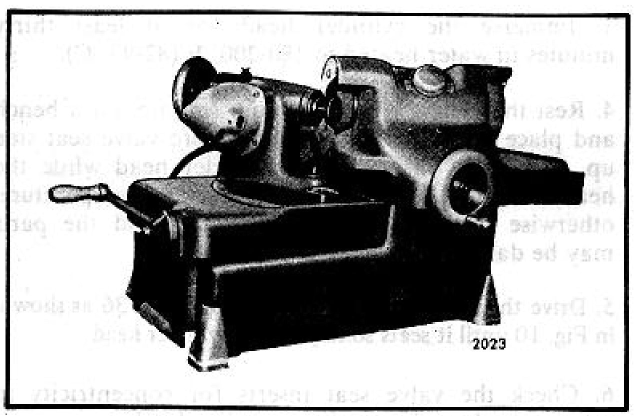


Fig. 11. Refacing Exhaust Valve

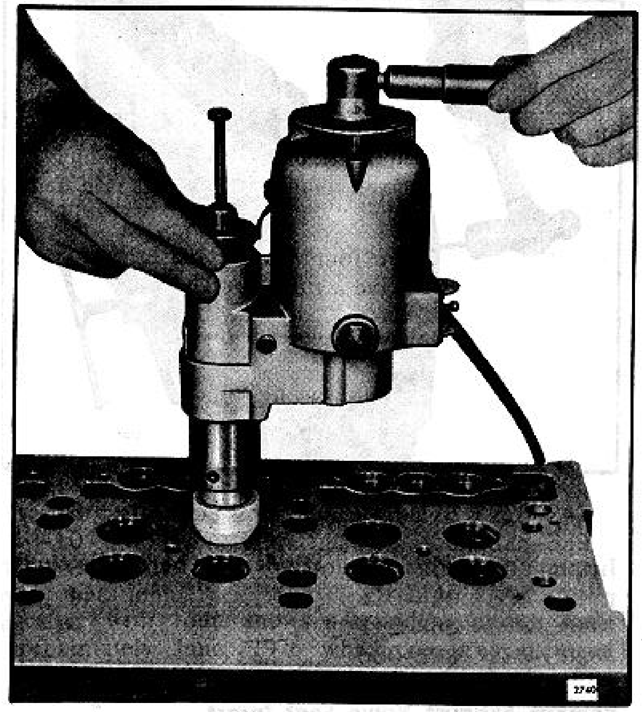


Fig. 12. Reconditioning Valve Seat Insert

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.

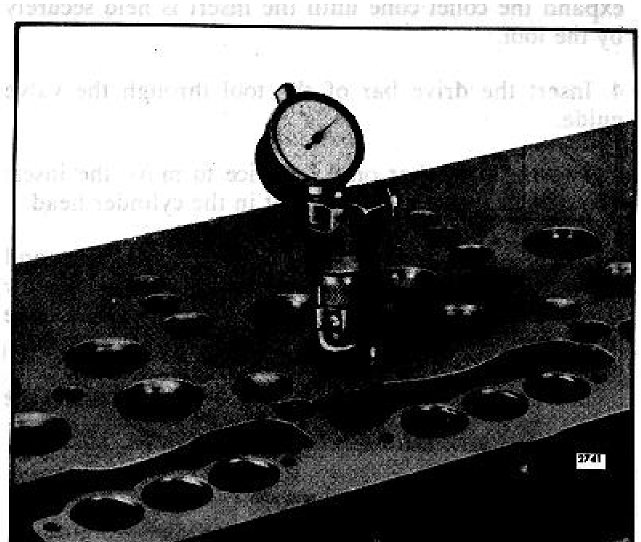


Fig. 13. Determining Concentricity of Valve Seat Insert with Dial Indicator

3. Grind the top surface of the insert with the 15 ° wheel to narrow the width of the seat to the dimensions shown in Fig. 14. The 31° face of the insert may be adjusted relative to the center of the valve face with the 15 ° and 60 ° grinding wheels.

NOTE:

Do not permit the grinding wheel to contact the cylinder head when grinding the insert. When an insert has been ground to the extent that the grinding wheel will contact the cylinder head, install a new insert.

The maximum amount the exhaust valve should protrude beyond the cylinder head (when the valve is closed) and still maintain the proper piston-to-valve clearance is shown in Fig. 14. Grinding will reduce the thickness of the valve seat insert and cause the valve to recede into the cylinder head. If, after several grinding operations, the valve recedes beyond the specified limits, replace the valve seat insert.

NOTE:

The engine must incorporate valve seat inserts that are no more than .251" thick to ensure adequate clearance between the pistons and the exhaust valves.

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with the dressing tool provided with the grinder set (Fig. 15).

4. After grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165-2 in position as shown in Fig. 13 and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. If the runout exceeds .002 ", check for a bent valve guide before regrinding the insert.

After the valve seat insert has been ground, determine the position of the contact area between the valve and the valve seat insert as follows:

1. Apply a light coat of Prussian blue, or a similar paste, to the valve seat insert.

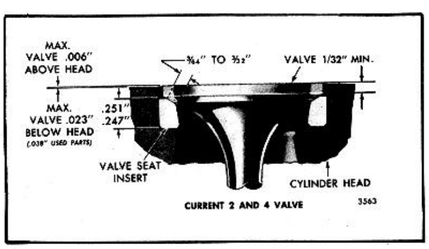


Fig. 14 - Relationship Between New Exhaust Valve, Insert and Cylinder Head

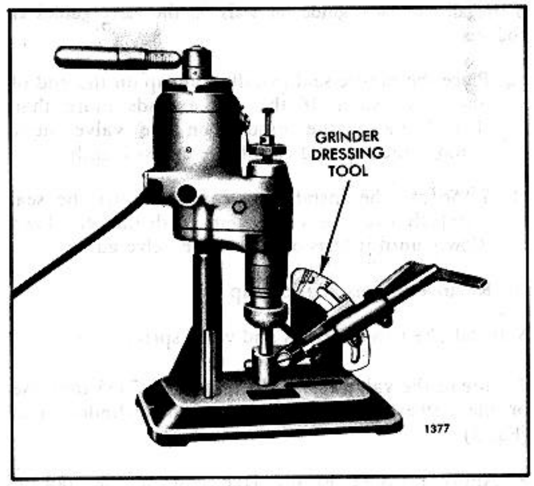


Fig. 15. Grinding Wheel Dressing Tool or Set J 8165-1

2. Lower the stem of the valve in the valve guide and "bounce" the valve on the seat. Do not rotate the valve. This procedure will show the area of contact on the valve face. The most desirable area of contact is at the center of the valve face.

NOTE:

The use of valve lapping compounds is not recommended.

After the valve seat inserts have been ground and checked, clean the cylinder head before installing the valves.

Install Exhaust Valves and Springs

Install the exhaust valves as follows:

1. Clean the valve guides.

2. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides.

IMPORTANT:

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

3. Hold the valves in place temporarily with a strip of masking tape. Then turn the cylinder head right side up on the work bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.

4. Install the valve spring seats.

5. Install the valve guide oil seals on the valve guides as follows:

a. Place the plastic seal installation cap on the end of the valve stem. If the cap extends more than 1/16 " below the groove on the valve stem, remove the cap and cut off the excess length.

b. Lubricate the installation cap and start the seal carefully over the valve stem. Push the seal down slowly until it rests on top of the valve guide.

c. Remove the installation cap.

6. Install the valve springs and valve spring caps.

7. Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig. 3).

8. Apply pressure to the free end of the tool to compress the valve spring and install the two-piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring.

NOTE:
Compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

9. Release the tool and install the valve locks on the remaining exhaust valves in the same manner.

10. Check the position of the exhaust valves (Fig. 14). Support the cylinder head at each end with wood blocks and remove the masking tape so that the exhaust valves are free. Then give the end of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.

11. With the exhaust valves installed in the cylinder head, use spring checking gage J 25076-01 and note the gage reading the moment the exhaust valve starts to open (Fig. 16). The minimum allowable pressure required to start to open the exhaust valve must not be less than 15 pounds (67 N).

12. Install the injectors, rocker arms, shafts, brackets and any other parts previously removed from the cylinder head.

13. Install the cylinder head. Refer to *Pre-Installation Inspection and Install Cylinder Head* on Page 10-2-25.

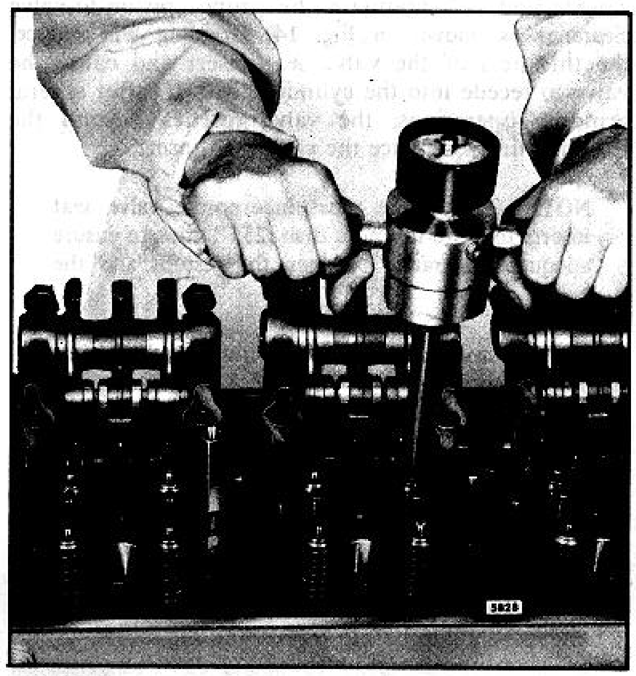


Fig. 16. Checking Pressure Required to Open the Exhaust Valve in Cylinder Head

ENGINE LIFTER BRACKETS

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.

The rear engine lifter bracket is also provided with drilled bosses to permit the use of a throttle control crosshaft. Lifter brackets require no servicing other than removal during other service operations.

Install Engine Lifter Bracket

1. Remove all traces of the old gasket material.

2. Affix a new gasket to the front lifter bracket.

3. Attach the lifter bracket and gasket to the cylinder head with two bolts and to the front balance weight cover with two bolts.

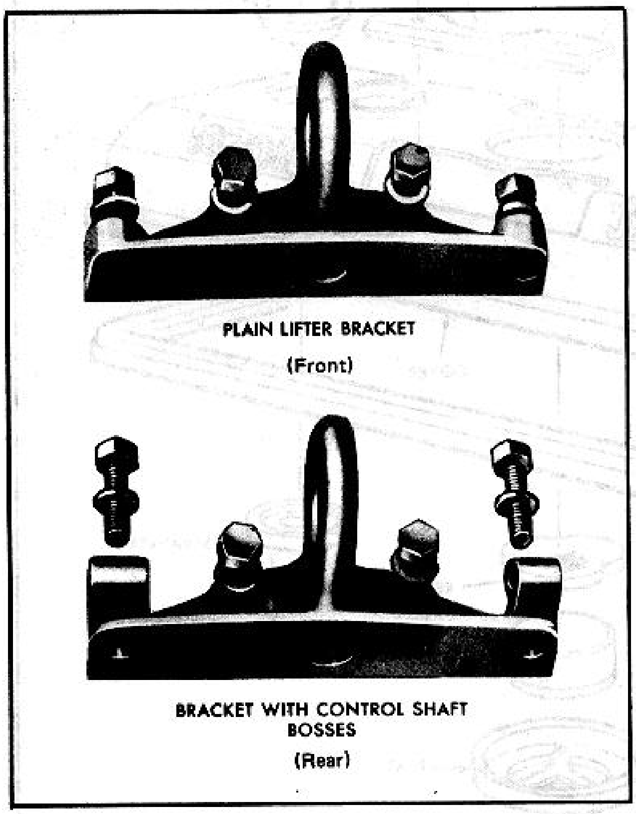


Fig. 1. Engine Lifter Brackets.

NOTE:

The lifter brackets must not be permanently attached until all of the cylinder head stud nuts or retaining bolts have been tightened to their specified torque.

4. Install the bolts finger tight, draw them down snug and then tighten to the specified torque. Draw the bolts down in the proper sequence (Fig. 2) for each of these steps to draw the mating parts together evenly, thus providing a good seal. Tighten the bolts to 55-60 lb-ft (75-81 Nm) torque.

5. Install the rear lifter bracket to the cylinder head and flywheel housing in a similar manner.

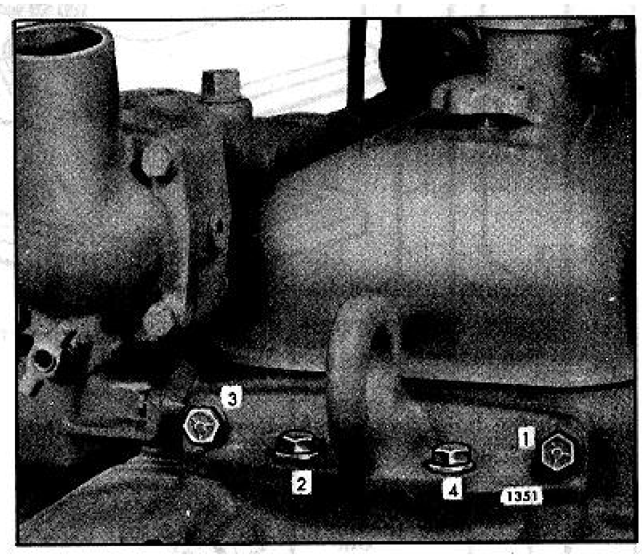


Fig. 2. Typical Installation of Lifter Bracket and Bolt Tightening Sequence.

VALVE ROCKER COVER

The valve rocker cover assembly (Fig. 1) completely encloses the valve and injector rocker arm compartment at the top of the cylinder head. The top of the cylinder head is sealed against oil leakage by a gasket located in the groove of the lower rail of the current die cast rocker cover.

An option plate is inserted in a retainer attached to the cover.

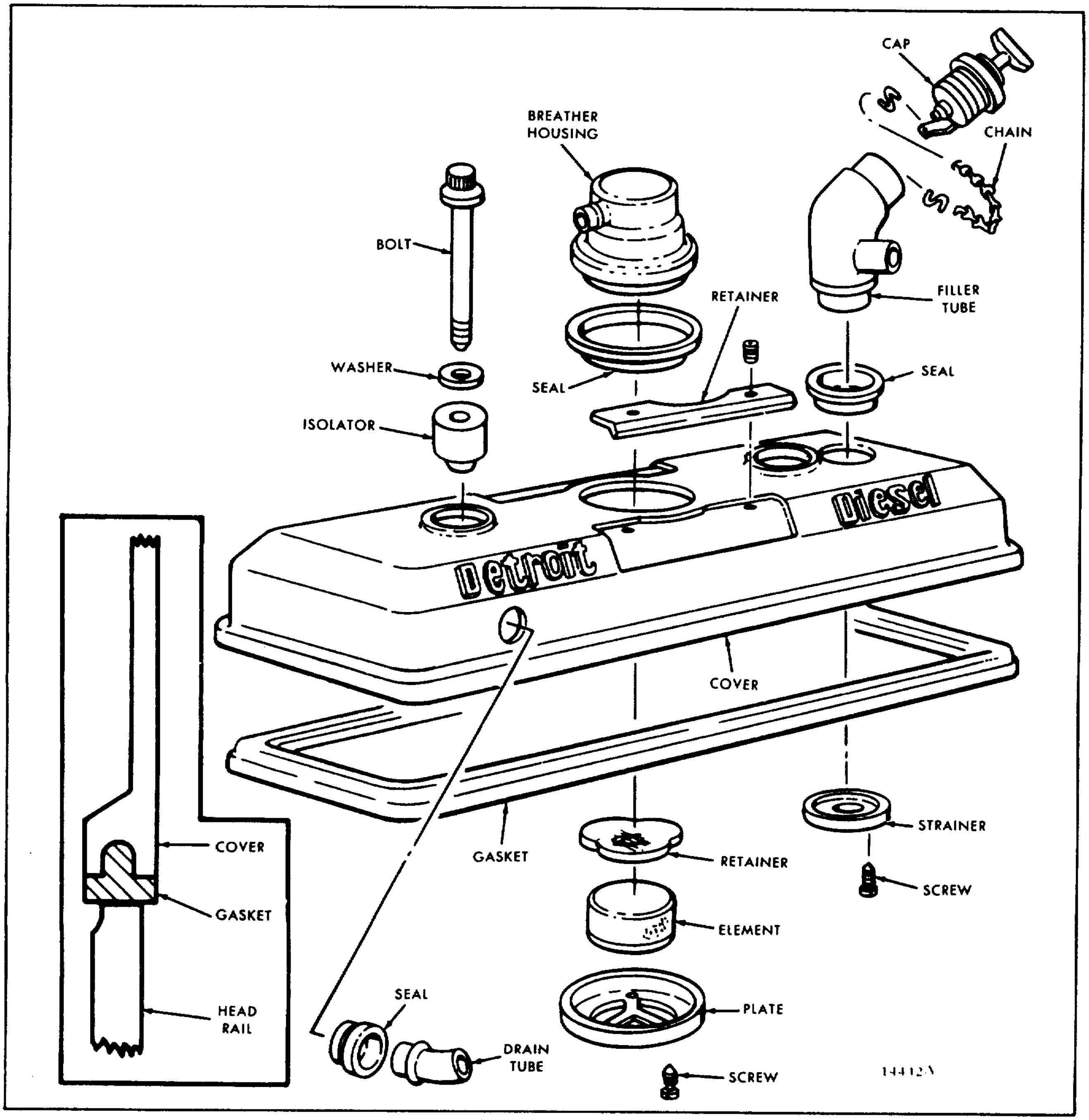


Fig. 1. Typical Valve Rocker Cover Assembly (Current)

The current die cast rocker cover (Fig. 1) is held in place by 3/8 "-16 twelve-point head shoulder bolts with a steel washer and silicone isolator. The bolts have a shoulder which bottoms out against the cylinder head. The isolaters 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.

The current rocker cover gaskets and the current hold-down bolts can only be used with the current die cast rocker cover. Do not use the former gasket and hold-down knobs with the die cast cover.

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 a rocker 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 rocker cover groove or on the silicone gasket will make it difficult to install.

2. Press the stem side of the new T 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 Fig. 1). 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

The crankshaft is a one-piece steel forging, heat-treated to ensure strength and durability (Figs. 1 and 2). 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.

Two dowels and six tapped holes are provided in the rear end of the former crankshaft for locating and attaching the flywheel (Fig. 2). One hole is unequally spaced so that the flywheel can be attached in only one position.

To standardize, the current crankshaft will no longer incorporate the two dowels in the flywheel end of the crankshaft. The former and current crankshafts are interchangeable.

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 transmission, then proceed as follows:

1. Clean the exterior of the engine.

2. Drain the cooling system.

3. Drain the engine crankcase.

4. Remove all engine to base attaching bolts. Then, with a chain hoist and sling attached to the lifter brackets or eye bolts at each end of the engine, remove the engine from its base.

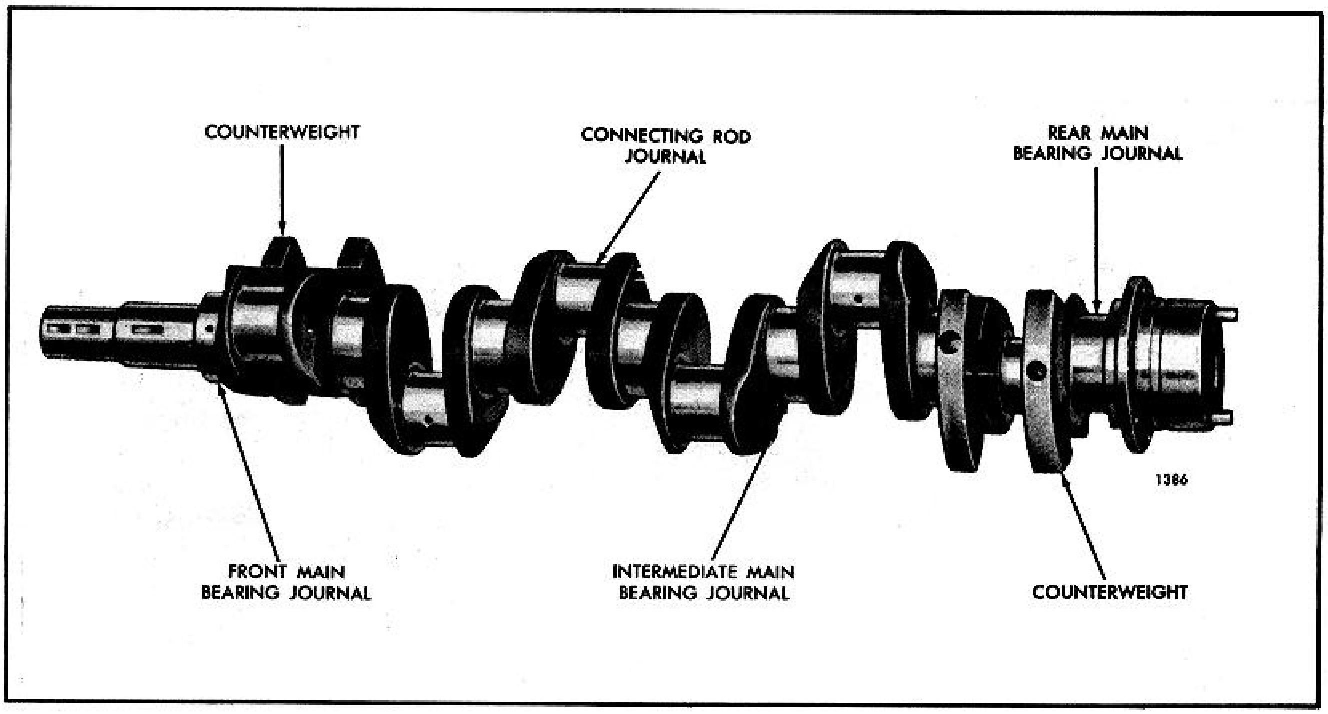


Fig. 1. Typical Six Cylinder Crankshaft (Former)

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 overhaul stand and fasten it securely to the mounting plate.

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 pulley.

11. Remove the vibration damper.

12. Remove the front engine support.

13. Remove the crankshaft front cover.

14. Remove the vibration damper inner cone or oil seal spacer.

15. Remove the cylinder head.

16. Remove the connecting rod bearing caps.

17. Remove the main bearing caps.

18. Remove the thrust washers from each side of the rear main bearing.

19. Remove the pistons, connecting rods and liners.

20. Remove the crankshaft, including the timing gear and oil pump drive gear (Fig. 2).

21. Refer to Page 10-2.123 for removal of the crankshaft timing gear and Page 10-5-9 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

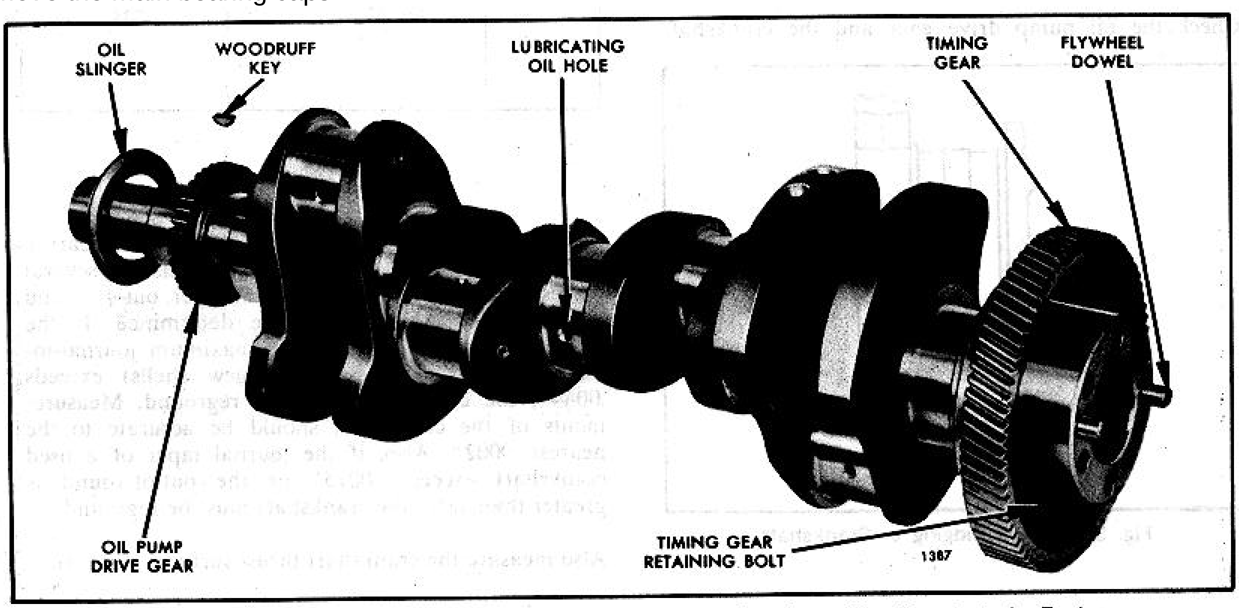


Fig. 2. Typical Crankshaft, Timing Gear and Oil Pump Drive Gear Assembly-Four Cylinder Engine

main bearing shell or lower connecting rod bearing shell (Fig. 3). Ridges exceeding .0002" must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0005", first use 120 grit emery cloth to clean up the ridge, 240 grit emery cloth for finishing and wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out-of-round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than .001", the crankshaft may have to be reground.

Carefully inspect the rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

Slight ridges on the crankshaft oil seal contact surface may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. If the crankshaft cannot be cleaned up satisfactorily, the oil seal may be repositioned in the flywheel housing as outlined on Page 10-2-56.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise it will be necessary to regrind the thrust surfaces.

Check the oil pump drive gear and the crankshaft timing gear for worn or chipped teeth. Replace the gears, if necessary.

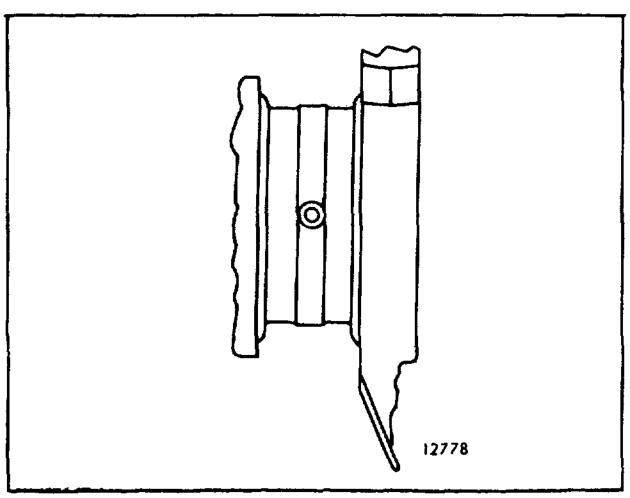


Fig. 3. Typical Ridging of Crankshaft

Check the crankshaft dowel extension. Current dowels extend 1/2" from the crankshaft while former dowels extend 5/8".

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 .003" total indicator reading. When the runout on the adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. If the runout limit is greater than given in Table 1, the crankshaft must be replaced.

CRANKSHAFT RUNOUT		
Engine	Journals	Max. Runout (Total indicator reading)
471	At No. 2 and No. 4 At No. 3	.002” .004”

TABLE 1

Measure all of the main and connecting rod bearing journals (Fig. 6). Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum journal-to-bearing shell clearance (with new shells) exceeds .0044", the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002". Also, if the journal taper of a used crankshaft exceeds .0015" or the out-of-round is greater than .001 ",the crankshaft must be reground.

Also measure the crankshaft thrust surfaces (Fig. 8).

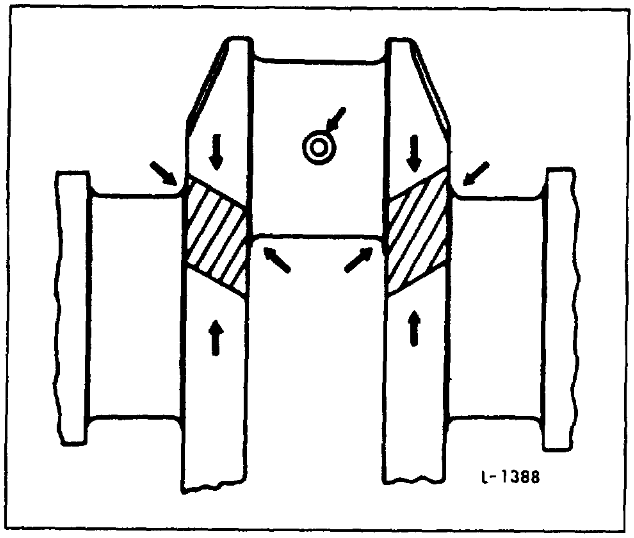


Fig. 4. Critical Crankshaft Loading Zones

Inspection for Cracks

Carefully check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 45 ° 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 employees magnetic particles which are fluorescent and glow under "black light, ". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "black light".

Fluorescent Penetrant Method: This is a method which may be used on 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 Detroit Diesel crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service - a *bending* force and a *twisting* force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load (Fig. 4).

Bending fatigue failures result from bending of the crankshaft which takes place once per revolution.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft.

Failure resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes

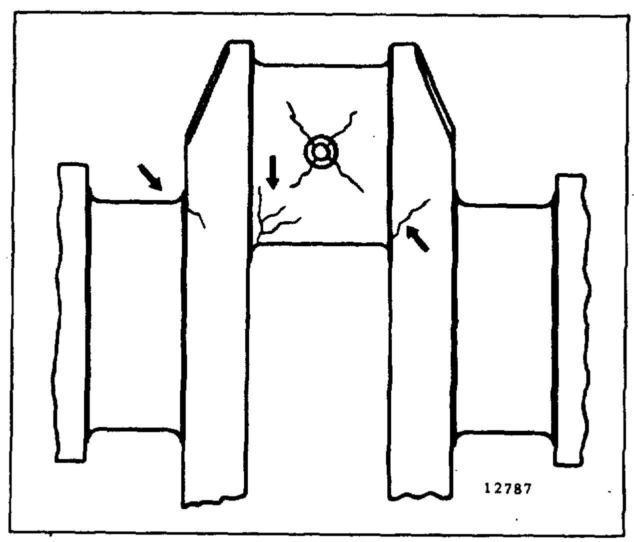


Fig. 5. Crankshaft Fatigue Cracks.

extending into the journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional fatigue failures result from torsional vibration which takes place at high frequency.

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 4.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are usual 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

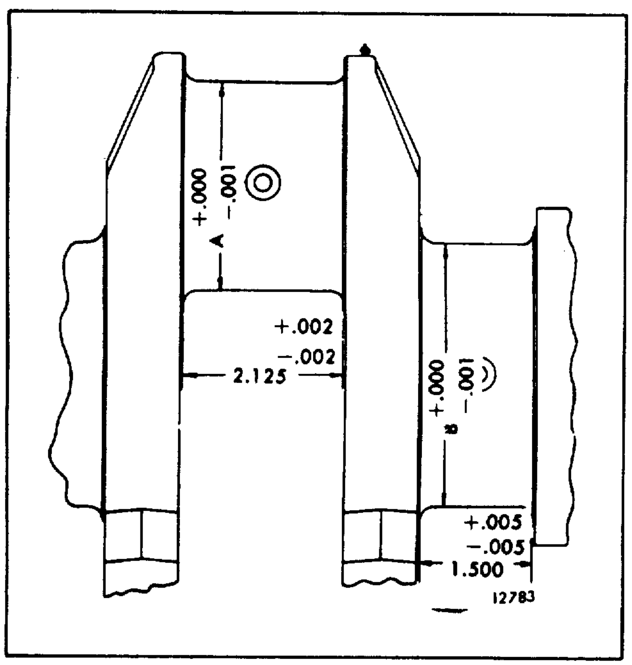


Fig. 6. Dimensions of Crankshaft Journals

circumferential fillet cracks at the critical areas and 45° cracks (45 ° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes as shown in Fig. 5. Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002 ", .010", .020" and .030" undersize bearings are available.

NOTE:
The .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 Table 2 and Fig. 6 and determine the size to which the journals are to be reground.

Bearing Sizes	Conn. Rod Journal Dia. A	Main Bearing Journal Dia. "B
Standard	2.750"	3.500"
.002" Undersize	2.750"	3.500"
.010" Undersize	2.740"	3.490"
.020" Undersize	2.730"	3.480"
.030" Undersize	2.720"	3.470"

TABLE 2

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 .130 " to .160 " radius between the crank cheek and the journal and must not have any sharp grind marks (Fig. 7). The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.

4. Care must be taken to avoid localized heating which

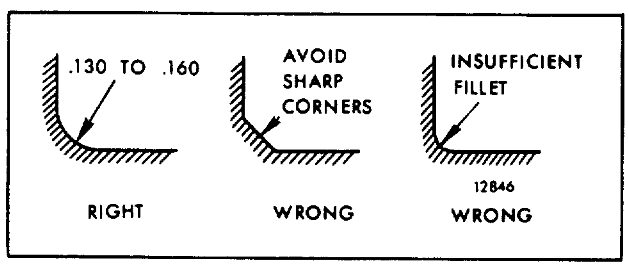


Fig. 7. Crankshaft Journal Fillets.

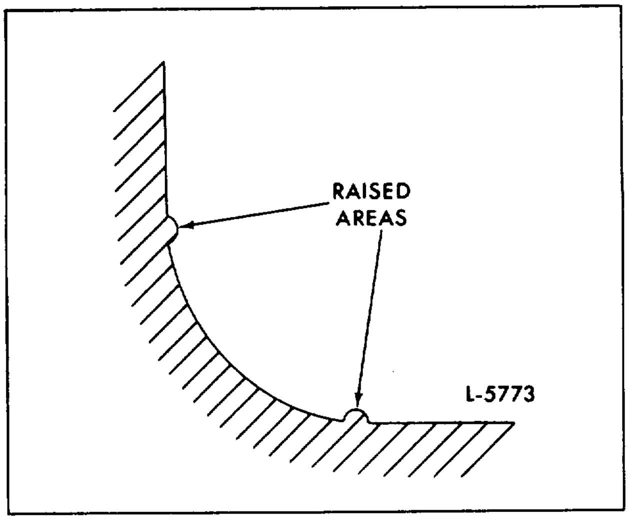


Fig. 8. New or Morco Remanufactured Crankshaft

often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.

5. Polish the ground surfaces to an 8-12 R.M.S. finish. The reground journals will be subject to excessive wear unless polished smooth.

6. If the thrust surfaces of the crankshaft (Fig. 9) are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .130 " to .160" radius between each thrust surface and the bearing journal.

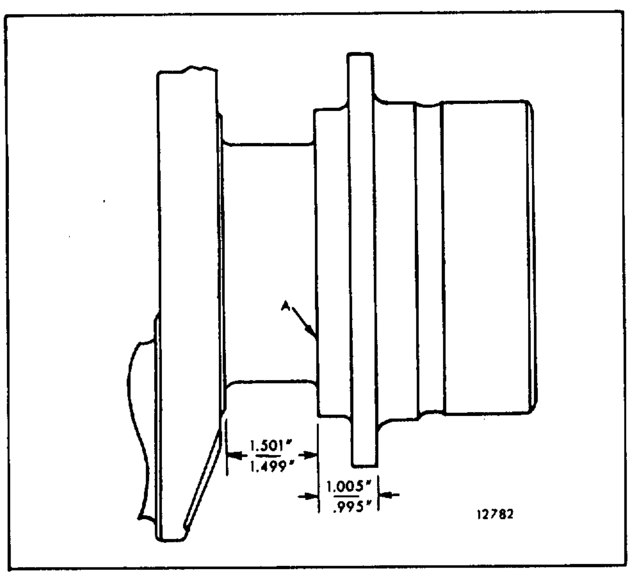


Fig. 9. Standard Dimensions at Crankshaft Thrust Surfaces

7. Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32 ".

8. After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

9. Demagnetize the crankshaft.

10. Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the plugs.

NOTE:

A new or remanufactured "Morco" 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 (Fig. 8). 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*.

Then install the crankshaft as follows:

1. Assemble the crankshaft timing gear (Page 10-2-123) and the oil pump drive gear (Page 10-5-10) on the crankshaft.

2. Refer to Page 10-2-59 for main bearing details and install the upper grooved main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed.

NOTE:

When a new or reground crankshaft is installed, *ALL* new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

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 Page 10-2-104 for the correct method of timing the gear train.

4. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. The grooved side of the thrust washers must face toward the crankshaft thrust surfaces.

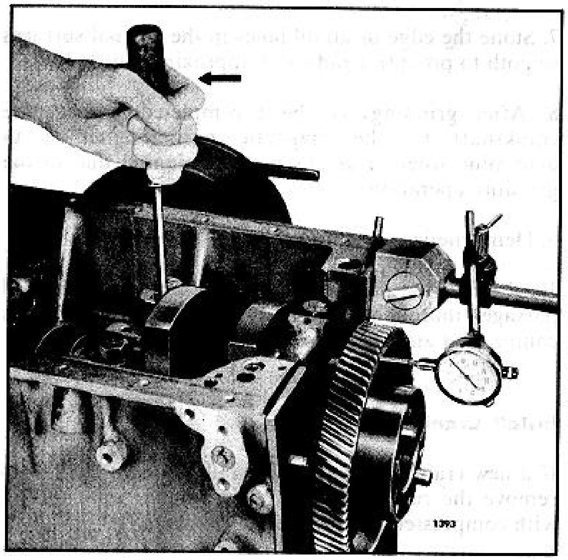


Fig. 10. Checking Crankshaft End Play

NOTE:
If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 9 and Table 3.

Nominol Size	Thrust Washer Thickness	
	Min.	Max.
Standard	.1190"	.1220"
.005" Oversize	.1240"	.1270"
.010" Oversize	.1290"	.1320"

TABLE 3

5. Install the lower bearing shells (no oil grooves) in the bearing caps. It' 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 on Page 10-2-62.

NOTE:
If the hearings 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 gage (Fig. 10) with a pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .004 " to .011 " with new parts or a maximum of .018 " with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers.

8. Install the cylinder liner, piston and connecting rod assemblies (Page 10-2-99).

9. Install the cylinder head (Page 10-2-25).

10. Install the flywheel housing (Page 10-2-76), then install the flywheel (Page 10-2-72).

11. Install the crankshaft front cover and gasket.

CAUTION:
Install the oil seal spacer or inner cone *after* the crankshaft front cover is in place to avoid damage to the oil seal lip.

12. Install the engine front support.

13. Install the vibration damper inner cone or oil seal spacer.

14. Install the vibration damper assembly.

15. Install the crankshaft pulley.

16. Install the lubricating oil pump assembly (Page 10-5-10).

17. Check the crankshaft for distortion at the rear connecting rod journal counterweights *before* and *after* installing the transmission. An improperly installed

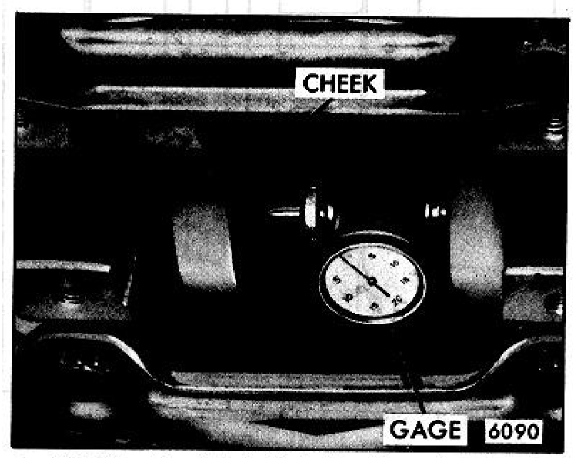


Fig. 11. Crankshaft Distortion Measuring Gage Mounted on Crankshaft.

transmission 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 gage.

c. Install a gage (Starrett Co. No. 696 dial gage, or equivalent) in the center punch holes in the cheek of each counterweight as shown in Fig. 11.

d. Set the dial indicator at zero, then rotate the crankshaft approximately 90° in both directions. Do not allow the gage 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 .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 gage exceeds .0045 ", check the reduction gear, transmission or power generator 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 bracket or eye bolts 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 the *Lubricating Oil Specifications* on Page 10-9-7 and refill the crankcase to the proper level on the dipstick.

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 (Page 10-9-2).

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring.

The front oil seal is pressed into the crankshaft front cover, and the lip of the seal bears against a removable spacer or vibration damper inner cone on the end of the crankshaft, next to the lubricating oil pump drive gear (Figs. 1 and 2).

A single-lip oil seal is used at the rear end of the crankshaft, (Fig. 3). The rear oil seal is pressed into the flywheel housing (Fig. 4).

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout or grooved sealing surfaces on the crankshaft or oil seal spacers. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

Remove Crankshaft Oil Seals

Remove the crankshaft front cover (Page 10-2-64) and the flywheel housing (Page 10-2-75) and remove the oil seals as follows:

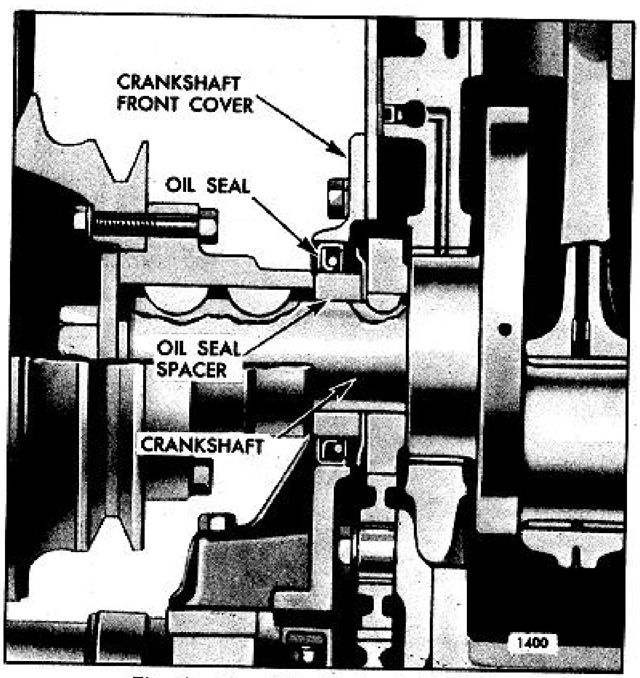


Fig. 1. Crankshaft Front Oil Seal

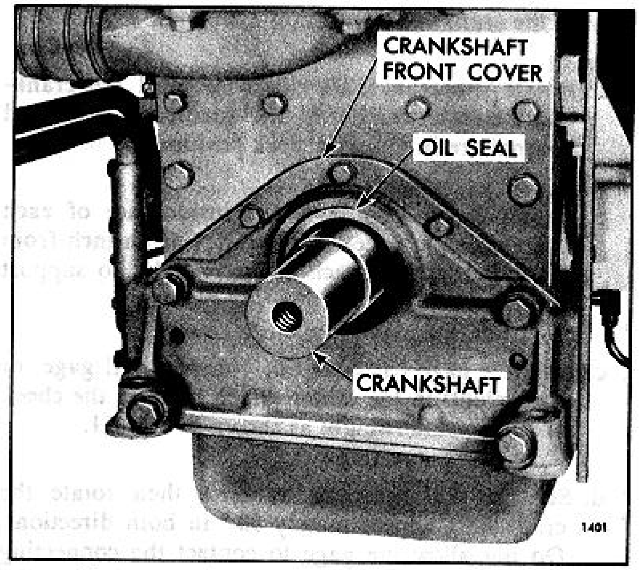


Fig. 2. Crankshaft Front Oil Seal Mounting

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.

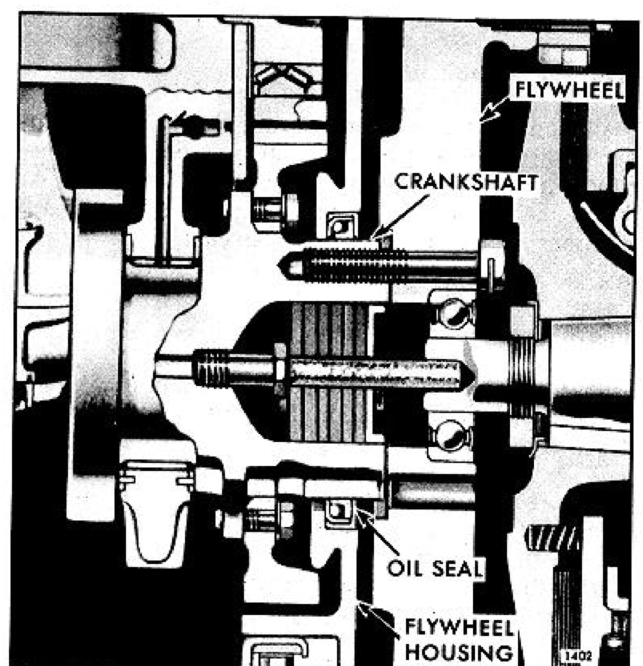


Fig. 3. Crankshaft Rear Oil Seal-Single Lip

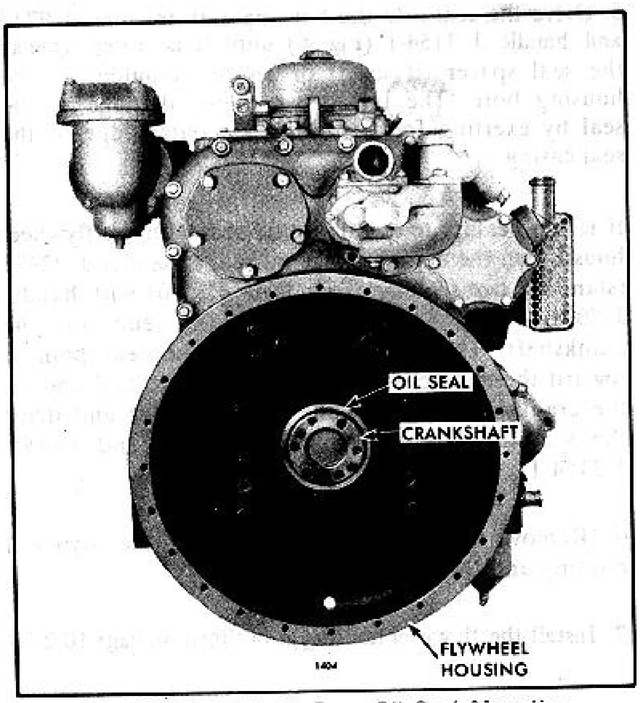


Fig. 4. Crankshaft Rear Oil Seal Mounting

Inspection

Inspect the rear end of the crankshaft for wear caused by the rubbing action of the oil seal, dirt build-up or fretting by the action of the flywheel. The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed. Slight ridges may be removed from the crankshaft as outlined under Inspection on Page 10-249.

The maximum runout of the oil seal bore in the flywheel housing is .008 ". The bore may be checked with a dial indicator mounted on the end of the crankshaft in a manner similar to the procedure for checking the flywheel housing concentricity as outlined on Page 10-2-76. This check must be made with the flywheel housing in place on the engine and the oil seal removed.

If the crankshaft rear oil seal surface is grooved excessively, an oil seal spacer (Fig. 5) may be installed between the counterbore in the flywheel housing and the oil seal. The spacer changes the relative position of the seal and establishes a new contact surface.

When the oil seal spacer can no longer be used, an oil seal sleeve (Fig. 5) may be installed on the crankshaft to provide a replaceable wear surface at the point of contact with the rear oil seal. The oil seal sleeve may be used with the single-lip type oil seal, and can also 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.

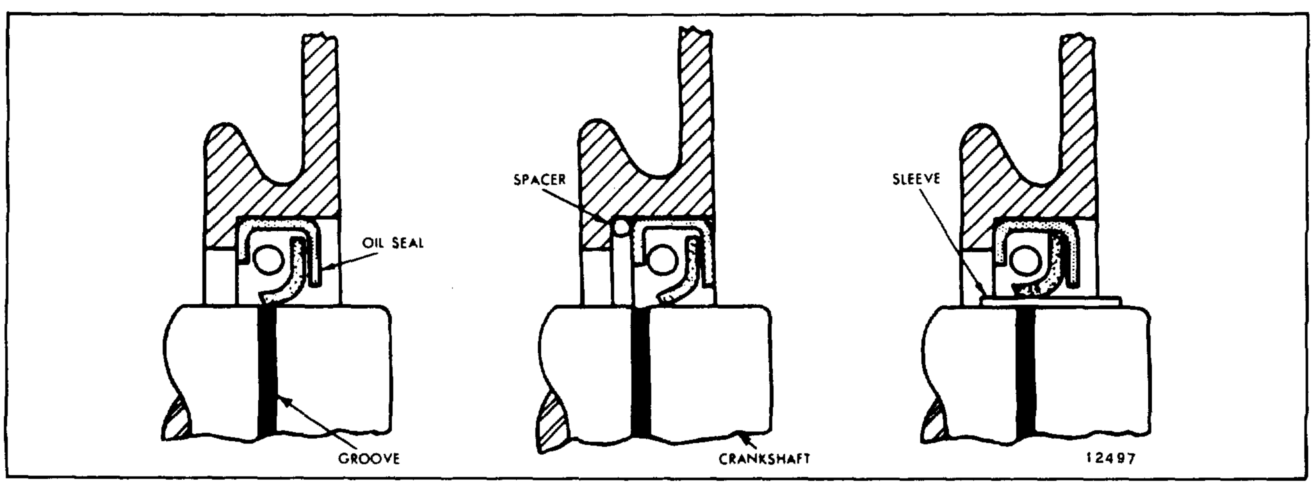


Fig. 5. Use of Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft.

Oil Seals

Current oil seals are made of an oil resistant synthetic rubber which is pre-lubricated with a special lubricant. *Do not remove this lubricant*. Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surface of the casing. Do not remove this coating

The rear oil seal may have either an open or closed back. Both types are serviced.

Install Crankshaft Front Oil Seal

1. If the oil seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing.

2. Coat the lip of the new oil seal lightly with grease or vegetable shortening. Then position the seal in the front cover with the lip of the seal pointed toward the inner face of the cover.

NOTE:
The vibration damper inner cone or oil seal spacer must be removed before installing the oil seal.

3. Drive the seal into the front cover with installer J 9783, which seats the oil seal in the bore. The installer prevents damage to the seal by exerting force only on the outer edge of the seal casing.

4. Remove any excess sealant from the cover and seal.

5. Install the crankshaft front cover as outlined on Page 10-2-64.

6. Install the vibration damper inner cone or oil seal spacer 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.

3. If the new seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing. Then position the seal with the lip pointed toward the inner face (or shoulder in the counterbore) of the housing.

4. Coat the lip of the oil seal lightly with engine oil. Do not scratch or nick the sealing edge of the oil seal.

5. Drive the seal into the housing with installer J 9727 and handle J 3154-1 (Fig. 6) until it is seated against the seal spacer (if used) or on the shoulder in the housing bore. The installer prevents damage to the seal by exerting force only on the outer edge of the seal casing.

If it is necessary to install the oil seal with the flywheel housing on the engine, place oil seal expander J 22425 (standard size seal) or expander J 4195-01 with handle J 8092 (oversize seal) against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the tool and on the crankshaft. Remove the seal expander and drive the seal in place with installer J 9727 and handle J 3154-1.

6. Remove any excess sealant from the flywheel housing and the seal.

7. Install the flywheel housing as outlined on Page 10-2-76.

NOTE:
If the oil seal is of the type which incorporates a brass retainer in the inner diameter of the seal, be sure the retainer is in place on the seal before installing the flywheel housing on the engine. If the retainer is left out, oil leakage will result.

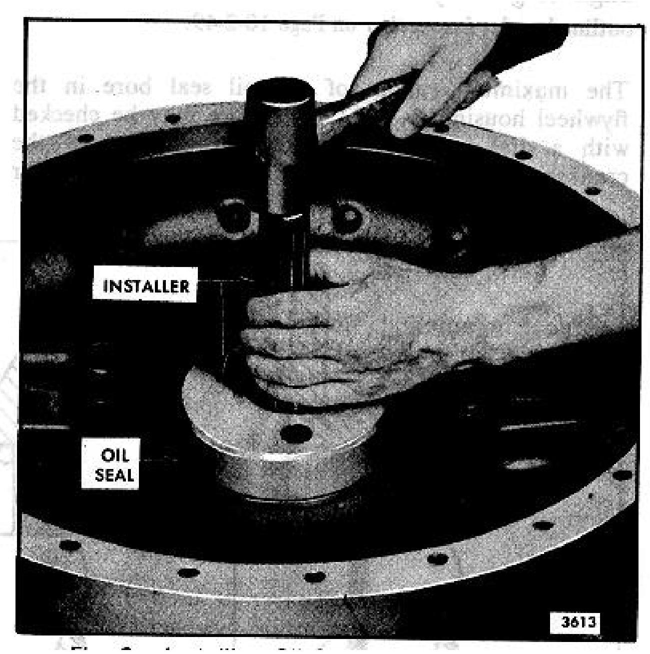


Fig. 6. Installing Oil Seal in Flywheel Housing

CRANKSHAFT MAIN BEARINGS

The crankshaft main bearing shells (Fig. I) are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

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, called 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. The former copper-lead bearings had a copper color when new and turned very dark during engine operation.

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.

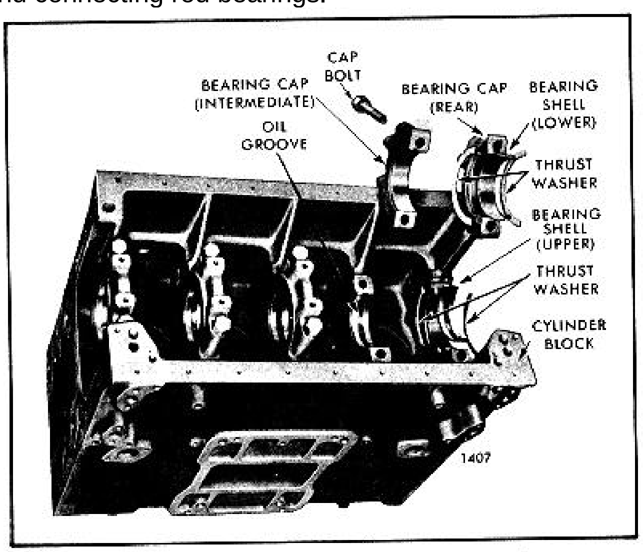


Fig. 1. Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers

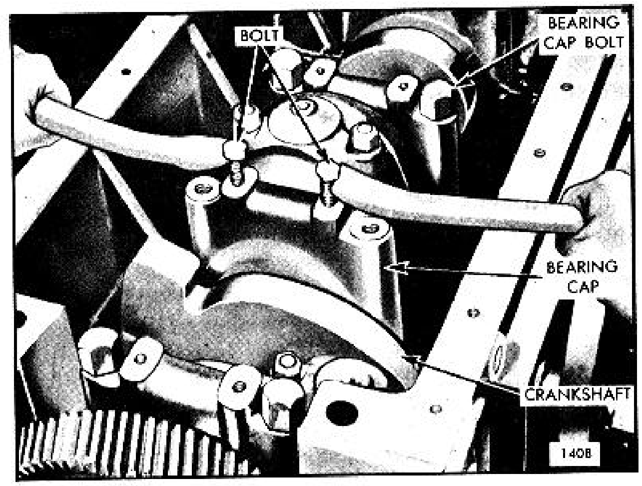


Fig. 2. Removing Main Bearing Cap

The lower main bearing shells have no oil grooves, therefore, the upper and lower bearing shells must not be interchanged.

Thrust washers (Fig. I), on each side of the rear main bearing, absorb the crankshaft thrust. The lower halves of the two-piece washers are doweled to the bearing cap; the upper halves are not doweled.

Main bearing trouble is ordinarily indicated by low or no oil pressure. All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower bearing shells may be observed by removing the main bearing caps.

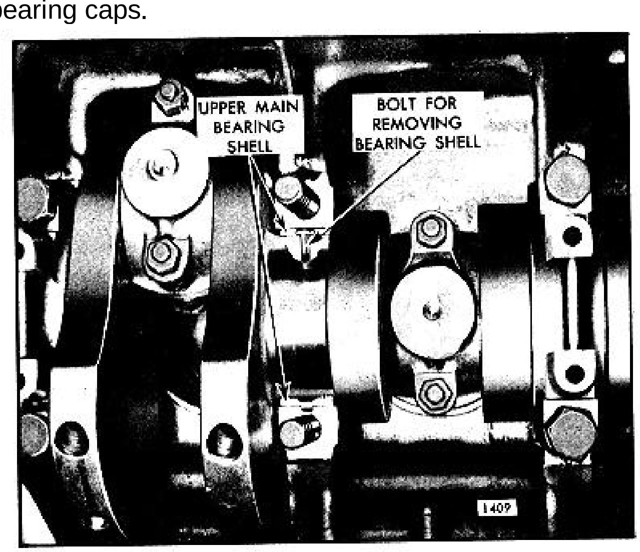


Fig. 3. Removing Upper Main Bearing Shell (Except Rear Main)

If main hearing trouble is suspected, remove the oil pan, then remove the main hearing 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., indicating their respective positions 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.

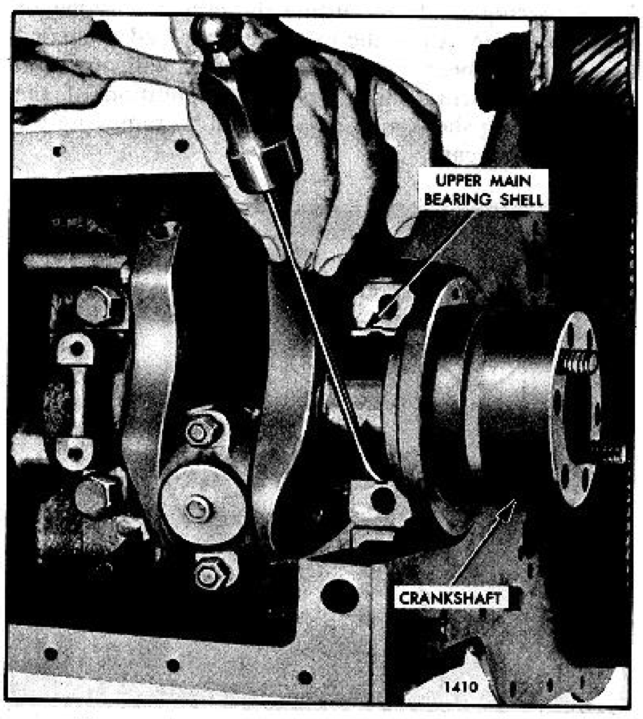


Fig. 4. Removing Upper Rear Main Bearing Shell

3. Remove one main bearing cap at a time (Fig. 2) and inspect the bearing shells as outlined under *Inspection*. Reinstall each bearing shell and bearing cap before removing another bearing cap:

a. To remove all except the rear main bearing shell, insert a 1/4 " x I " 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 Fig. 3. The head of the bolt must not extend beyond the outside diameter of the bearing shell.

b. Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out as shown in Fig. 4.

c. The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

Check the oil filter elements and replace them if necessary. Also. check the oil by-pass valve to make sure it is operating freely.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt or signs of overheating (Fig. 5). The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are not detrimental to this type of bearing. They should not be replaced for these minor surface imperfections since function of the bearings is in no way impaired and they will give many additional hours of trouble-free operation.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

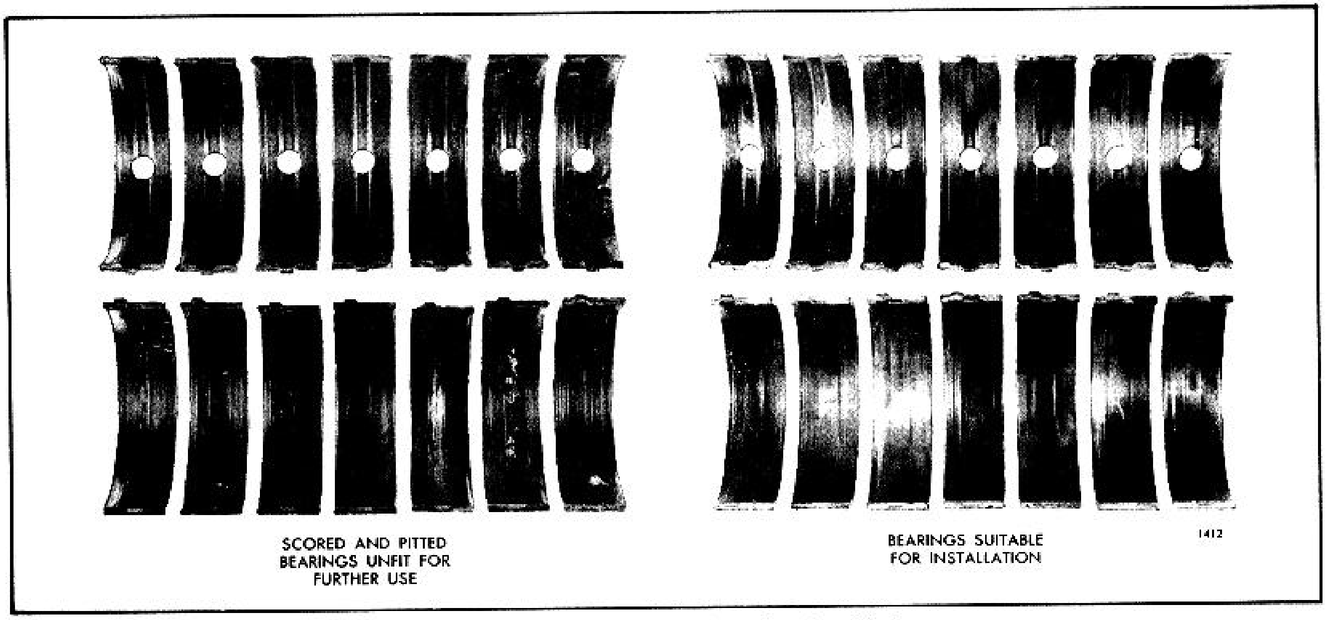


Fig. 5. Comparison of Main Bearing Shells Minimum

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"

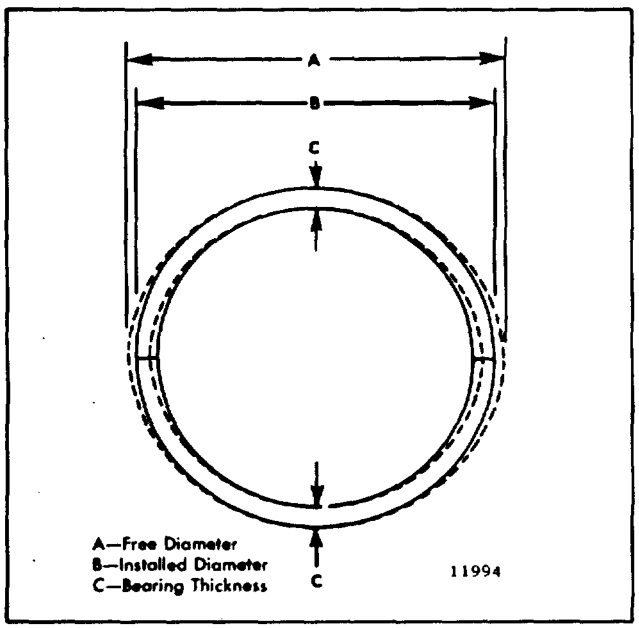


Fig. 6. Main Bearing Measurements

Measure the thickness of the bearing shells at point "C", 90 from the parting line, as shown in Figs. 6 and 7. Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is .1530 " and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of .1548 " to .1553 ". Refer to Table 1.

In addition to the thickness measurement, check the clearance between the main bearings and the

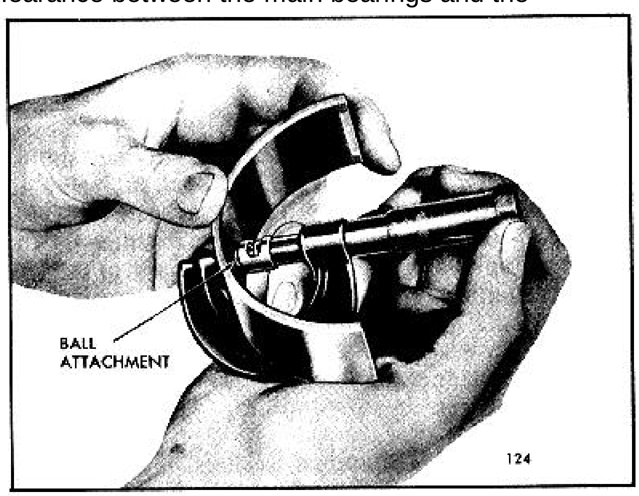


Fig. 7. Measuring Thickness of Bearing Shell

crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* on Page 10-2-131). With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque on the bearing cap bolts. When installed, the bearing shells are .001 " larger in diameter at the parting line than 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 .0060 ", all of the bearing shells must be discarded and replaced. This clearance is .0014 " to .0044 " with new parts.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to Page 10-2-49 under *Crankshaft Inspection* for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .010 ", .020 " and .030 " undersize for service with reground crankshafts.

To determine the size bearings required, refer to *Crankshaft Grinding* on Page 10-2-52. Bearings which are .002 " undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

NOTE

Bearing shells are NOT reworkable from one undersize to another under any circumstances.

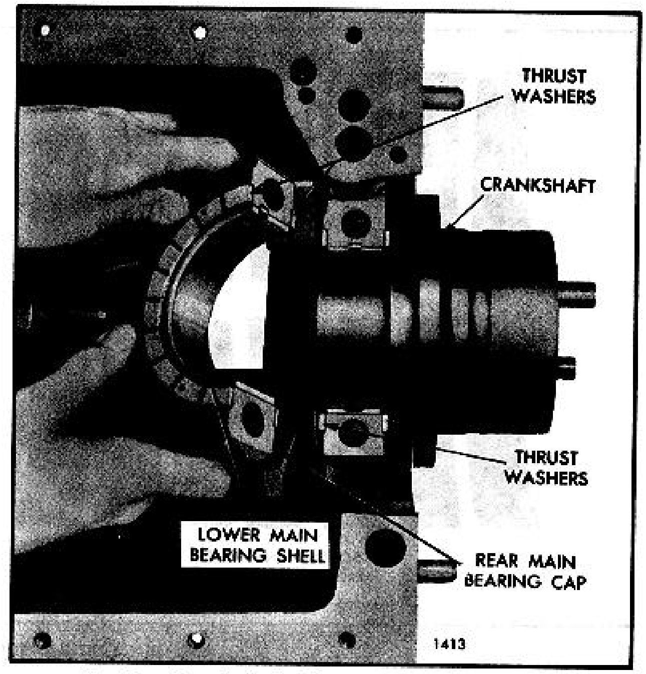


Fig. 8. Crankshaft Thrust Washers in Place

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 10-2-53. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is .1190 " to .1220 " thick. Thrust washers are available in .005 " and .010" oversize.

Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then apply clean engine oil to each crankshaft journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

The upper and lower main bearing shells are not alike; the upper bearing shell is grooved and drilled for lubrication -- the lower bearing shell is not. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

1. When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that,

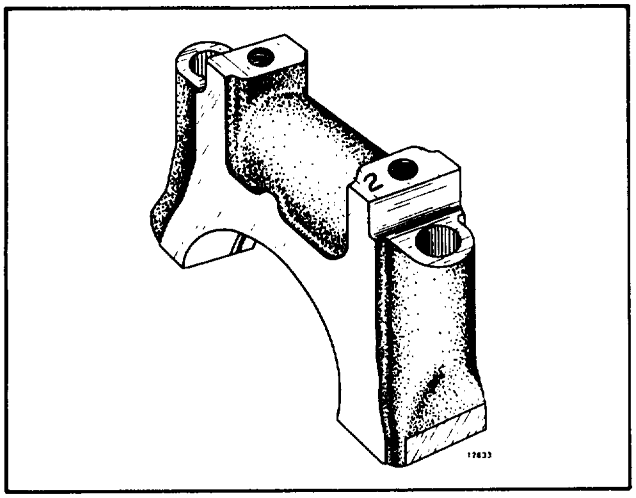


Fig. 9 - Main Bearing Cap Marking

when the bearing is in place, the tang will fit into the groove in the bearing support.

2. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.

3. Assemble the crankshaft thrust washers (Fig. 8) before installing the rear main bearing cap. Clean both halves of each thrust washer carefully and remove any burrs from the washer seats -- the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then assemble the lower halves over the dowel pins in the bearing cap.

NOTE

The main bearing caps are bored in position and stamped 1, 2, 3, etc. (Fig. 9). They must be installed in their original positions with the marked side of each cap toward the blower side of the cylinder block.

4. With the lower main hearing shells installed in the bearing caps, apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolt head contact area. Install the bearing caps and draw the bolts 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) 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 (Fig. 10). 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.

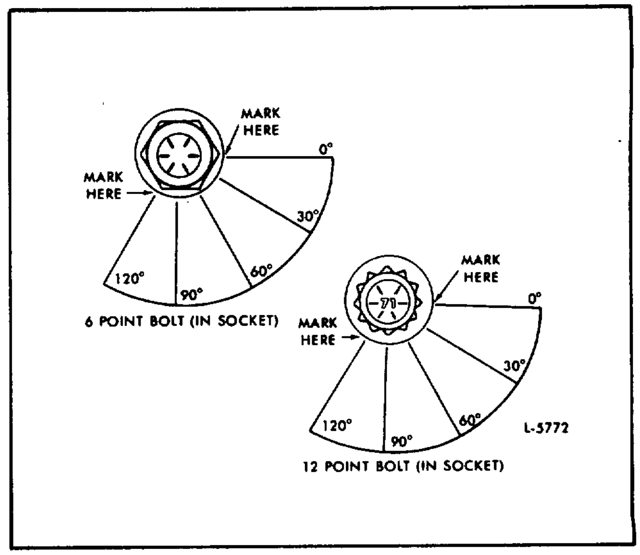


Fig. 10 - Main Bearing Cap Bolt Turn Torque Method

Strike both ends of the crankshaft two or three sharp blows with a soft hammer to insure proper positioning of the rear main bearing cap in the block saddle. Turn the rear main bearing cap bolts an addition 110 °-130 ° of bolt head rotation.

NOTE

If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

5. Check the crankshaft end play as outlined under *Install Crankshaft* on Page 10-2-53.

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 (Page 10.5-10).

7. Install the oil pan, using a new gasket.

8. Fill the crankcase to the proper level on the dipstick with *heavy-duty* lubricating oil of the recommended grade and viscosity (refer to *Lubricating Oil Specifications* on Page 10-9-9).

9. After installing new bearing shells, operate the engine on a run-in schedule as outlined on Page 10-9-2.

CRANKSHAFT FRONT COVER

The crankshaft front cover is mounted against the cylinder block end plate at the lower front end of the engine (Fig. 1). The engine is supported at the front end by engine supports attached to the front cover.

It will be necessary to remove the crankshaft front cover to remove and install the crankshaft or when the engine is overhauled.

Remove Crankshaft Front Cover

1. Drain the oil and remove the oil pan.

2. Remove the vibration damper (Page 10-2-66), crankshaft pulley (Page 10-2-69) and any other accessories that may be mounted on the front of the crankshaft.

3. Remove the vibration damper inner cone or oil seal spacer.
4. Remove the cover attaching bolts and washers (Fig. 1).

5. Strike the rear face of the ears on the cover with a soft hammer to free the cover from the dowels. Pull the cover straight off the end of the crankshaft.
6. Remove the cover gasket.

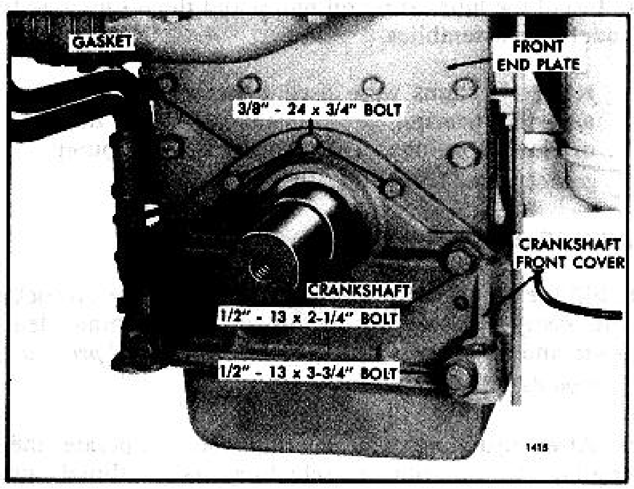


Fig. 1. Crankshaft Front Cover Mounting (Vibration Damper Removed)

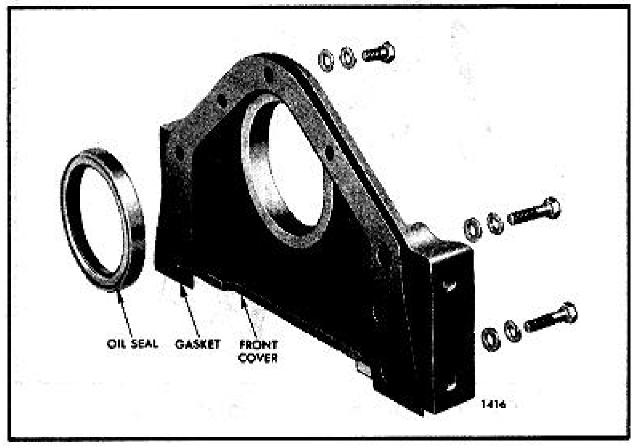


Fig. 2 - Crankshaft Front Cover Details and Relative Location of Parts

7. Remove and inspect the oil slinger.

8. Replace the oil seal (Page 10-2-58).

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.

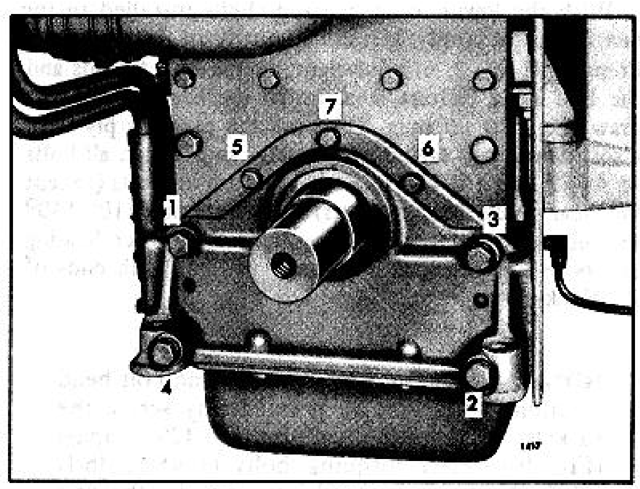


Fig. 3. Crankshaft Front Cover Bolt Tightening Sequence

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 lock washers.

5. Tighten the cover attaching bolts by following the tightening sequence indicated in Fig. 3. Follow this sequence as the bolts are drawn up and then tightened to their proper torque to effect a good seal between the mating parts. Tighten the 3/8" -24 bolts to 25-30 lb-ft (34-41 Nm) and the 1/2"-13 bolts to 80-90 lb-ft (108-122 Nm) torque.

6. Apply a light coating of engine oil to the vibration damper inner cone or the oil seal spacer and slide it into place on the crankshaft.

7. Install the oil pan, using a new gasket.

8. Refer to *Lubricating Oil Specifications* on Page 10-9-9 and refill the crankcase with oil to the proper level on the dipstick.

CRANKSHAFT VIBRATION DAMPER

The 4-71 engine uses a viscous type vibration damper to reduce the crankshaft stresses to a safe value.

The *viscous (fluid) type damper* is employed where the equipment which the engine 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. an internal flywheel and a quantity of highly viscous fluid (Fig. 1). 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.

Remove Vibration Damper From Crankshaft

1. Remove drive line adapter plate by removing the five capscrews from crankshaft pulley.
2. Remove the crankshaft pulley retaining bolt and washer.
3. Remove the crankshaft pulley.
4. Reinstall the pulley crankshaft bolt and install a puller as shown in Figs. 1 and 2 to loosen the outer cone wedged between the crankshaft and the damper hub. After loosening the cone. it may be "fished" from the inner diameter of the damper hub with two thin shank screw drivers.

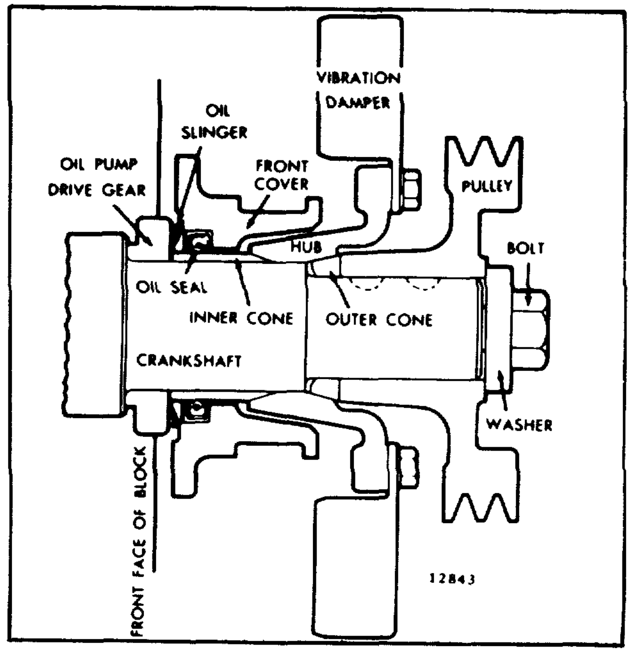


Fig. 1. Removing Vibration Damper Assembly (Viscous Type)

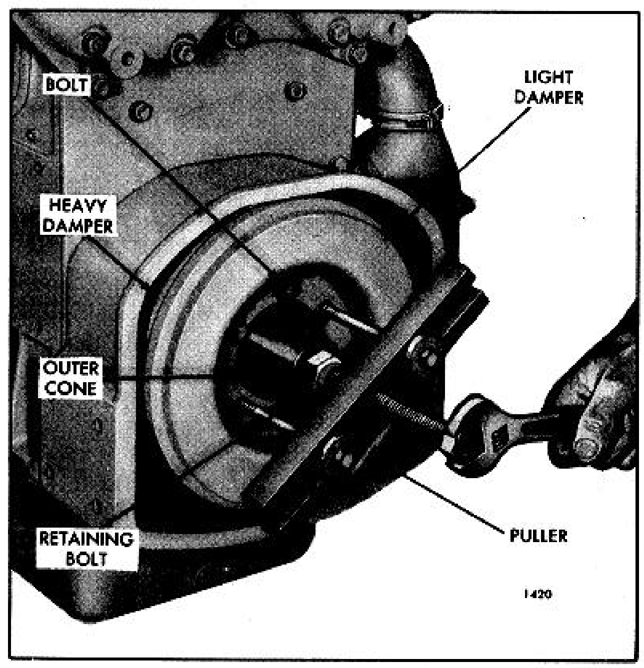


Fig. 2. Loosening Vibration Damper Outer Cone

CAUTION

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 fly-wheel to turn at the same speed as the outer shell, thus rendering the damper ineffective. *The damper cannot be repaired*.

5. Slide the vibration damper or dampers and damper hub as an assembly off the end of the crankshaft by hand.
6. 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 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 as outlined on Page 10-2-49. A loose or defective vibration damper. after extended operation, may result in a cracked crankshaft.

Inspect the damper spacer cones, hub 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 (Page 10-2-58).

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 the illustrations for relative location of the parts and assemble as follows:

1. Coat the lip of the oil seal in the front cover (trunnion) lightly with cup grease or vegetable shortening.
2. Slide the inner cone, with the tapered end pointing to the front of the crankshaft, next to the oil slinger.

NOTE

When the vibration damper and crankshaft pulley are bolted together and mounted on the front end of the crankshaft (Fig. 3), extra precaution should be taken to be certain that the inner cone does not prematurely clamp to the crankshaft.

3. 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.

4. Install the crankshaft pulley and vibration damper assembly with the damper assembly side of the pulley facing the crankshaft front cover.
5. Slide the outer cone over the crankshaft and into the hub of the vibration damper.

6. Install the crankshaft pulley.

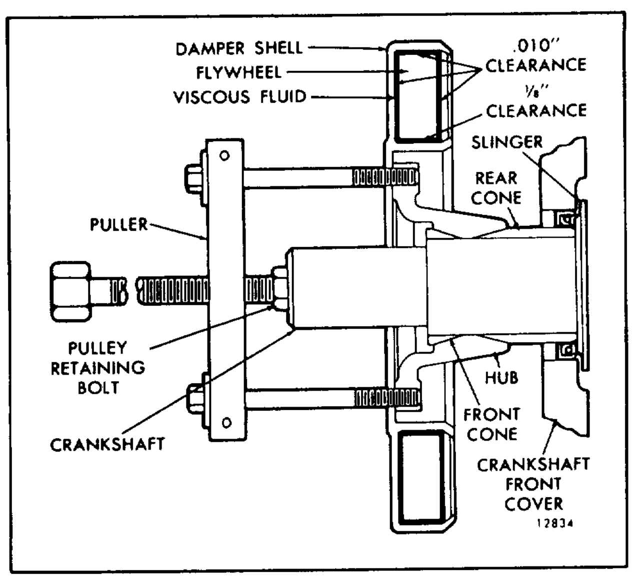


Fig. 3. Vibration Damper and Crankshaft Pulley Assembly Mounting

7. Thread the crankshaft pulley retaining bolt with washer, into the crankshaft and tighten 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 lb. 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.

8. Install drive line adapter plate on crankshaft pulley with five capscrews.

CRANKSHAFT PULLEY

The crankshaft pulley incorporates a rubber insulator between the pulley and the pulley hub for vibration dampening.

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 washer can be identified by their black color. The former bolts and washer are a steel (gray) color.

Remove Crankshaft Pulley

1. Remove drive line adapter plate by removing the five capscrews from crankshaft pulley.
2. Remove the bolt and washer.
3. Use puller J 5356 as illustrated in Fig. 1. Clean the threads of the tool and pulley. Screw the 2 1/2"-16 thread into the pulley hub as far as possible with the center screw backed off. Then force the pulley off the crankshaft by turning the center screw in.

Inspection

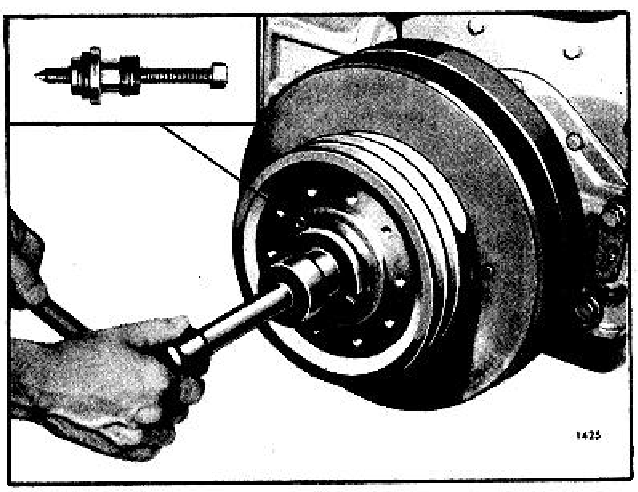


Fig. 1. Removing Rubber Mounted Pulley from Crankshaft using Tool J 5356

The appearance of the rubber bushing does not determine the condition of a rubber mounted crankshaft pulley. Check for failure of the rubber bushing by locking the crankshaft and applying pressure to the crankshaft pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. If necessary, replace the rubber bushing.

Install Crankshaft Pulley

Refer to Fig. 2 and install the crankshaft pulley as follows:

1. Place the Woodruff keys in the key slots in the front end of the crankshaft, if they were removed.
2. Slide the pulley over the end of the 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. The pulley must be drawn tight against the outer cone.
4. Tighten the crankshaft pulley retaining bolt as follows:

a. Tighten the bolt to 180 lb-ft (244 Nm) torque.
b. Strike the end of the bolt a sharp blow with a 2 or 3 lb. 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.

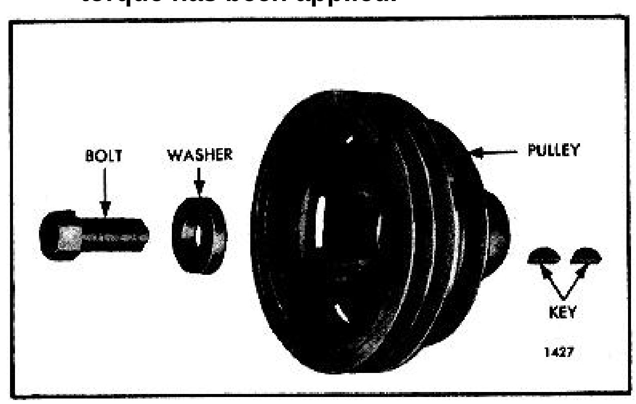


Fig. 2. Crankshaft Pulley Details

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.

5. Install the drive line adapter plate on crankshaft pulley with five capscrews.

FLYWHEEL

The flywheel (Fig. 1) is attached to the rear end of the crankshaft with six self-locking bolts. Two dowels in the end of the crankshaft aid flywheel alignment and provide support when the flywheel bolts are removed. 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 (Fig. 2) is driven in the end of the crankshaft to prevent the pilot bearing from entering the crankshaft cavity.

The flywheel is machined to provide true alignment with the clutch, and the center bore provides for installation of a clutch pilot bearing. The clutch is bolted to the flywheel.

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing.

Remove Flywheel (Transmission Removed)

1. Remove the six flywheel attaching bolts and scuff plate.

CAUTION Install one flywheel bolt after removing the scuff plate to hold the flywheel in place until the lifting tool is attached.

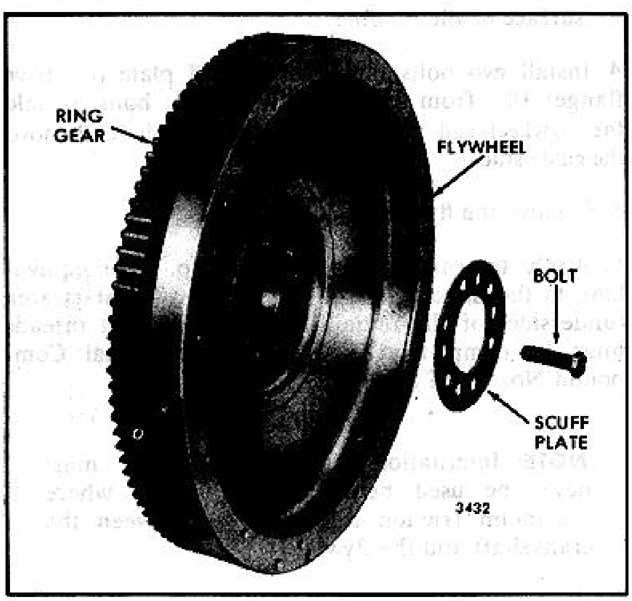


Fig. 1. Typical Flywheel Assembly

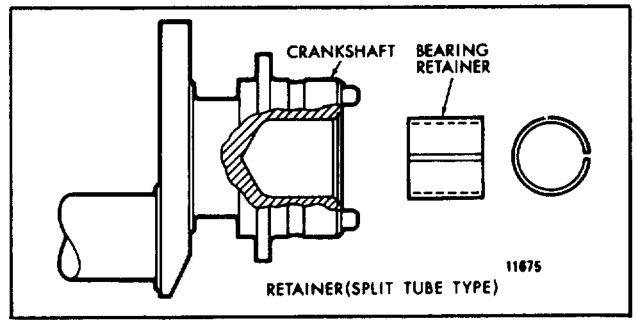


Fig. 2. Pilot Bearing Retainer

2. Attach flywheel lifting tool J 6361-01 to the flywheel with two 7/16" -14 bolts of suitable length or use tool J 25026. Remove the remaining flywheel attaching bolt.
3. Attach a chain hoist to the lifting tool to support the flywheel as shown in Fig. 3.

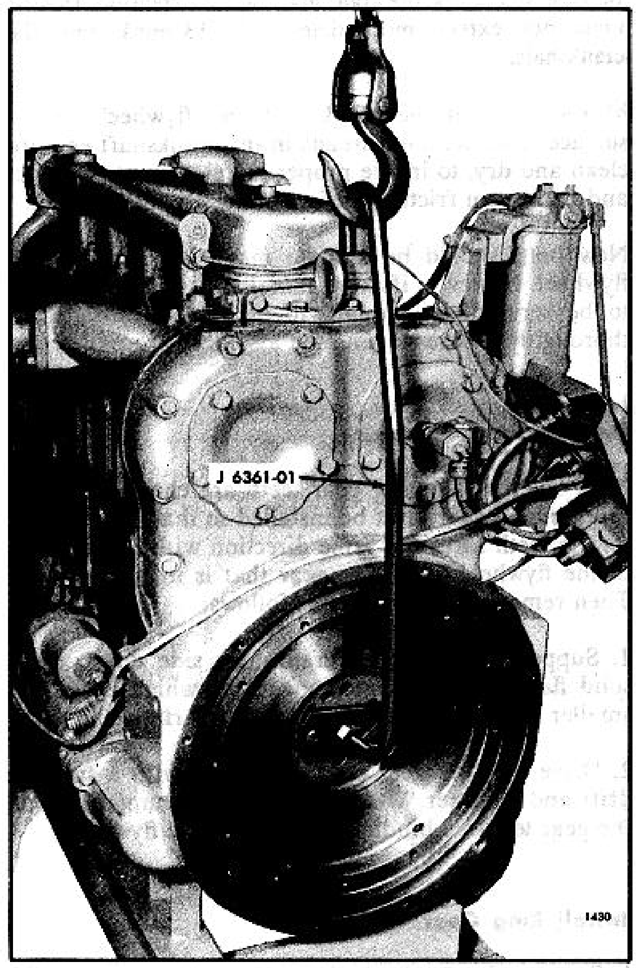


Fig. 3. Removing Flywheel

4. Move the upper end of the lifting tool in and out to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.
5. Remove the clutch pilot bearing, as outlined on Page 10-2-74.

NOTE

It is not necessary to remove the split type tube retainer.

Inspection

Check the clutch contact face of the flywheel for scoring, overheating or cracks. If scored, the flywheel may be refaced. However, *do not* remove more than .020" of metal from the flywheel. Maintain all of the radii when refacing the flywheel.

Replace the ring gear if the gear teeth are excessively worn or damaged. Check the butt end of the crankshaft and flywheel contact surface. If necessary lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

Be sure and check the crankshaft dowel extension. Dowels must not extend more than 1/2" (13 mm) from the crankshaft.

Make sure that the crankshaft and flywheel contact surfaces and the bolt threads in the crankshaft end are clean and dry, to insure proper metal-to-metal contact and maximum friction, before attaching the flywheel.
New bolts should be used to mount or remount the flywheel. However, if the original bolts are determined to be serviceable and are to be reused, clean them thoroughly before starting the assembly procedure.

Remove Ring Gear

Note whether the ring gear teeth are chamfered. The replacement gear must be installed so that the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that is to be removed.
Then remove the ring gear as follows:

1. Support the flywheel, crankshaft side down, on a solid flat surface or hardwood block which is slightly smaller than the inside diameter of the ring gear.
2. Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.

Install Ring Gear

1. Support the flywheel, ring gear side up, on a solid flat surface.
2. Rest the ring gear on a **flat metal** surface and heat the gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.

CAUTION

Do not, under any circumstances, heat the gear over 400°F (204°C); excessive heat may destroy the original heat treatment.

NOTE

Heat indicating "crayons", which are placed on the ring gear and melt at a predetermined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

3. Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.
4. Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it and apply additional heat, noting the above caution.

Install Flywheel

1. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs). Align the flywheel bolt holes with the crankshaft bolt holes.
2. Install the clutch pilot bearing.
3. To install a split tube type retainer, (if removed), drive the retainer in flush with the end of the crankshaft with a soft hammer.

CAUTION

Do not mar the bearing contact surface of the retainer.

4. Install two bolts through the scuff plate (or drive flange) 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide studs.
5. Remove the flywheel lifting tool.
6. Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2 and any excess wiped off.

NOTE

International Compound No. 2 must never be used between two surfaces where maximum friction is desired as between the crankshaft and the flywheel.

7. Install the remaining bolts and run them in snug.

8. Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.

9. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb-ft (68 Nm) torque.

10. Turn the bolts an additional 90°-120° (Fig. 4) to obtain the required clamping.

NOTE

Since the torque-turn method provides more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

IMPORTANT

When a clutch pilot bearing is installed, index the flywheel bolts so that the corners of the bolt heads do not overlap the pilot bearing bore in the flywheel. Thus, one of the flats of each bolt head will be in line with the bearing bore. Always rotate bolts in the *increased* clamp direction to prevent underclamping.

12. Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. The maximum allowable runout is .001 " total indicator reading per inch of radius (or .001mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

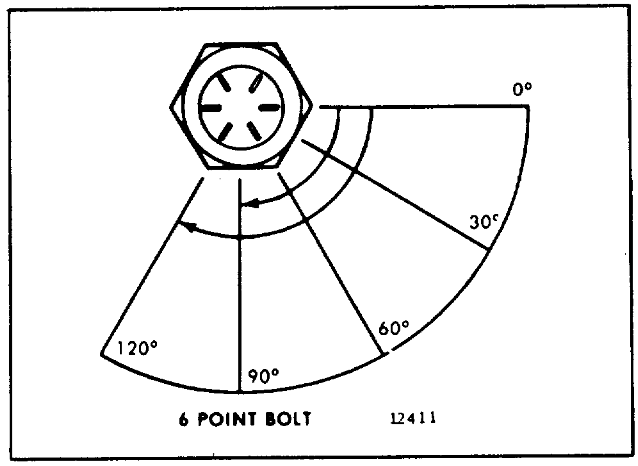


Fig. 4. Torque - Turn Limits

CLUTCH PILOT BEARING

The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft.

The clutch pilot bearing is held in place by a scuff plate, or bearing retainer, secured in place by the flywheel attaching bolts.

Lubrication

A double-sealed ball type clutch pilot bearing is prepacked with grease and requires no further lubrication.

Remove Clutch Pilot Bearing (Transmission Removed)

1. Remove the six bolts attaching the flywheel to the crankshaft. Remove the bearing retainer and re-install two of the bolts to hold the flywheel in place.

2. With the clutch pilot bearing remover adapter J 23907-2 attached to slide hammer J 23907-1, insert the fingers of the adapter through the pilot bearing and tighten the thumb screw to expand the fingers against the inner race of the bearing.
3. Tap the slide hammer against the shoulder on the shaft and pull the bearing out of the flywheel.

With the flywheel removed from the engine, the clutch pilot bearing may be removed as follows:
1. Place the flywheel on wood supports to provide clearance for the bearing.
2. Use bearing remover J 23907-2, as outlined above, or tool J 3154-04 with suitable adapter plates, to tap the bearing from the flywheel.

Inspection

Wipe the prepacked double-sealed bearing clean on the outside and inspect it. *Shielded bearings must not be washed*, dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing.

Check the bearing for free rolling by holding the inner race and revolving the outer race *slowly* by hand. Rough spots in the bearing are sufficient cause for rejecting it.

Install Clutch Pilot Bearing.

1. Lubricate the outside diameter of the bearing with clean engine oil.
2. Start the bearing in the bore of the flywheel, with the numbered side of the bearing facing away from the engine, and drive the bearing in place with bearing installer J 3154-04 and suitable adapter plates.

3. Install the flywheel on the crankshaft (refer to Page 10-2.72).

FLYWHEEL HOUSING

The flywheel housing (Fig. 1) is a one-piece casting, mounted against the rear cylinder block end plate, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motor and the transmission.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing (Page 10-2-58).

Remove Flywheel Housing

1. Mount the engine on an overhaul stand as outlined on Page 10-2-4.

2. Remove the starting motor, oil pan, flywheel and any accessories attached to the flywheel housing.

3. Remove the two bolts securing the engine lifter bracket to the cylinder head. This will leave the lifter bracket attached to the flywheel housing for convenience in handling.

4. Remove the twelve attaching bolts inside of the flywheel housing bell which attach the housing to the idler gear hub, spacer and cylinder block. Remove the twelve remaining bolts around the upper portion of the housing and the. two bolts which go through the rear end plate from the front and thread into the housing (Fig. 1).

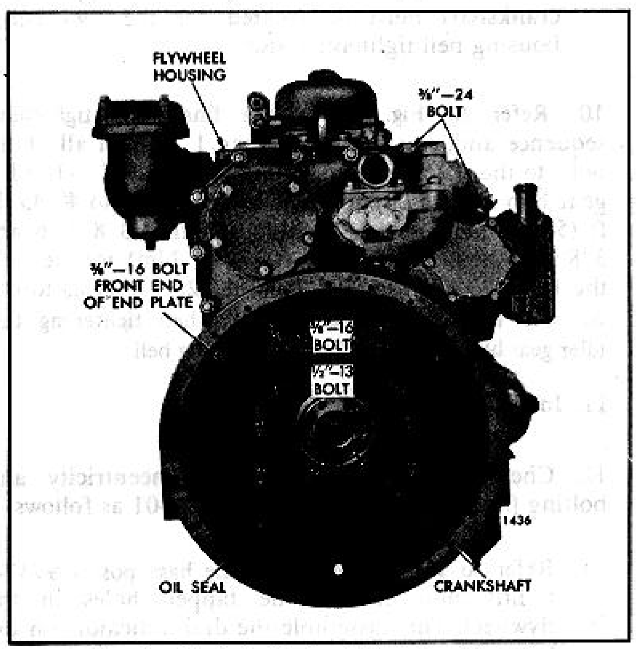


Fig. 1. Typical Flywheel Housing Mounting

NOTE

When removing the flywheel housing bolts, note the location of the various bolts and washers so they may be reinstalled in their proper location.

5. To guide the flywheel housing until it clears the end of the crankshaft, thread four pilot studs J 1927-01 into the cylinder block (Fig. 2).

6. With the flywheel housing supported by a chain hoist attached to the lifter bracket, strike the front face of the housing alternately on each side with a soft hammer to work it off the dowels and away from the cylinder block rear end plate.

Inspection

Clean the flywheel housing and inspect it for cracks or any other damage.

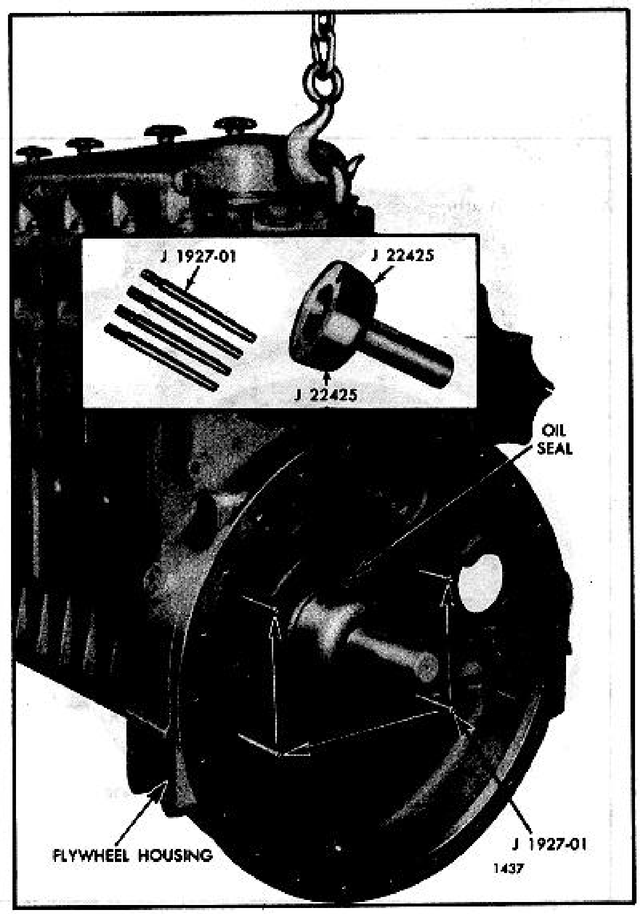


Fig. 2. Removing or Installing Flywheel Housing

It is very important that all old gasket material be thoroughly removed from the flywheel housing and the endplate, otherwise runout of the pilot and the face of the housing may be affected when the housing is installed on the engine.

Remove and discard the crankshaft rear oil seal. Install a new oil seal as outlined on Page 10-2-56.

Install Flywheel Housing

1. Lubricate the gear train teeth with clean engine oil.
2. Affix a new housing-to-end plate gasket to the flywheel housing.
3. Coat the lip of the oil seal lightly with engine oil. Do not scratch or nick the sealing edge of the oil seal.
4. Thread four pilot studs J 1927-01 into the cylinder block to guide the housing in place (Fig. 2). Use oil seal expander J 22425 (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.

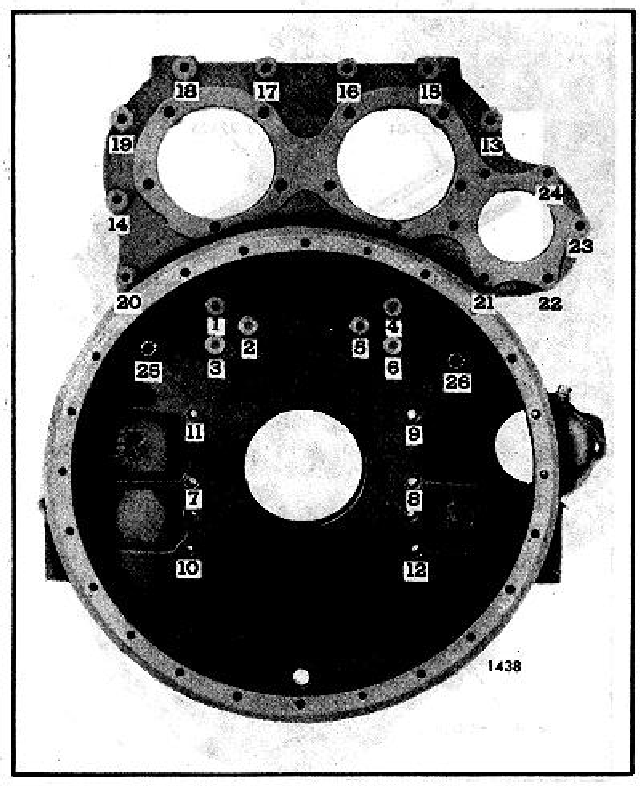


Fig. 3. Flywheel Housing Bolt Tightening Sequence (Operation 1)

5. With the housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket. Remove the oil seal expander.
6. Refer to Fig. I 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.

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 bolt, the additional operation of securing the bolts with a lock wire is eliminated, inasmuch as the head of the bolt is so designed that it will lock 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 lockwashers, finger tight.
8. Install the remaining flywheel housing attaching bolts and washers, finger tight.
9. Refer to Fig. 3 for the bolt tightening sequence. Start at number I 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 Fig. 4 for the final bolt tightening sequence and, starting at number 1, tighten all of the bolts to the specified torque. Tighten the 3/8 "-16 idler gear hub and hole spacer self-locking bolts to 40-45 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 (Page 10-2-72).

12. Check the flywheel housing concentricity and bolting flange face with tool set J 9737-01 as follows:
    a. Refer to Fig. 5 and thread the base post J 9737-3 tightly into one of the tapped holes in the flywheel. Then assemble the dial indicators on the base post.

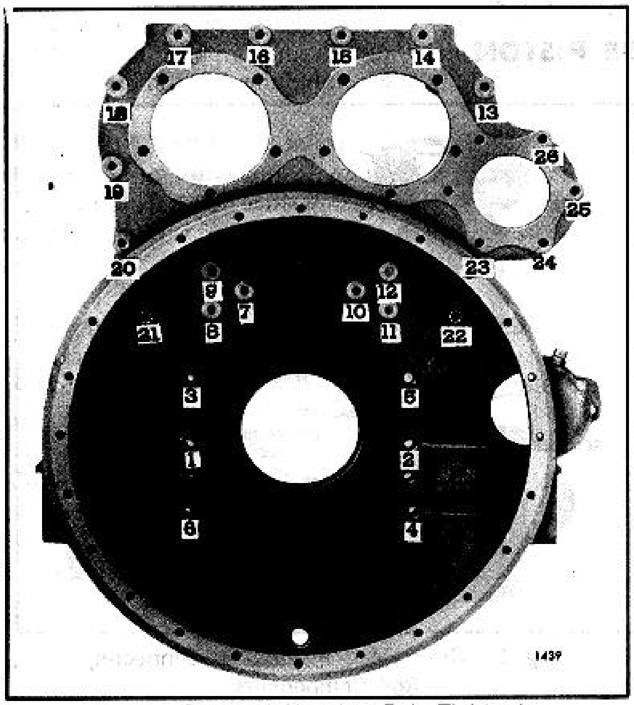


Fig. 4. Flywheel Housing Bolt Tightening Sequence (Operation 2)

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 adapter in the tool set to check the housing bore.

c. Pry the crankshaft toward one end of the block to ensure the end play is in one direction only.

d. Adjust each dial indicator to read zero at the twelve o'clock position. Then rotate the crankshaft one full revolution, taking readings at 45 intervals (8 readings each for the bore and the bolting flange face). Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed .013 " for either the bore or the face.

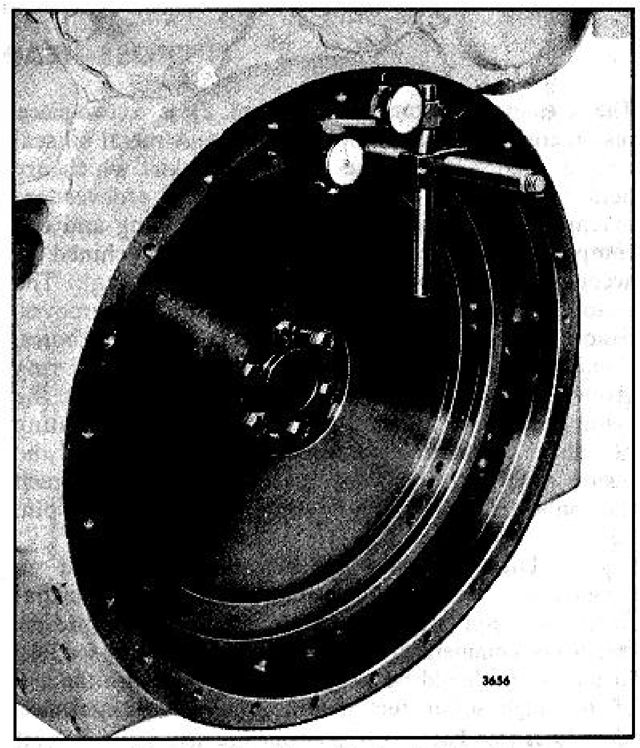


Fig. 5. Checking Flywheel Housing Concentricity

e. If the runout exceeds the maximum limits, remove the flywheel housing and check for dirt or foreign material, such as old gasket material, between the end plate, flywheel housing and the new gasket (and between the end plate and the cylinder block).

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 bracket-to-cylinder head bolts, thus drawing the bracket into the corner formed by the cylinder head and housing (Page 10-2-45).

14. Install the oil pan (Page 10-5-21).

15. Remove the engine from the overhaul stand and complete assembly of the engine.

CROSS-HEAD TYPE PISTON

The cross-head piston (Figs. I and 2) is a two-piece piston consisting of a crown and skirt. A metal oil seal ring is used between the crown and skirt which are held together by the piston pin. Ring grooves are machined in the piston crown for a fire ring and two compression rings. The crown is also machined to accept a 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.

Detroit Diesel engines are designed to operate on diesel fuels containing less than 0.5% sulfur. Plasma-faced fire rings may be used in areas where approved fuel is not commercially available or economically feasible to obtain. It should be recognized that even with the use of the high sulfur fuel modification and maintenance procedures (see Page 10-9-7), engine life may still not equal that with our recommended fuels.

NOTE

Recommended engine modifications do not apply to U.S. certified automotive engines.

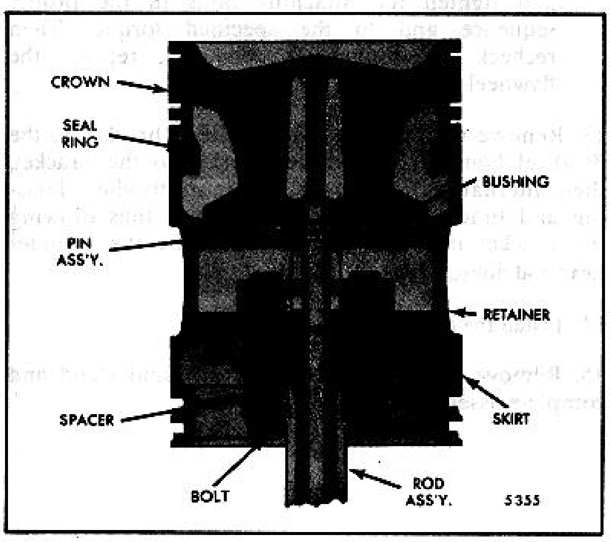


Fig. 1. Cross-Head Piston and Connecting Rod Assembly

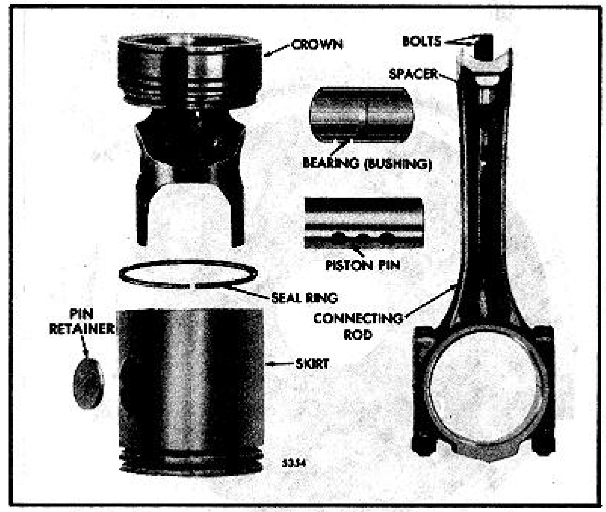


Fig. 2. Cross-Head Piston and Connecting Rod Components

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. 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.

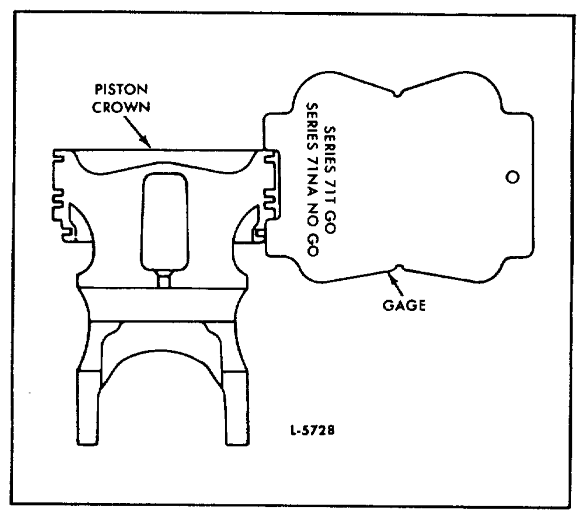


Fig. 3. Piston Identification using Gage J 25397

The non-turbocharged (naturally aspirated) engines use an 18.7:1 compression ratio piston and the turbocharged engines use a 17:1 compression ratio piston. To aid identification of a piston, refer to Fig. 3. Fit the end of the gage 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 .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.

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. Refer to Page 10-11-9 for the procedure for checking compression pressure.

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 (Page 10-5-6).

4. Remove the cylinder head (Page 10-2-20).

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.

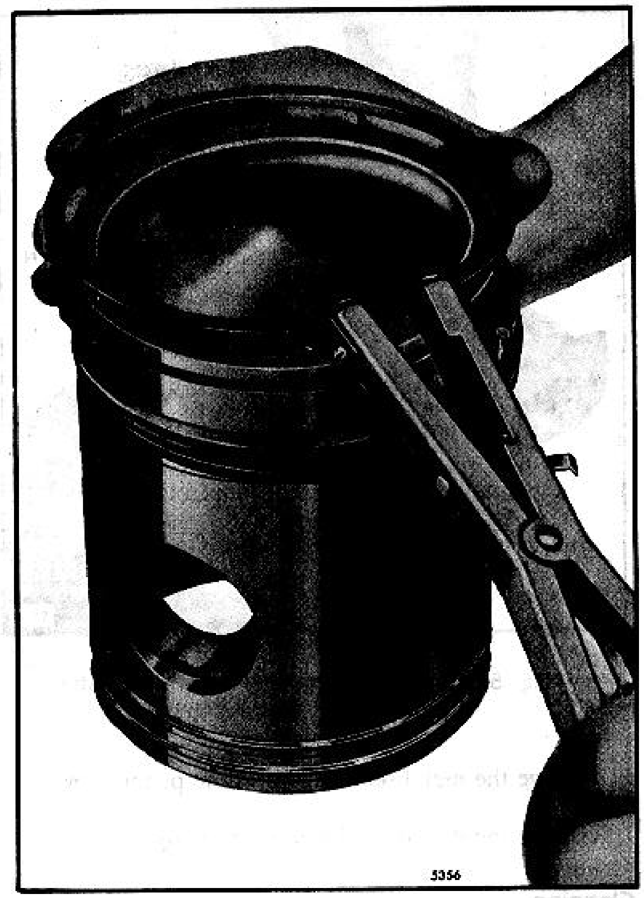


Fig. 4. Removing or Installing Piston Rings using Tool J 8128

Disassemble Piston and Connecting Rod

Note the condition of the piston and rings. Then remove the rings and disassemble the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 as shown in Fig. 4.
2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushing. Remove the opposite retainer in the same manner.
3. Loosen the two bolts which secure the connecting rod to the piston pin. Then remove the rod and piston assembly from the vise and place the assembly on the bench. Remove the two bolts and spacers and remove the connecting rod.
4. Withdraw the piston pin.
5. Separate the piston skirt from the piston crown.

Fig. 5. Checking Fire Ring Groove in Piston Crown using Tool J 24599

6. Remove the metal seal ring from the piston crown.
7, Remove the piston pin bushing (bearing).

Cleaning

Clean the piston components with fuel oil and dry them with compressed air. If fuel oil does not remove the carbon deposits. use a chemical solvent 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 (.0029"-.0058") is recommended. Allowable air pressure is 80-100 psi (552-689 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 tinplating.

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 types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

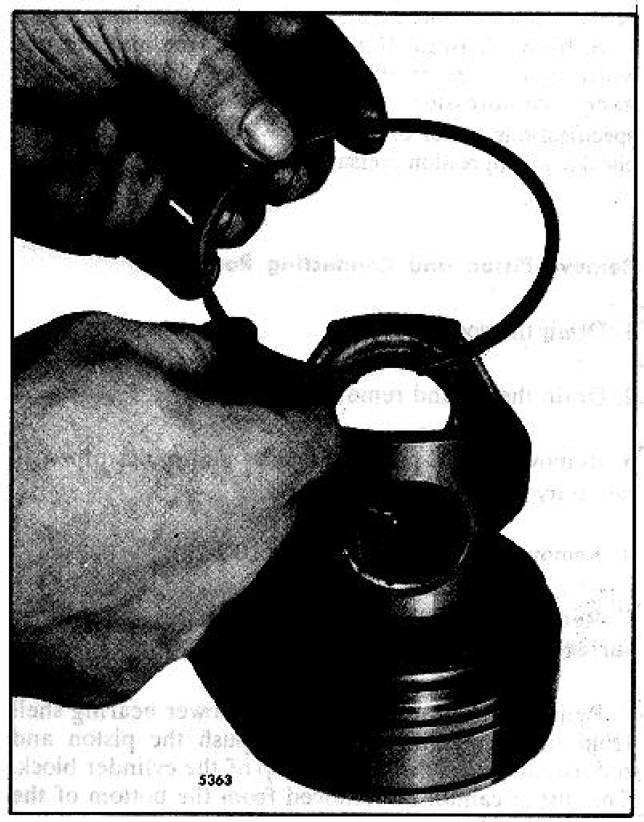


Fig. 6. Installing Seal Ring

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 current piston crown with tool J 24599 as shown in Fig. 5 Slide the "NO-GO" wire (.106" diameter) of the tool completely around the fire ring groove. Should the wire be below flush at any one area, the piston crown must be replaced. The "GO" wire (.100" diameter) should be flush or protrude slightly from the fire ring groove.

Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston (refer to Page 10-2-133 for specifications.)

Inspection of the connecting rod, piston pin and piston pin bushing are covered on Page 10-2-86.

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).

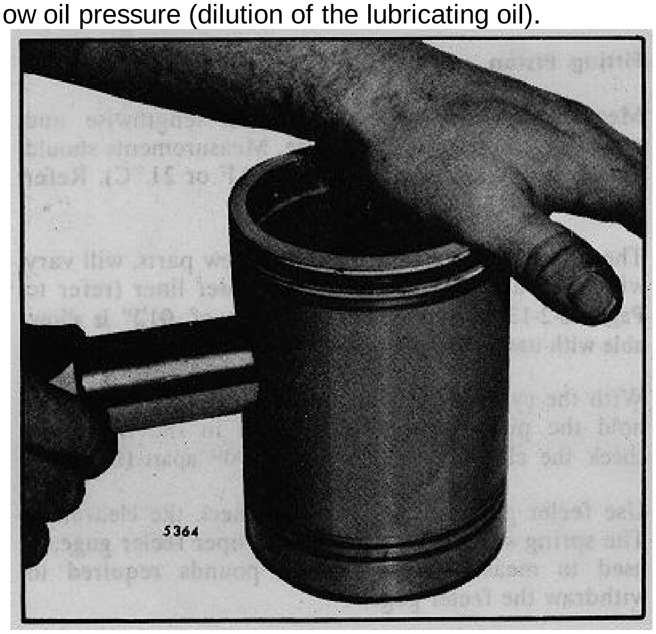


Fig. 7. Installing Piston Pin

Assemble Piston

1. Install the bearing (bushing) in the piston crown. It should slide into the piston crown without force. With new parts, there is .0005" to .0105" clearance between the edge of the bushing and the groove in the piston crown.

NOTE

The bearing must be installed before assembling the piston skirt and crown.

2. Lubricate the metal seal ring (Fig. 6) with engine oil and install it with *the chamfer or counterbore directed toward the bottom of the piston*.

NOTE

The current 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 ring, identified by a very shiny appearance, *must not* be used for service.

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 there are no tight spots. When the piston crown, seal ring and piston skirt are assembled, the skirt should spin freely on the crown (crown top down on the bench). If the seal ring sticks, remove high spots or nicks in the groove with a flat file. If this does not relieve sticking, replace the piston crown.

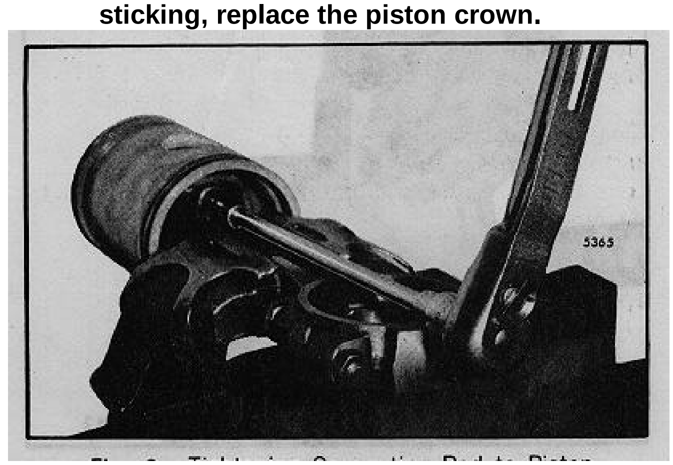


Fig. 8. Tightening Connecting Rod to Piston Pin Bolts

4. Lubricate the piston pin with clean engine oil and install it as shown in Fig. 7.

CAUTION

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 (Fig. 8). 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 (Fig. 9).

9. Install the second piston pin retainer in the same manner.

NOTE

Due to the size of the counterbore in the piston skirt, be careful when installing the piston pin retainers and inspect them to be sure they are not buckled and that they are fully seated in the counterbore. The width of the land should be even around the retainer.

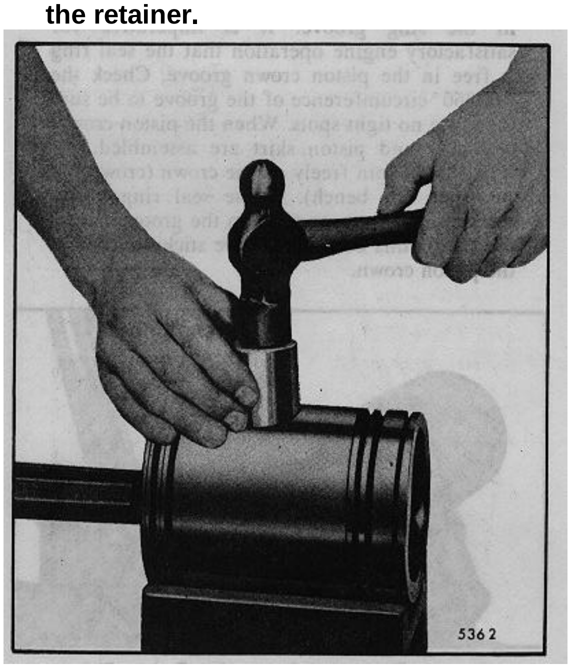


Fig. 9. Installing Piston Pin Retainer using Tool J 23762

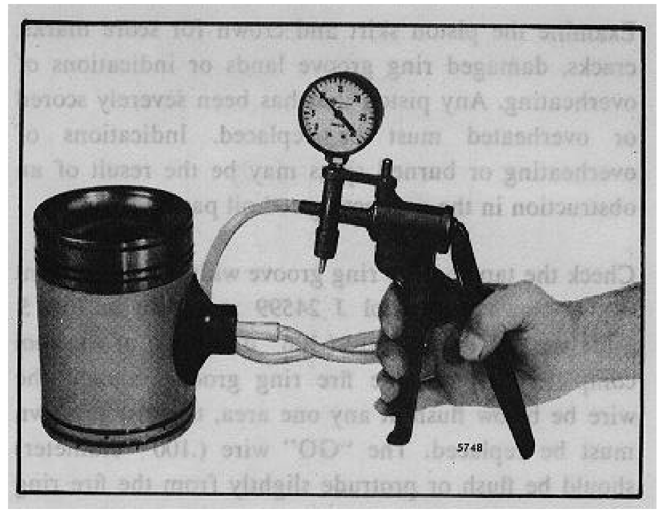


Fig. 10- Checking Piston Pin Retainer for Proper Sealing using Tool J 23987-01

10. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushing, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987-01 (Fig. 24). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

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). Refer to Page 10-2-134 for specifications.

The piston-to-liner clearance, with new parts. will vary with the particular piston and cylinder liner (refer to Page 10-2-134). A maximum clearance of .012" is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston skirt upside down in the liner and check the clearance in four places 900 apart (Fig. 11).

Use feeler gage set J 5438-01 to check the clearance. The spring scale, attached to the proper feeler gage. Is used to measure the force in pounds required to withdraw the feeler gage.

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be

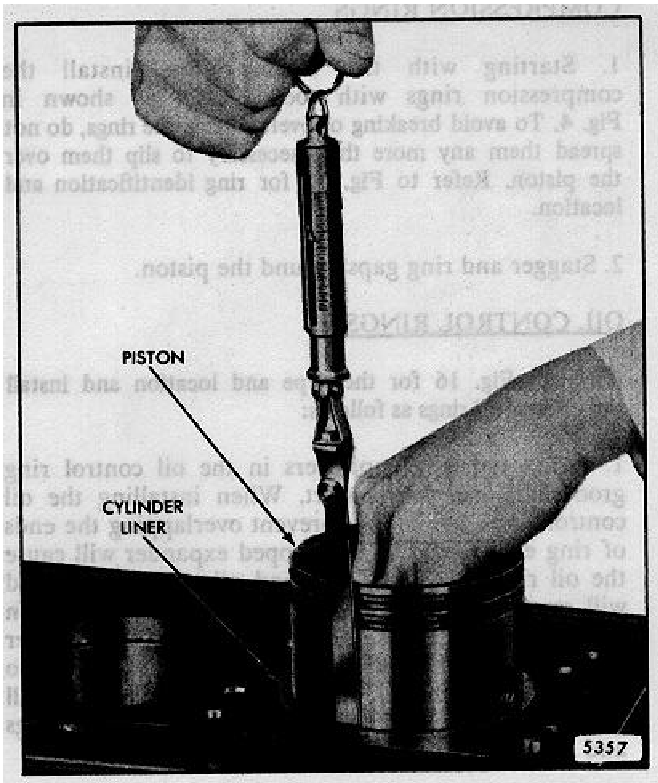


Fig. 11 - Measuring Piston-to-Liner Clearance using Tool J 5438-01

.001" greater than the thickness of the feeler gage used, i.e., a .004" feeler gage will indicate a clearance of .005" when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. 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 (Fig. 12).

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.

> **NOTE**: The current piston crowns (18.7: 1 and 17: 1 compression ratio) have a tapered fire ring groove. To conform with this change, a tapered fire ring (Fig. 13) must be used. The former piston crown (17: 1 compression ratio) had a rectangular fire ring groove. Only pistons with

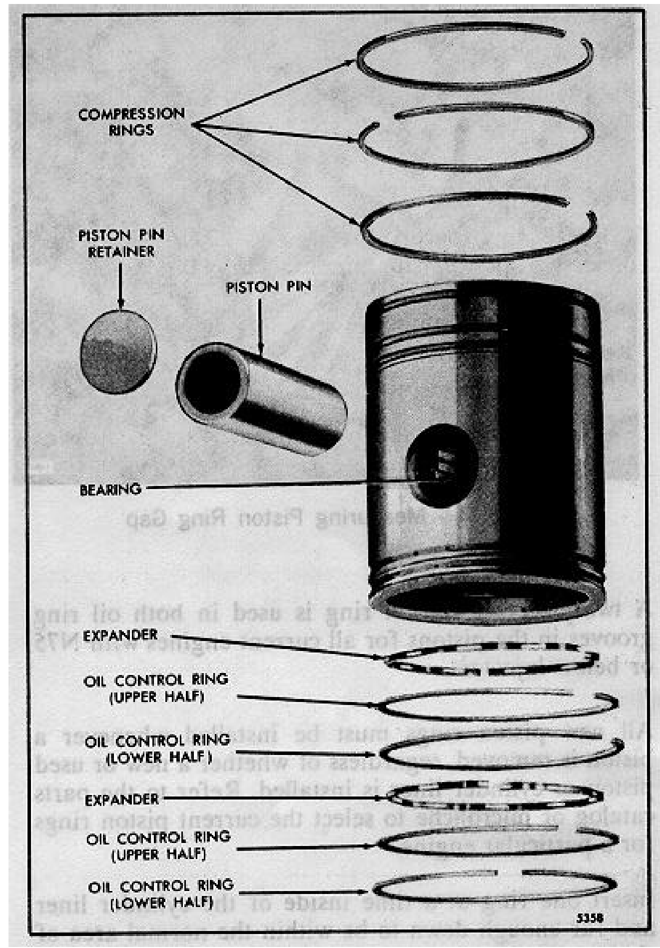


Fig. 12 - Piston Ring Location (Non-Turbocharged Engine)

> the tapered fire ring groove are available for service.

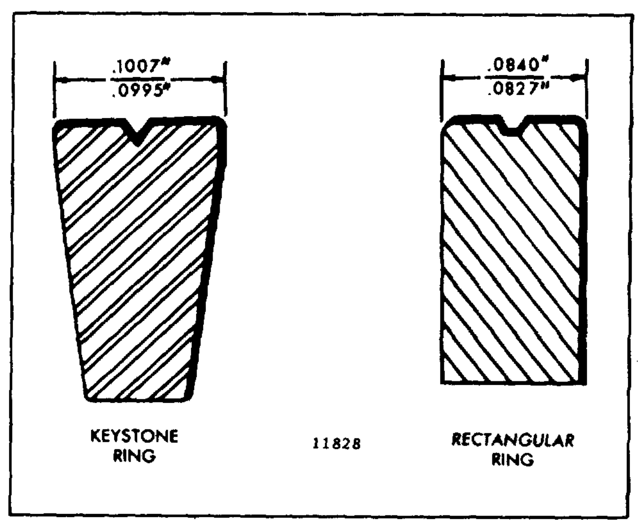


Fig. 13 · Comparison of Fire Rings

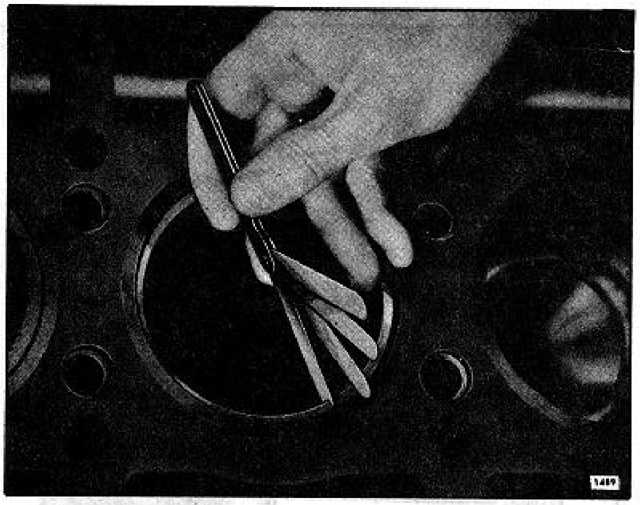


Fig. 14 - Measuring Piston Ring Gap

A two-piece oil control ring is used in both oil ring grooves in the pistons for all current engines with N75 or below injectors.

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 catalog or microfiche to select the current piston rings for a particular engine.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston skirt to push the ring down to be sure it is parallel with the top of the liner. Then measure the ring gap with a feeler gage as shown in Fig. 14. Refer to Page 10-2-134 for ring gap specifications.

If the gap on a compression ring is insufficient. it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately .015".

Check the ring side clearance as shown in Fig. 15. Ring side clearances are specified on Page 10-2-134.

Install Piston Rings

> **NOTE**: Lubricate the piston rings and piston with engine oil before installing the rings.

COMPRFSSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 as shown in Fig. 4. To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. Refer to Fig. 16 for ring identification and location.

2. Stagger and ring gaps around the piston.

OIL CONTROL RINGS

Refer to Fig. 16 for the type and location and install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston skirt. When installing the oil control rings, use care to prevent overlapping the ends of ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

> **NOTE**: When peripheral abutment type ring expanders are used, install them with the legs of the free ends toward the top of the piston. With the free ends pointing up, a noticeable resistance will be encountered during installation of the piston if the ends of the expander are over-lapped and corrective action can be taken before ring breakage occurs.

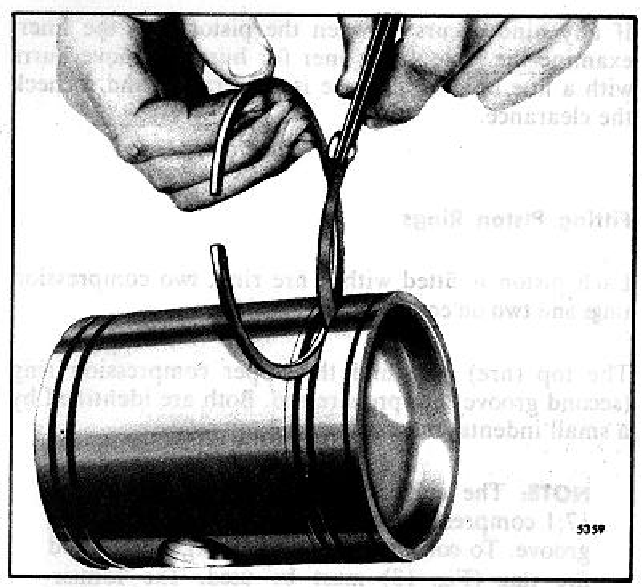


Fig. 15 Measuring Piston Ring Side Clearance

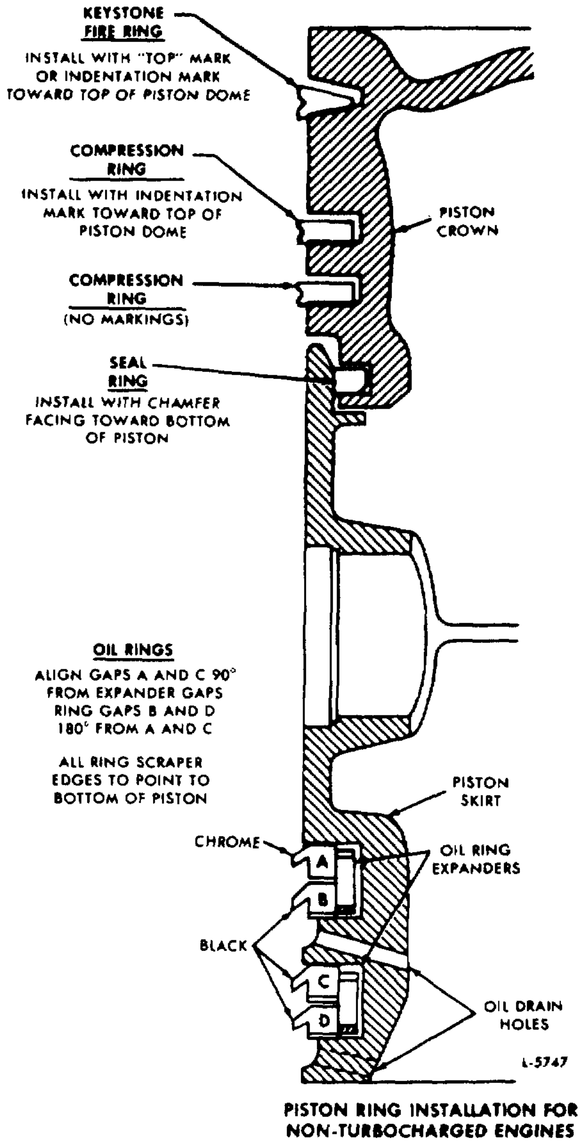


Fig. 16. Piston Ring Installation Instructions.

2. Install the oil control rings by hand. Start with the upper half of the top oil ring and align the gaps as indicated in Fig. 16.

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 as outlined on Page 10-2-99.

CONNECTING ROD

Cross-Head Type Piston

The connecting rod (Fig. 1) is forged to an "I" section with an open or saddle type contour at the upper end and a bearing cap at the lower end. The bearing cap and connecting rod are forged in one piece and bored prior to separation.

The upper end of the connecting rod is machined to match the contour of the piston pin. The piston pin is secured to the connecting rod with two self-locking bolts and spacers. The 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.

The replaceable connecting rod bearing shells are covered on Page 10-2-90.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined on Page 10-2-79.

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 corrosion on the connecting rod saddle and piston pin contact surface with the rod before reassembly.

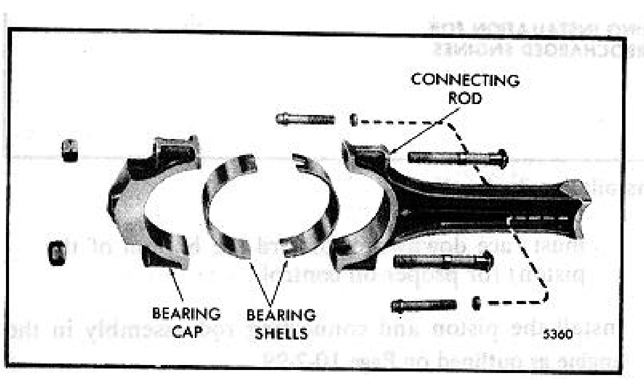


Fig. 1. Connecting Rod Details.

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 end?
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 build engine, the following checks should be made in addition to the above.

1. Check for cracks (Fig. 2) by the magnetic particle method outlined on Page 10-2.49 under *Crankshaft Inspection.*

2. Determine bore diameter of the rod, using a dial bore gage and master ring as follows (Fig. 3).

a. Install the connecting rod cap on the connecting rod and tighten the bolt nuts to 60-70 lb ft (81-95 N•m) torque.

CAUTION: 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 Fig. 3.

c. Obtain average of A and B to obtain size at split line.

$$\frac{A + B}{2} = X \quad \text{which is the average of A + B}$$

d. Measure C. The difference in the results of the measurements X and C gives bore out-of-round and can be .005 " maximum.

e. Add C with X and average to obtain average bore size.

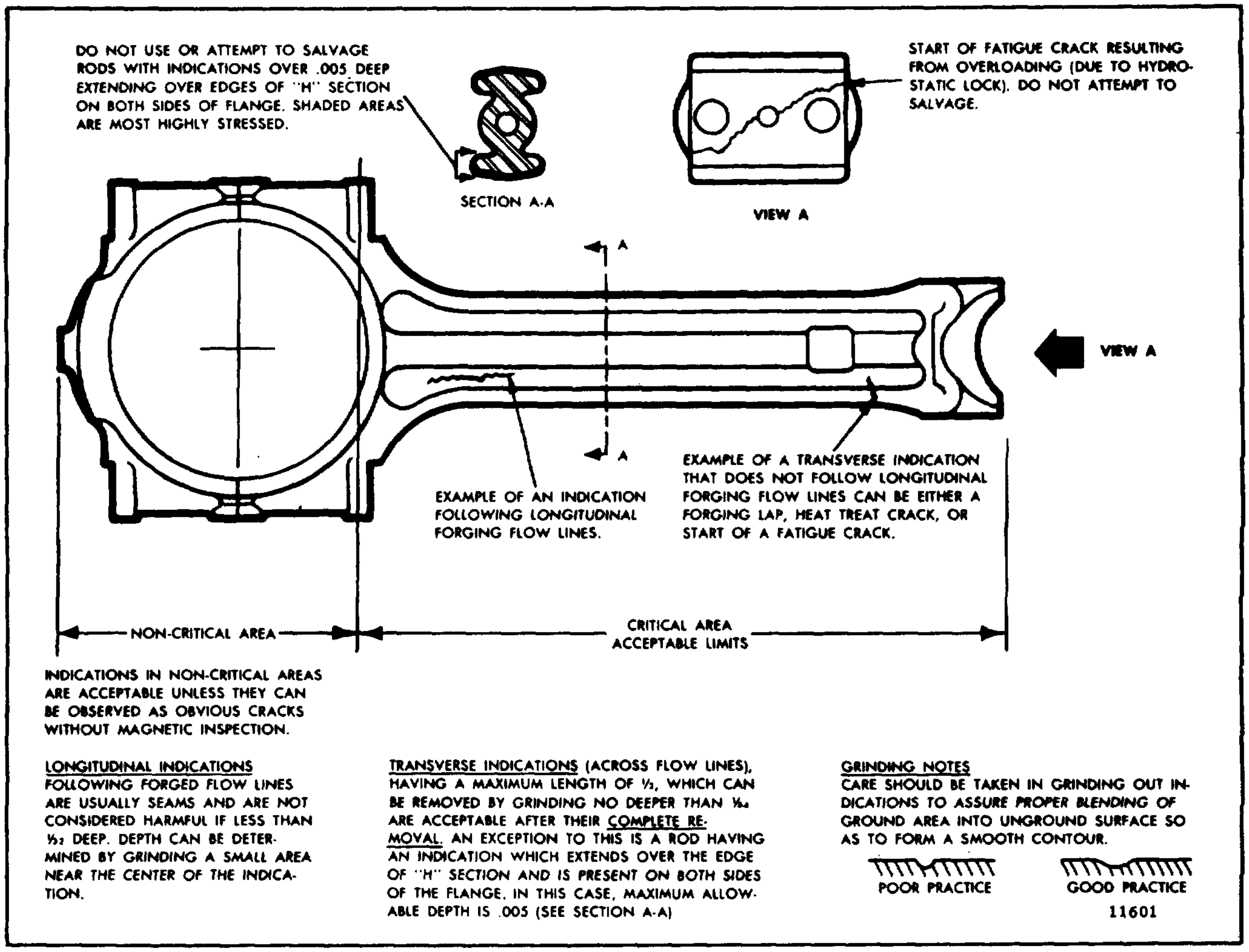


Fig. 2. Magnetic Particle Inspection Limits for Connecting Rod.

$\frac{C + X}{2}$ = Average diameter of bore

Specifications: 3.2495 " to 3.2515 ".

IMPORTANT: If the crosshead connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.

3. Determine taper as follows (Fig. 1):

a. Subtract D1 from D2 to find the difference.
b. The difference can be .0005 " maximum.

4. Determine length by finding the distance between E1 and E2 (Fig. 3).

Specifications: 10.121 " to 10.126 ".

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 (refer to Page 10-2-99).

IMPORTANT: Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clear of obstructions. Also make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Inspect the bearing (bushing) for indications of

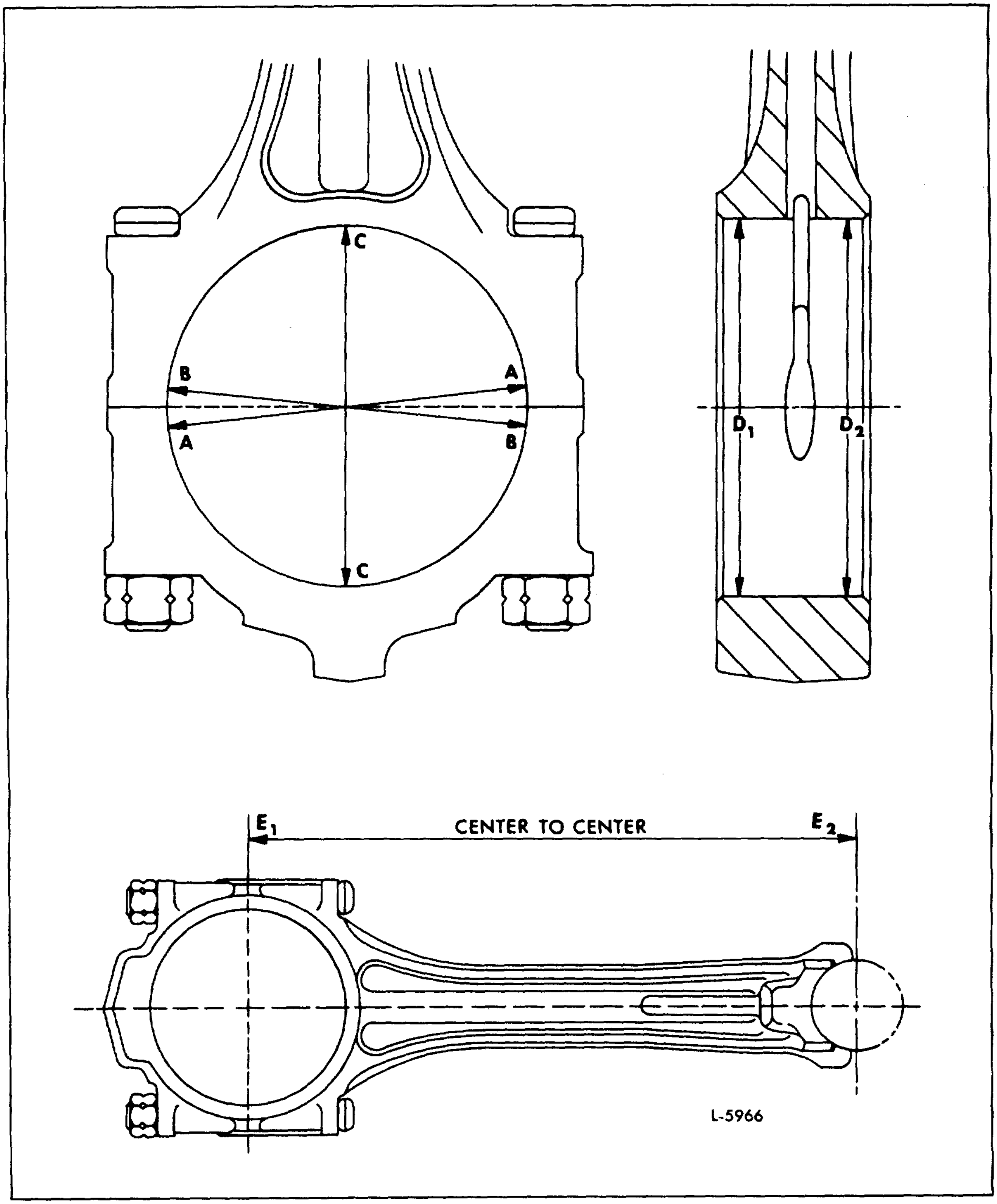


Fig. 3 - Dimensional Inspection of Cross-Head Piston Connecting Rods

scoring, overheating or other damage. Measure the thickness of the bushing along the center. Replace the bushing if it is damaged or worn to a thickness of .086 " or less. A new bushing is .087 " to .088 " thick.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished.

Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear. 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 Connecting Rod to Piston

Refer to *Assemble Piston* on Page 10-2-81 for assembly of the connecting rod to the piston.

CONNECTING ROD BEARINGS

The connecting rod bearing shells (Fig. 1) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell.

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, called 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. The former copper-lead bearings had a copper color when new and turned very dark during engine operation.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell is grooved midway between the bearing edges, part way up from each parting line, with an oil hole through the shell at the termination of each groove. The lower bearing shell has a continuous oil groove, extending from one parting line to the other, in line with that of the upper bearing shell. These grooves maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings and spray nozzle through the oil passage in the connecting rod.

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 the 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.

5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

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.

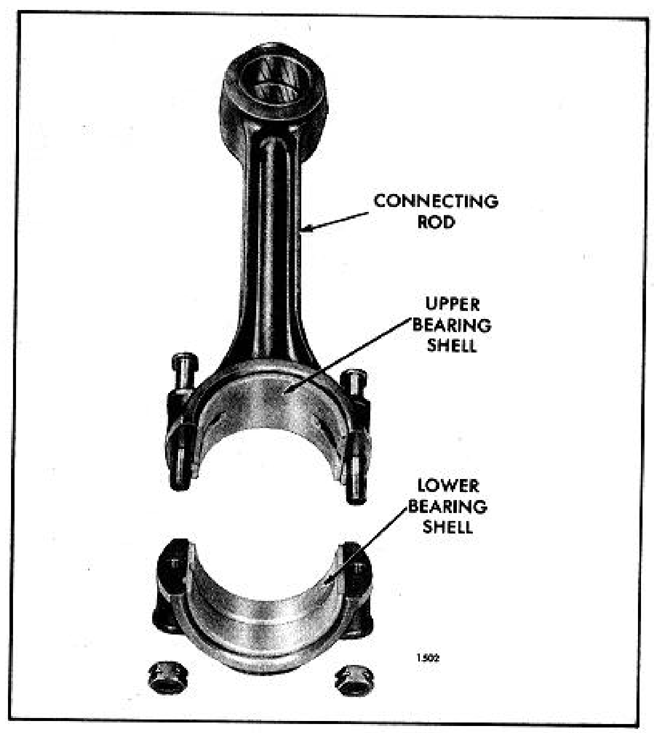


Fig. 1 - Connecting Rod and Bearing Shells

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 characteristics of and are NOT detrimental to this type of bearing. The bearings should not be replaced for these minor surface imperfections. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been shifting in their supports. If such spots are present, discard the bearing shells. Also inspect the connecting rod bearing bore for burrs, foreign particles, etc.

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under Inspection on Page 10-2-60. The minimum thickness of a worn standard connecting rod bearing shell should not be less than .1530" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1548" to .1553". Refer to Table 1.

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"	.1 680"

*Thickness 90° from parting line of bearing.

TABLE 1

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to Shop Notes on Page 10-2-131.) The maximum connecting rod bearing-to-journal clearance with used parts is .006" .

Before installing the bearings, inspect the crankshaft journals (refer to Inspection on Page 10-2-49).

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in .010", .020" and .030 " undersize for service with reground crankshafts. To determine the size bearings required, refer to Crankshaft Grinding on Page 10-2-52. Bearings which are .002" undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

> **NOTE**: Bearing shells are NOT reworkable from one undersize to another under any circumstances.

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 N•m) torque (lubrite nut) or 65-75 lb-ft (88-102 N•m) 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 the Lubricating Oil Specifications on Page 10-9-9 and fill the crankcase to the proper level on the dipstick.

If new bearings were installed, operate the engine on the run-in schedule as outlined on Page 10-9-2.

CYLINDER LINER

The replaceable type cylinder liner (Fig. 1) is accurately machined and heat treated to provide a long wearing scuff-resistant surface. The flange at the top fits into a counterbore in the cylinder block and rests on a replaceable cast iron insert which permits accurate alignment of the cylinder liner.

A long-oval port cylinder liner (Fig. 2) is used with pistons equipped with three compression rings and a fire ring (top ring groove).

NOTE: Do not use the short-oval port liners in this engine. Only long oval port liners can be used.

The liner is cooled by means of a water jacket in the cylinder block and by the scavenging air introduced into the cylinder through the air inlet ports around the liner (Figs. 1 and 2). The air inlet ports are machined at an angle to create a uniform swirling motion to the air as it enters the cylinder.

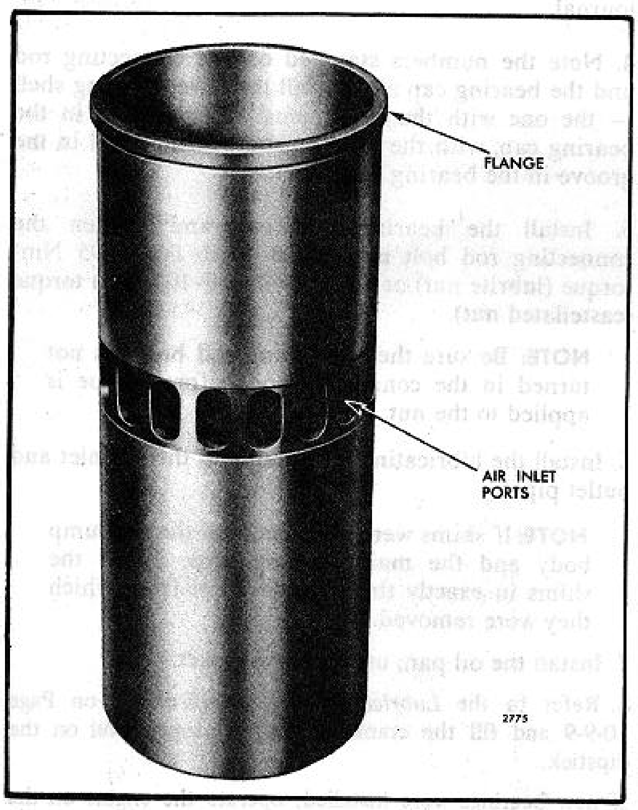


Fig. 1. Typical Cylinder Liner.

This motion persists throughout the compression stroke and facilitates scavenging and combustion.

The wear on a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaners must be serviced regularly according to the surroundings in which the engine is operating.

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 as follows:

1. Remove the piston and connecting rod assembly as outlined on page 10-2-79.

2. Remove the cylinder liner with tool J 1918-02 as follows:
   a. Slip the lower puller clamp up on the puller rod and off the tapered seat. Cock the clamp so it will slide down through the liner. The clamp will drop back on the tapered seat after it clears the bottom of the liner. Then slide the upper puller clamp down against the top edge of the liner.

   b. With the tool in place, strike the upset head on the upper end of the puller rod a sharp blow with the puller weight, thus releasing the liner (Fig. 3).

   c. Remove the tool from the liner. Then remove the liner from the block.

   d. Remove the liner insert and shims (if used) from the counterbore in the block.

   e. Tag the liner, insert and shims.

If tool J 1918-02 is unavailable, tap the liner out with a hardwood block and hammer.

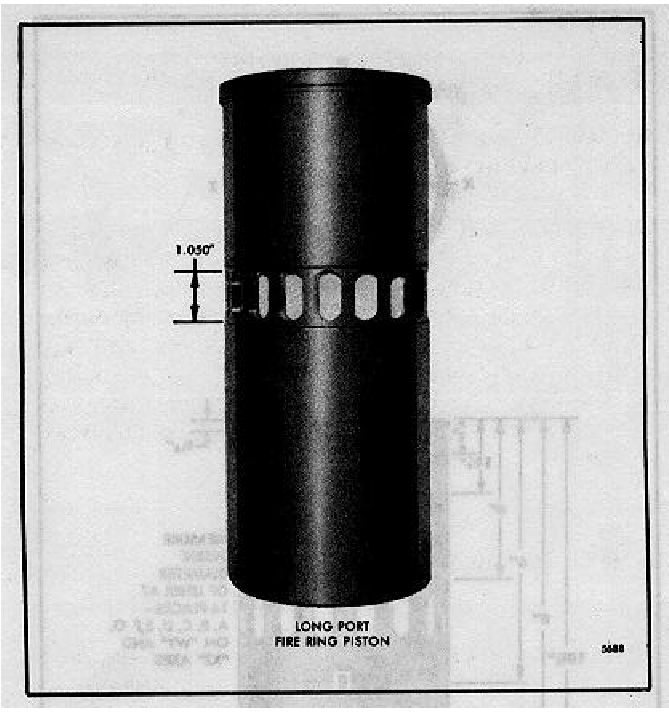


Fig. 2 -Cylinder Liner

Inspect Used Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for:

Cracks	Inside diameter
Scoring	Outside diameter
Poor contact on outer surface	Out-of-round
Flange irregularities	Taper

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned-up and reused.

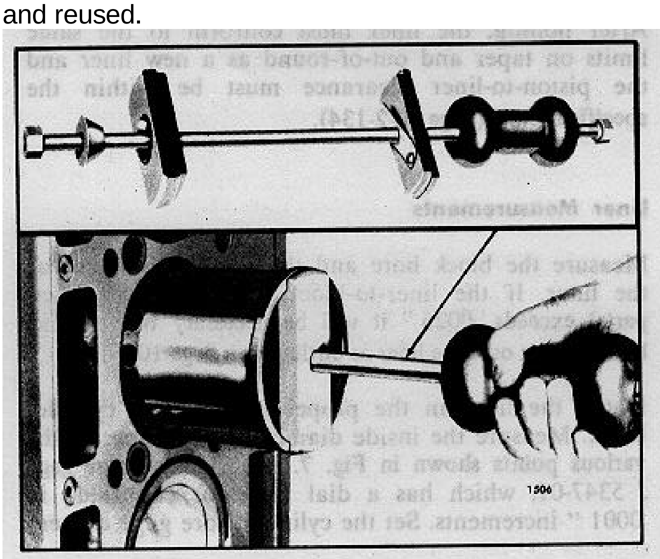


Fig. 3. Removing Cylinder Liner.

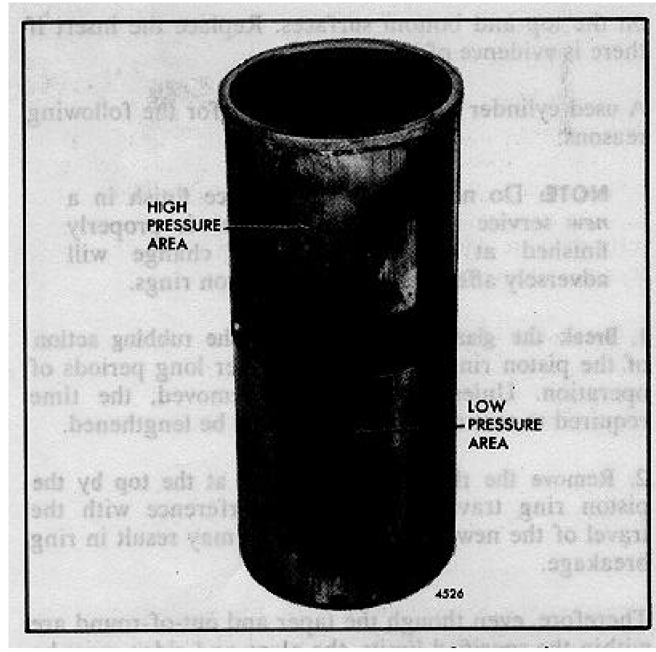


Fig. 4 - High and Low Pressure Contact Areas on Cylinder Liner

Excessive liner-to-block clearance or block bore distortion will reduce heat transfer from the liner to the block and to the engine coolant. Poor contact between the liner and the block bore may be indicated by stains or low pressure areas on the outer surface of the liner (Fig. 4).

Examine the outside diameter of the liner for fretting. Fretting is the result of a slight movement of the liner in the block bore during engine operation, which causes material from the block to adhere to the liner. These metal particles may be removed from the surface of the liner with a coarse, flat stone.

The liner flange must be smooth and flat on both the top and bottom surfaces. Check for cracks at the flange. The liner insert must also be smooth and flat

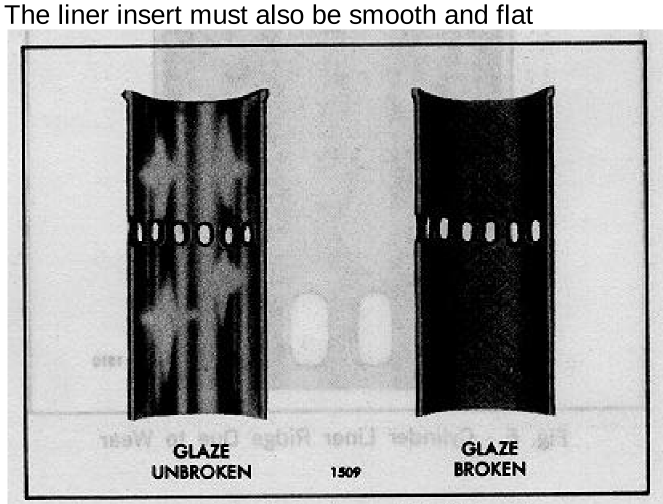


Fig. 5. Glazed Surface of Cylinder Liner.

on the top and bottom surfaces. Replace the insert if there is evidence of brinelling.

A used cylinder liner must be honed for the following reasons:

> **NOTE**: Do not modify the surface finish in a new service liner. Since the liner is properly finished at the factory, any change will adversely affect seating of the piston rings.

1. Break the glaze (Fig. 5) due to the rubbing action of the piston rings which results after long periods of operation. Unless this glaze is removed, the time required to seat new piston rings will be lengthened.

2. Remove the ridge (Fig. 6) formed at the top by the piston ring travel. Otherwise, interference with the travel of the new compression rings may result in ring breakage.

Therefore, even though the taper and out-of-round are within the specified limits, the glaze and ridge must be removed by working a hone up and down the full length of the liner a few times.

Place the liner in a fixture (a scrap cylinder block makes an excellent honing fixture). However, if it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

The hone J 5902-01, equipped with 120 grit stones J 5902-14, should be worked up and down the full length of the liner a few times in a criss-cross pattern that produces hone marks on a 45°' axis.

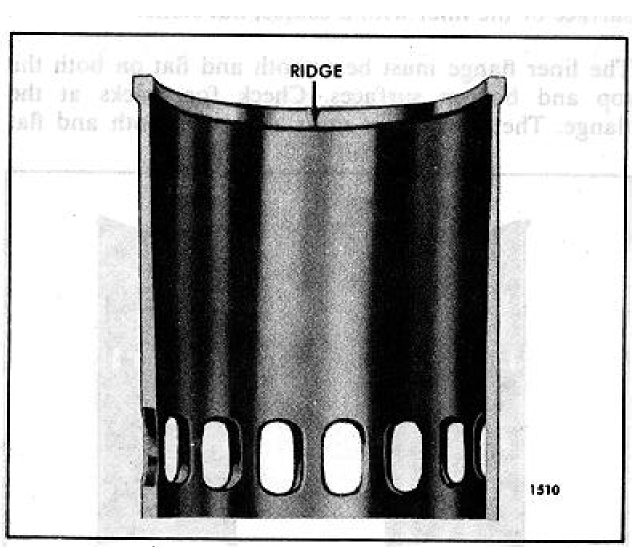


Fig. 6. Cylinder Liner Ridge Due to Wear.

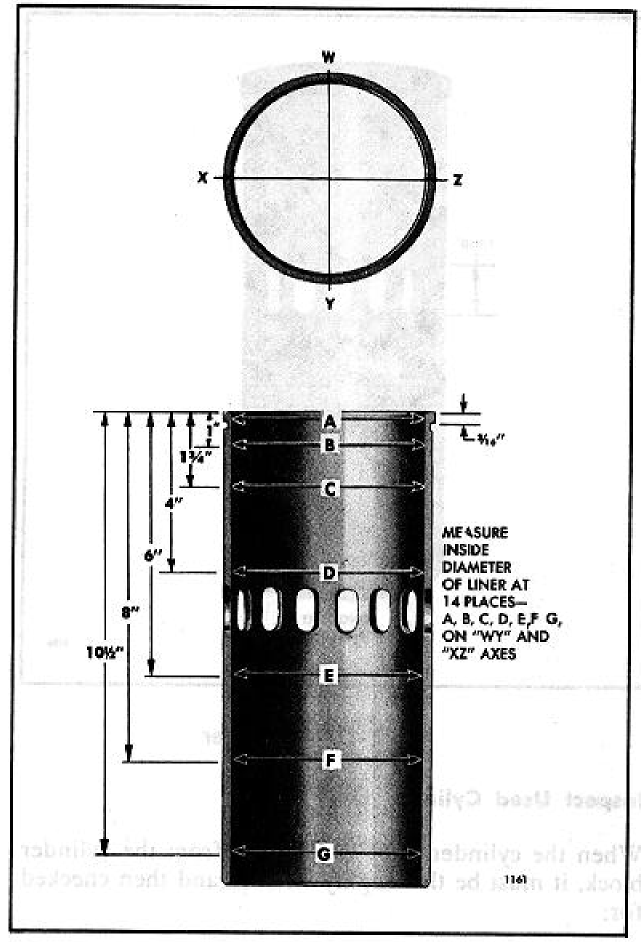


Fig. 7. Cylinder Liner Measurement Diagram.

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 (Page 10-2-134).

Liner Measurements

Measure the block bore and the outside diameter of the liner. If the liner-to-block clearance (with used parts) exceeds .0025" it will be necessary to bore the block for an oversize liner as outlined on Page 10-2-10.

Install the liner in the proper bore of the cylinder block. Measure the inside diameter of the liner at the various points shown in Fig. 7. Use cylinder bore gage J 5347-01, which has a dial indicator calibrated in .0001" increments. Set the cylinder' bore gage on zero

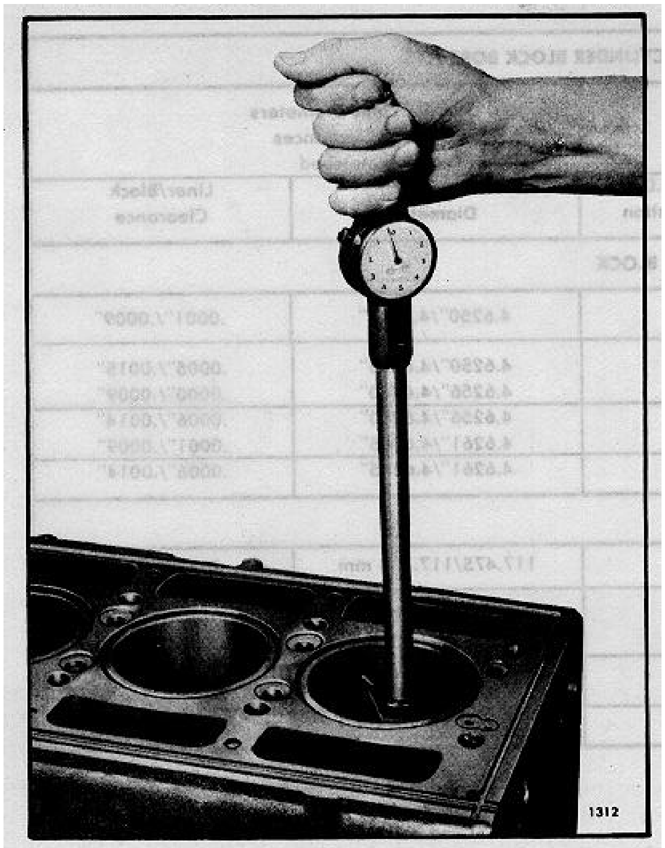


Fig. 8 - Checking Bore of Cylinder Line Using Tool J 5347-01

in master ring gage 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 gage master setting fixture J 23059-01 may be used in place of the master ring gage.

The piston-liner clearance must be within the specified limits (Page 10-2-133). Also, the taper must not exceed .002" and the out-of-round must not exceed .0025" on a used liner. If the out-of-round exceeds .0025 ", rotate the liner 90° in the block bore and recheck.

New service liners, standard and oversize, have an inside diameter of 4.2489 " to 4.2511 "':

Cylinder liners are available in .001 ", .005 ", .010 ", .020 " and .030 " oversize on the outside diameter. When an oversize liner is installed, stamp the amount of oversize on top of the cylinder bore adjacent to the liner counterbore.

Selection of New Cylinder Liner

The cylinder bores in a new cylinder block are classified as # 1, #2 or #3 (Table I) 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 # I, # 2 or # 3 as illustrated in Fig. 9 and Table 1.

Although the block bores and liners should be measured to determine the liner-to-block clearance, the selection of a liner is narrowed down to only those in the appropriate classifications or possibly a .001" oversize liner.

Before installing a liner in a used cylinder block, always lightly hone the block bore (refer to Page 10-2-9).

After honing the block bore, check the bore measurements to determine if a standard liner (classification # , #2 or #3) or possibly a .001 " oversize liner car he used (refer to Tables I and 2). A push fit between the liner and the block is desirable. If an adequate push lit 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 outof-round or tapered more than .002 ". If the average block bore is over 4.6285" the cylinder block should be bored oversize.

To determine what size to 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 = .0005"
bore size = 4.6285"

Then. 4.6285 " + .001" boring tolerance will allow a

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

TABLE 1

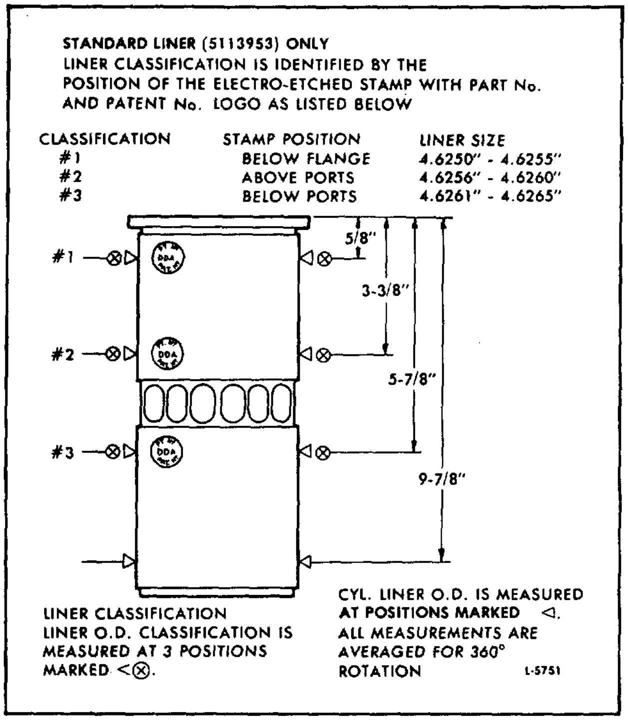


Fig. 9. Cylinder Liner Classification

bore size of 4.6285" to 4.6295" and a possible liner-to block clearance of .0005" to .0015". The clearance tolerance is the dimensional difference between the liner O.D. and the block bore I.D.

OVERSIZE SERVICE CYLINDER LINERS			
Service Liner Oversize	Liner Outside Diameter		Liner/Block Clearance Req'd After Boring Block
	inches	mm	
.001"	4.6280	117.551	.0005"/.0015"
(.0254 mm)	4.6265	117.513	(.013/.038 mm)
.005"	4.6315	117.640	.0005"/.0015"
	4.6300	117.602	(.013/.038 mm)
.010"	4.6365	117.767	.0005"/.0015"
	4.6350	117.729	(.013/.038 mm)
.020"	4.6465	118.021	.0005"/.0015"
	4.6450	117.983	(.013/.038 mm)
.030	4.6565	118.275	.0005"/.0015"
	4.6550	118.237	(.013/.038 mm)

TABLE 2

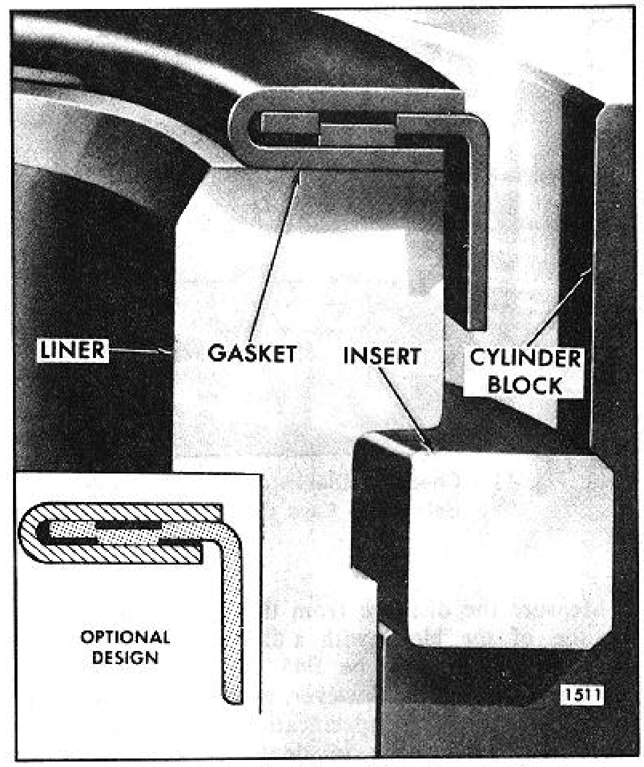


Fig. 10. Cylinder Liner Mounting in Block

Fitting Cylinder Liner in Block Bore

1. Wipe the inside and outside of the liner clean and make sure the block bore and counterhore are clean.

2. Place a standard size cylinder liner insert (.1795 "-.1800" thick) in the block counterbore (Fig. 10).

3. Push the cylinder liner into the cylinder block until the liner flange rests on the insert. Do not use excessive force to install the liner. The liner should slide smoothly in place with hand pressure. If a new liner cannot he pushed in place, *light* honing of the block bore may be necessary to obtain the desired fit for best heat transfer.

4. Install a cylinder liner hold-down clamp as illustrated in Fig. 11.

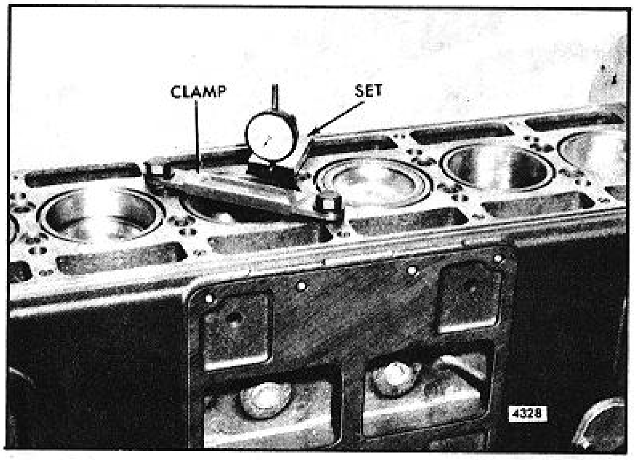


Fig. 11. Checking Distance of Liner Flange Below Top Face of Block

5. Measure the distance from the top of the liner to the top of the block with a dial indicator (Fig. 11). The liner flange must be .045 " to .050 " below the surface of the block. However, even though all of the liners are within these specifications. there must not be over .002" difference in depth between any two adjacent liners when measured along the cylinder longitudinal center line.

NOTE:
A .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 .0015 " thicker or thinner than standard are also available for service. In addition, the .004 " and .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 same block bore. The matchmarks should be toward the blower side of the engine.

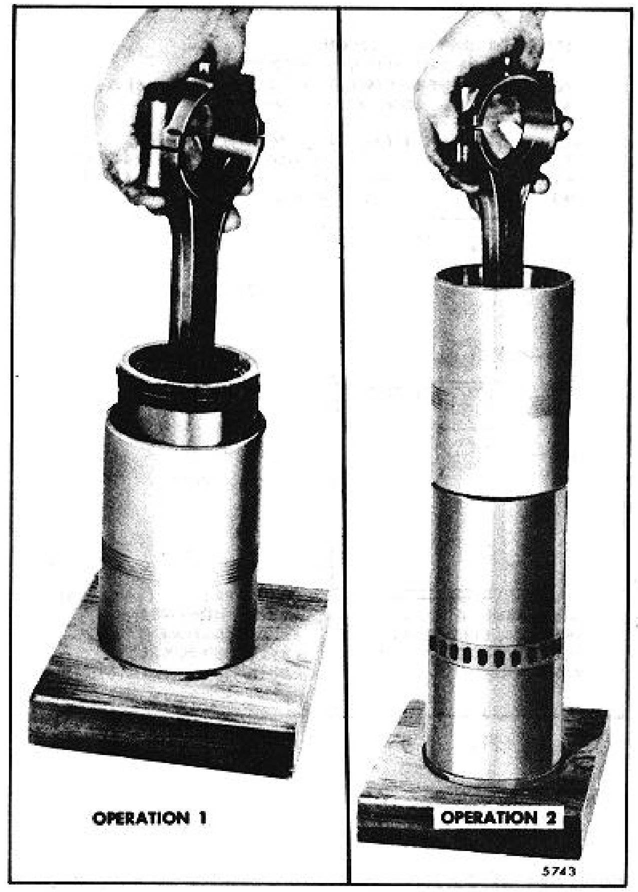


Fig. 12. Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

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 as outlined on Pages 10-2-81 and 10-2-89, apply clean engine oil to the piston, rings and the inside surface of the piston ring compressor J 3272-03.

CAUTION:
Inspect the ring compressor for nicks or burrs, especially at the non-tapered inside diameter end. Nicks or burrs on the inside diameter of the compressor will result in damage to the piston rings.

2. Place the piston ring compressor on a wood block, with the tapered end of the ring compressor facing up.

3. Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of the oil control ring expanders are not overlapped.

4. Start the top of the piston straight into the ring compressor. Then push the piston down until it contacts the wood block ("Operation 1" of Fig. 12).

5. Note the position of the matchmark and place the liner, with the flange end down, on the wood block.

6. Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner ("Operation 2" of Fig. 12).

NOTE:
The numbers on the side of the connecting rod and cap (Fig. 13) identify the rod with the cap and indicate the particular cylinder in which they are used. If' a new service connecting rod is to he installed. the same identification numbers must he stamped in the same location as on the connecting rod that was replaced.

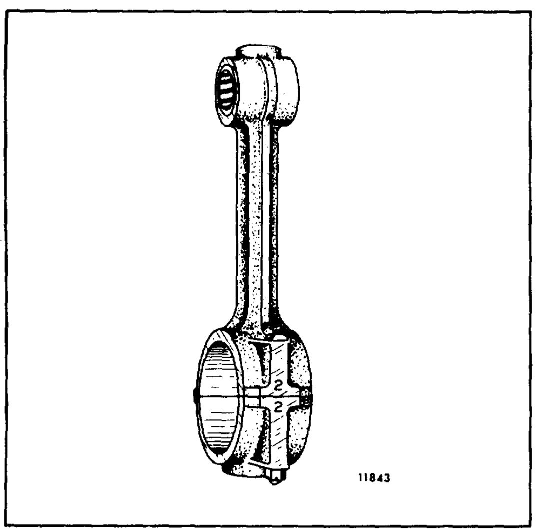


Fig. 13. Typical Connecting Rod Markings

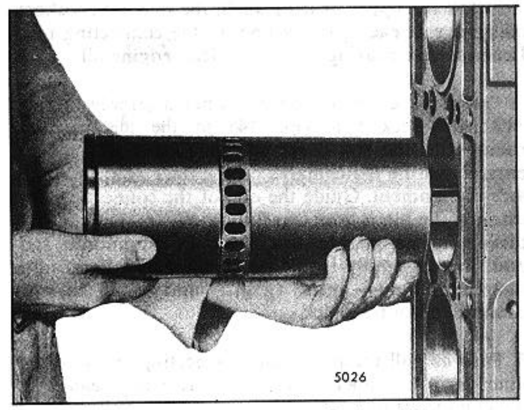


Fig. 14. Installing Piston, Rod and Liner Assembly in Cylinder Block

7. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.

NOTE:
Do not force the piston into the liner. The peripheral abutment type expanders apply considerably more force on the oil ring than the standard expander. Therefore, extra care must be taken during the loading operation to prevent ring breakage.

8. Remove the connecting rod cap and the ring compressor. Then push the piston down until the compression rings pass the cylinder liner ports.

Install Cylinder Liner, Piston and Connecting Rod Assembly

After the piston and connecting rod assembly have been installed in the cylinder liner, install the entire assembly in the engine as follows:

1. 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.

3. Install the upper bearing shell, the one with a short oil groove at each parting line, in the connecting rod. Lubricate the bearing shell with clean engine oil.

4. Position the piston, rod and liner assembly in line with the block bore (Fig. 14) so the identification number on the rod is facing the blower side of the engine and the 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 flange rests against the insert in the counterbore in the block.

5. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

6. Place the lower bearing shell, the one with the continuous oil groove from one parting line to the other, in the connecting rod cap, with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.

7. Install the bearing cap and the bearing shell on the connecting rod with the identification numbers on the cap and the rod adjacent to each other. Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut. 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:

The current connecting rod bolt is .200 " longer than the former bolt. After the oil pump piping is installed, bar the engine over for a clearance check. In the event interference occurs, loosen the pipe or item involved and retighten it while holding it away from the point of interference.

8. Check the connecting rod side clearance. The clearance must be .006 " to .012 "

9. Install the remaining liner, piston and rod assemblies in the same manner. Use hold-down clamps to hold each liner in place.

10. After all of the liners and pistons have been installed, remove the hold-down clamps.

11. Install new compression gaskets and water and oil seals as outlined on Page 10-2-25. Then install the cylinder head and any other parts which were removed from the engine.

12. After the engine has been completely reassembled, refer to the *Lubrication Specifications* on Page 10-9-9 and refill the crankcase to the proper level on the dipstick.

13. Close all of the drains and fill the cooling system.

14. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the run-in schedule given on Page 10-9-2.

ENGINE BALANCE AND BALANCE WEIGHTS

Both rotating and reciprocating forces are completely balanced in the engines. The eccentric rotating masses of the crankshaft and connecting rods are balanced by counterweights on the crankshaft cheeks.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple by virtue of an arrangement on the crankshaft in which reciprocating masses, though equal, are not opposite. This unbalanced couple, which tends to rock the engine from end to end, is balanced by an arrangement of rotating counterweights, mounted at the front and rear ends of the camshaft and balance shaft, which produce a couple equal and opposite in magnitude. Consequently the engine will operate smoothly and in balance throughout its entire speed range.

Each set of weights (weights on one shaft comprise a set) rotates in an opposite direction with respect to the other. 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 unbalanced couple; when they are in a horizontal plane, the centrifugal forces of these balance weights are opposite and are therefore canceled. The front balance weights are eccentric in a direction opposite to the rear balance weights. Therefore, rotation will result in the desired couple effective only in a vertical plane.

The balance weights consist of two eccentric weights at each end of the engine and additional weights attached to the gears.

The front balance weights are keyed to the front end of the camshaft and the balance shaft (Fig. 1).

Current balance weights are of one-piece construction. Formerly, spring-loaded balance weights were used. The balance weight bushing oscillates on the hardened surface if the hub during engine operation. Torque variations are transmitted from the hub to the weight through the spacer and spring leaves.

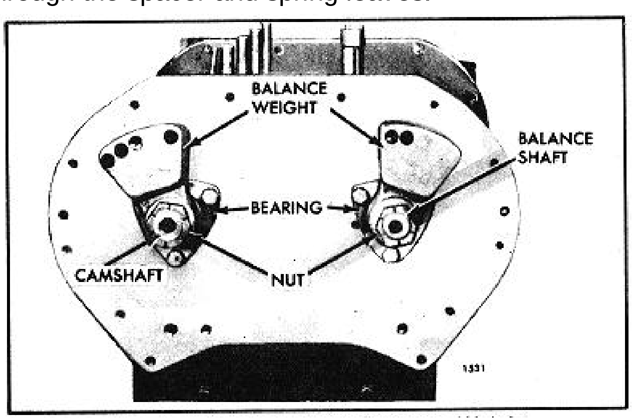


Fig. 1. Typical Front Balance Weight Mounting

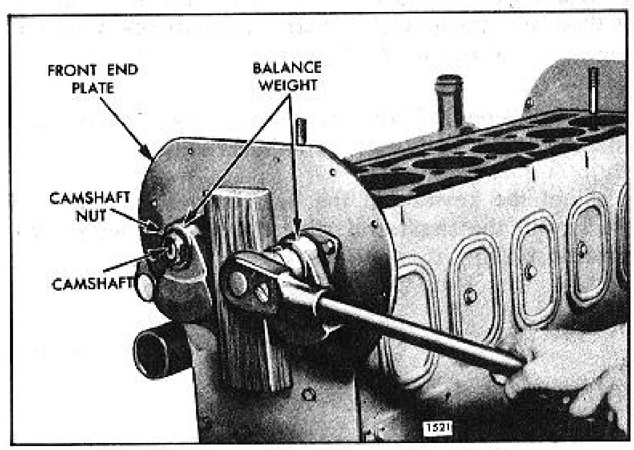


Fig. 2. Loosening Nut on Camshaft or Balance Shaft.

Remove Front Balance Weights

1. Remove the balance weight cover.

2. Place a block of wood between the balance weights to prevent rotation (Fig. 2).

3. Loosen the balance weight retaining nuts on the camshaft and balance shaft with a 1-1/2 " socket wrench and remove the nuts and internal tooth lock washers.

4. Force the balance weight off the end of each shaft with two heavy screw drivers or pry bars between the heads of the bearing retaining bolts and the balance weight (Fig. 3).

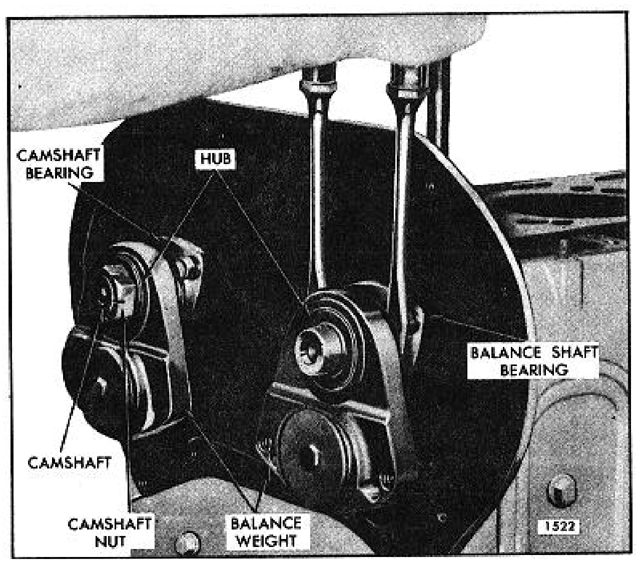


Fig. 3. Removing Balance Weight Assemblies

Install Front Balance Weights

1. Apply heavy cup grease to the steel faces of the thrust washers and install the washers up against the camshaft and balance shaft and bearings.

2. Install Woodruff keys in the keyways at the front end of the camshaft and the balance shaft.

3. Align the keyway in the balance weight hub with the key in the shaft and slide the balance weight on the camshaft.

4. Install the balance weight on the balance shaft in the same manner.

5. Slip an internal tooth lock washer over the end of each shaft. Start the nuts on both shafts.

6. Place a block of wood between the balance weights as shown in Fig. 2 and tighten the retaining nuts to 300-325 lb-ft (407-441 Nm) torque.

7. Install the balance weight cover, using a new gasket.

GEAR TRAIN AND ENGINE TIMING

GEAR TRAIN

A completely enclosed train of five helical gears is located at the rear end of the engine as shown in Fig 1. A gear bolted to the crankshaft flange drives the camshaft and balance shaft gears, as well as the blower drive gear, through an idler gear mounted between the crankshaft and balance shaft gears.

The camshaft gear and balance shaft gear mesh with each other and run at the same as 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 flywheel or gear train end, the right-hand gear, (camshaft) has left-hand helical teeth (Fig. 1).

The idler gear rotates on a double-row, tapered roller bearing mounted on a stationary hollow hub. This hub is accurately located on the cylinder block end plate at the left-hand side of the engine as viewed from the gear train end.

A blower drive gear is located on the blower side to transmit power to the blower, governor, fuel pump and water pump.

Since the camshaft must be in time with the crankshaft, identification marks are located on two teeth of the idler gear with corresponding match marks stamped on the crankshaft gear and the camshaft gear as shown in Fig. 1.

Before removing or replacing any of the gears, it is advisable to line up and make a sketch indicating the position of the timing marks. To do this, rotate the crankshaft until the timing marks are aligned on the camshaft gears. Then check whether the "R" timing mark on the crankshaft gear is aligned with the "R" on the idler gear and record this information for reassembly purposes. Standard gear train timing is used with advanced timing being incorporated in the design of the camshaft.

Gear	Number of Teeth
Crankshaft	78
Idler	68
Cam or Balance Shaft	78
Blower Drive	40

TABLE 1

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.

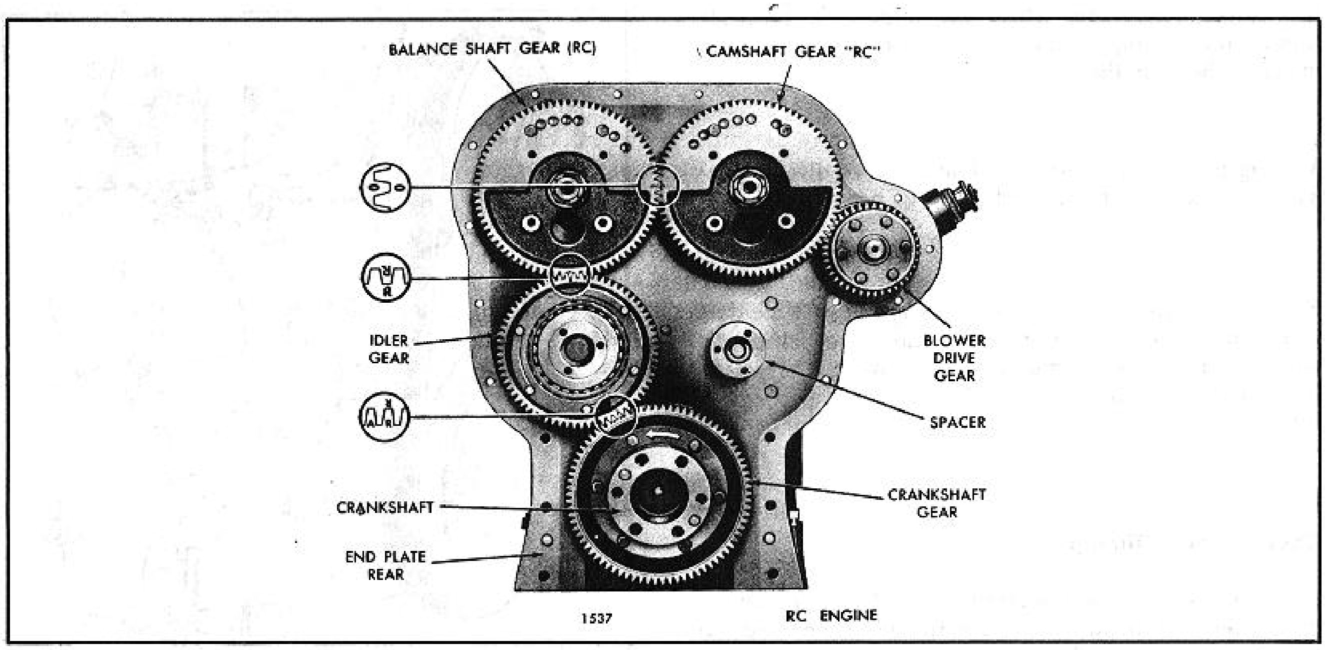


Fig. 1. Gear Train and Timing Marks-Right-Hand Rotation Engine (Standard Timing Shown)

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 current 19 helix steel gear train is from .003 " to .008 " with new parts and .010 " with used parts.

Since the camshaft and balance shaft gears each have the same number of teeth as the crankshaft gear, they will turn at crankshaft speed. 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

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 Fig. 1.

An engine which is *out of time* may result in pre-ignition, uneven running and a loss of power.

When an engine is suspected of being out of time due to an improperly assembled gear train, a quick check can be made without having to remove the flywheel and flywheel housing by following the procedure outlined 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 for turning the crankshaft is necessary when performing the timing check. Then proceed as follows:

1. Clean and remove the valve rocker cover.

2. Select any cylinder for the timing check -- it is suggested that a cylinder adjacent to one of the valve rocker cover bolt or stud holes be chosen since the stud or bolt may be used to mount a dial indicator.

3. Remove the injector as outlined on Page 10-3-6.

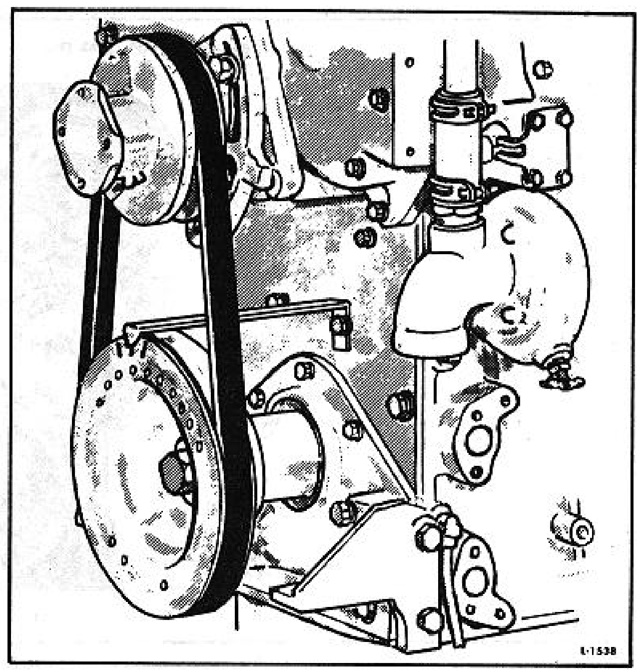


Fig. 2. Pointer Installation for Marking Top-Dead-Center

4. Carefully slide a rod, approximately 12" long, through the injector tube until the end of the rod rests on top of the piston.

5. Place the throttle in the no-fuel position. Then turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.

6. Select a dial indicator with .001 " graduations and with a spindle movement of at least one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also select suitable mounting attachments for the indicator so that it can be mounted over the injector tube in the cylinder head.

7. Mount the indicator over the injector tube. The indicator mounting may be threaded into the rocker cover stud or the tapped hole in the cylinder head. Make sure that the indicator spindle is free in the injector tube and is free to travel at least one inch.

8. Attach a suitable pointer to the crankshaft front cover or engine front end plate as illustrated in Fig. 2. The pointer should extend over the vibration damper (or crankshaft pulley).

9. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

10. Reset the dial indicator to zero. Turn the crankshaft until the indicator reading is .010 ".

11. Scribe a line on the vibration damper (or crankshaft pulley) in line with the end of the pointer.

12. Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

13. Set the dial to zero. Then turn the crankshaft until the indicator reading is .010 "

14. Scribe a second line on the vibration damper (or crankshaft pulley) in line with the end of the pointer.

15. Scribe a third line halfway between the first two lines. This is top-dead-center. The three scribed lines are shown on the crankshaft pulley in Fig. 2. Remove the indicator and rod from the engine.

NOTE:

If the crankshaft pulley retaining bolt has loosened, tighten it to the specified torque (Page 10-2-69).

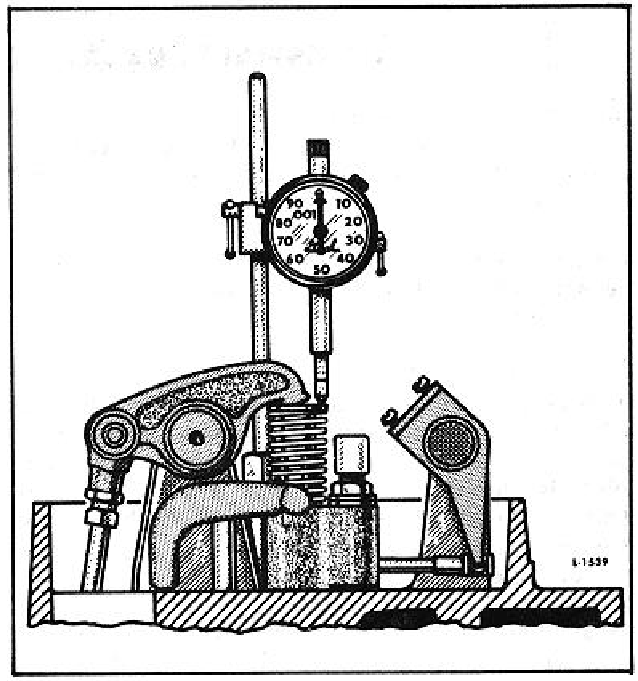


Fig. 3. Checking Engine Timing By Measuring Injector Depression

	*Indicator Reading		
	Correct	Retarded 1 Tooth	Advanced 1 Tooth
	Standard Timing		
	.230”	.197”	.262”

*Indicator readings shown are nominal values. The allowable tolerance is ±.005 in.

TABLE 2

16. Install the injector as outlined on Page 10-3-8 or 10-3-23. Then refer to Chapter 10 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 (Fig. 3). Then set the indicator on zero. Next turn the crankshaft slowly in the direction of engine rotation until the center mark on the pulley is in line with the pointer.

18. Note the indicator reading and compare it with the dimensions listed in Table 2.

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

The camshaft and the balance shaft are located just below the top of the cylinder block (Fig. 1). The camshaft actuates the exhaust valve and injector operating mechanism.

The accurately ground cams ensure efficient, quiet cam follower roller action. They are also heat treated to provide a hard wear surface.

Both ends of the cam and balance shaft are supported by bearing assemblies, each consisting of a flanged housing and two bushings. In addition, intermediate two-piece bearings support the camshaft at uniform intervals throughout its length. The intermediate bearings are secured to the camshaft by lock rings, thereby permitting them to be inserted into the cylinder block with the shaft. Each intermediate bearing is secured in place, after the camshaft is installed, with a lock screw threaded into a counterbored hole in the top of the cylinder block.

The current engines are equipped with a low velocity, low lift injector cam lobe and a long closing ramp exhaust cam lobe design camshaft.

On both the camshaft and the balance shaft, the gear thrust load is absorbed by two thrust washers, one on each end of the front end shaft bearings. The thrust washers bear against thrust shoulders on the shafts.

A helical drive gear with a counterweight is secured to each shaft with a Woodruff key (Fig. 2), nut, nut retainer, retainer bolts and 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.

Advanced Timed Camshafts

Effective with four and six cylinder engines built approximately June, 1976 which require advanced timing in conjunction with N65 mm or larger fuel injectors are equipped with the current camshaft which also has the required advance timing incorporated into the camshaft.

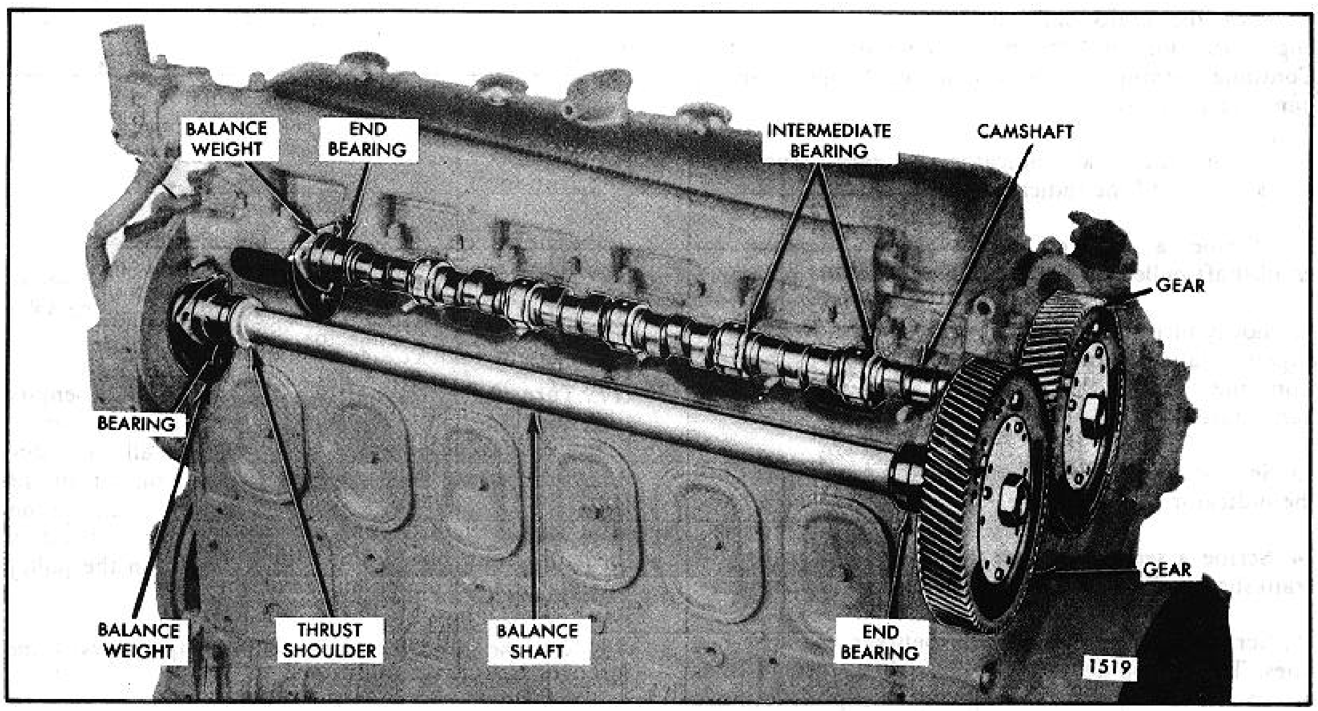


Fig. 1. Camshaft and Balance Shaft Assemblies

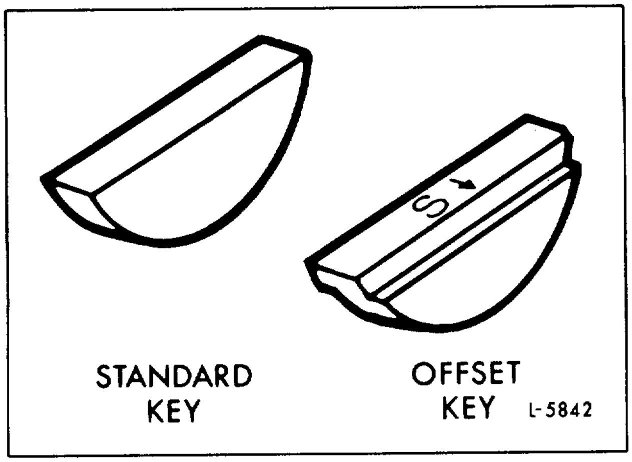


Fig. 2. Woodruff Keys for Current Camshafts

The option data plate is marked to indicate whether an engine was built with the former standard camshaft with advanced gear timing or the current camshaft which has the required advance timing incorporated into the camshaft.

The required advanced timing built into the new (current) camshafts eliminate the need for installing the crankshaft gear one tooth advanced to the "A" position. This was accomplished by relocating the keyways at each end of the camshaft. Continue to use the standard (straight) Woodruff key (Fig. 2) with the new camshaft.

IMPORTANT:
When using the new camshaft make certain the gear train is NOT in the "A" position.

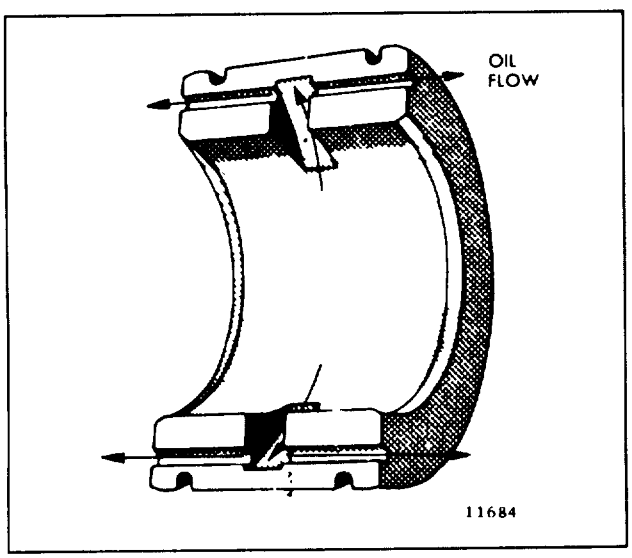


Fig. 3. Camshaft Intermediate Bearing (Lower Half)

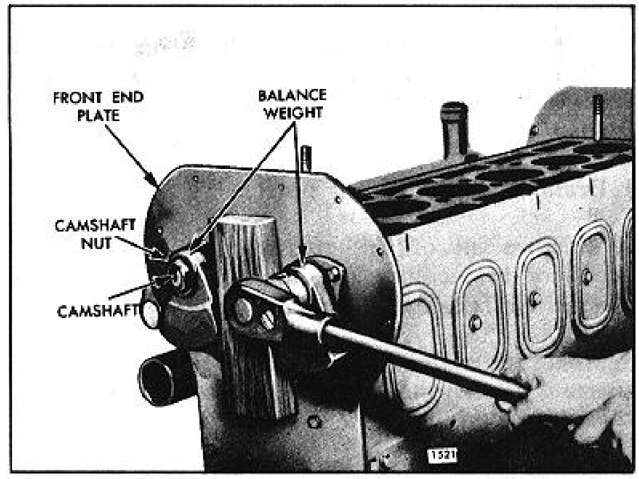


Fig. 4. Loosening Nut on Camshaft or Balance Shaft

Service

Only the new camshafts (which have the required advanced timing incorporated into the camshaft and includes both the standard and offset Woodruff keys) are serviced. Use the new camshafts and straight key combination to service an advanced timed engine. Use the new camshafts and the offset key to service a standard timed engine.

NOTE:
The offset key is identified with an S (standard) and an arrow stamped on the face of the key. With the keyways up, always install the offset keys with the arrow pointing inboard toward the center of the engine.

Lubrication

Lubricating oil is supplied under pressure to the bearings from the main oil gallery through a horizontal transverse passage at each end of the cylinder block, then up the connecting vertical passages in each corner of the block to the camshaft and balance shaft end bearings. The camshaft intermediate bearings are lubricated by the oil from the end bearings passing through the drilled passage in the shaft.

The lower halves of the camshaft intermediate bearings are grooved along the horizontal surface that mates with the upper halves of the bearings (Fig. 3). Oil from the passage in the camshaft is forced through the milled slots in the bearing and then out the grooves to furnish 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 replacing, remove the shafts from 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 (Page 10-2-4).

3. Mount the engine on the overhaul stand. *Be sure the engine is securely mounted on the overhaul stand before releasing the lifting sling.*

4. Remove the cylinder head (refer to Page 10-2-20).

5. Remove the flywheel and flywheel housing (refer to Page 10-2-71 and 10-2-75).

6. Remove the front balance weight cover and place a wood block between the balance weights (Fig. 4) or wedge a clean rag between the camshaft and balance shaft drive gears at the rear of the engine.

7. Remove the gear nut retaining plates.

8. Remove the gear retaining nuts on the gear end of the camshaft and the balance shaft. Remove the nut and lock washer from the balance weight end of each shaft.

9. Remove the front balance weights.

10. Remove the thrust washers between the bearings and the balance weight hubs.

11. Remove the lock screws that secure the camshaft intermediate bearings.

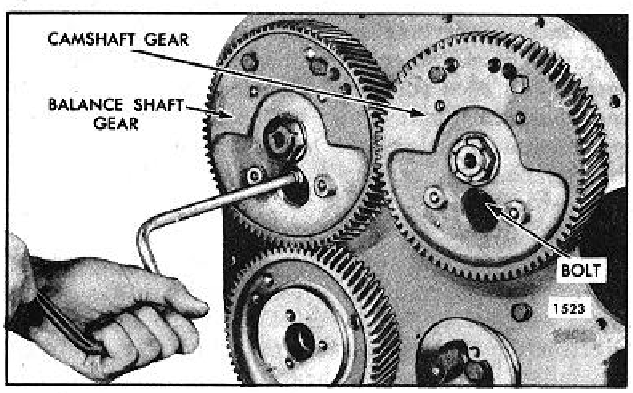


Fig. 5. Removing or Installing Shaft Bearing Retainer Bolts

12. Rotate the gears as required to reveal the end bearing retaining bolts. Remove the bolts as shown in Fig. 5.

13. Withdraw the camshaft bearing and gear assembly and the balance shaft and gear from the rear end of the cylinder block.

If the thrust washers, located between the bearings and thrust shoulders at the front end of the shafts are not removed with the shafts, they should be pulled out when removing the bearings.

14. The cam and balance shaft front end bearings and thrust washers may be removed after taking out the bolts that hold the bearings to the end plate and cylinder block. If necessary, use a pry bar under the bearing flange.

Remove Camshaft (Flywheel Housing and Transmission in Place)

The camshaft may be removed and replaced without removing the flywheel housing and disconnecting the transmission.

1. Drain the engine cooling system.

2. Remove the parts, accessories and assemblies that are necessary to facilitate the removal of the flywheel

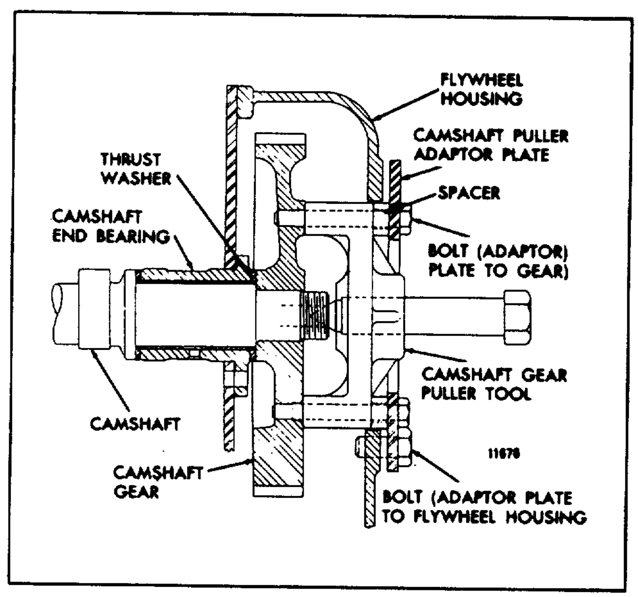


Fig. 6. Removing Camshaft With Camshaft Gear Puller J 1902-01 and Adaptor Plate Set J 6202

housing hole cover over the camshaft and the front balance weight cover.

3. Remove the cylinder head.

4. Remove the front balance weight cover and place a wood block between the balance weights (Fig. 4).

5. Remove the gear nut retainer after removing the bolts. Remove the tachometer drive adaptor, if used.

6. Loosen and remove the nut at each end of the camshaft.

7. Remove the front balance weights.

8. Remove the thrust washer between the bearing and the balance weight hub.

9. Remove the lock screws that secure the camshaft intermediate bearings.

10. Remove the three bolts that secure the camshaft bearing to the front end plate.

11. Install the camshaft gear puller J 1902-01, four spacers J 6202-2 and camshaft gear puller adaptor plate J 6202-1 on the camshaft gear (Figs. 6 and 7).

12. Turn the center screw of the puller clockwise to disengage the camshaft from the camshaft gear.

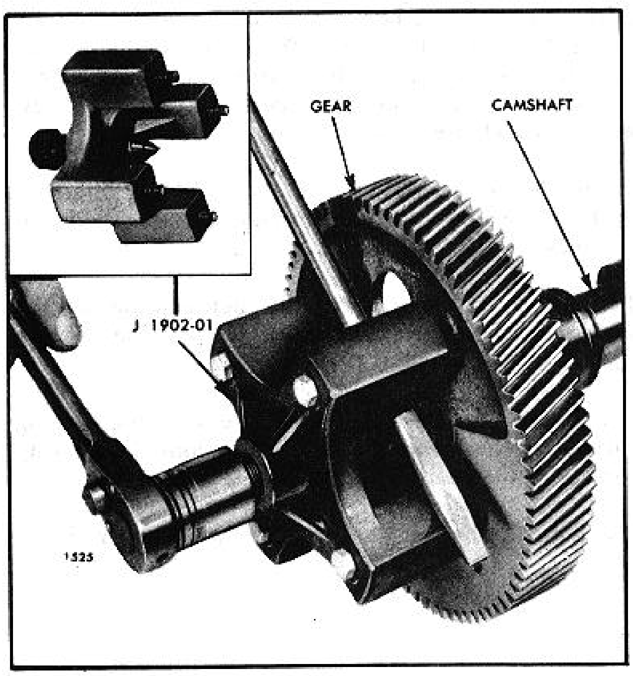


Fig. 7. Removing Gear (Camshaft or Balance Shaft Gear Puller J 1902-01)

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 securely in place and in alignment which will aid in the reinstallation of the camshaft.

13. Remove the front bearing from the camshaft and pull out the inner thrust washer. Then pull the camshaft and intermediate bearings from the cylinder block.

Disassemble Camshaft and Balance Shaft

1. Remove the gear from the shaft (refer to Page 10-2-115).

2. Slide the rear bearing off of the shaft.

3. Remove the lock rings from the camshaft intermediate bearings and free the two halves of each bearing.

4. To facilitate the removal of any foreign material lodged behind the plugs, remove the end plugs from each camshaft as follows:

a. Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shaft.
b. Make an indentation in the center of the camshaft end plug with a 31/64 " drill (carboloy tip).
c. Punch a hole as deeply as possible with a center punch, to aid in breaking through the hardened surface of the plug.
d. Then, drill a hole straight through the center of the plug with a 1/4 " drill (carboloy tip).
e. Use the 1/4 " drilled hole as a guide and re-drill the plug with a 5/16 " drill (carboloy tip).
f. Tap the drilled hole with a 3/8 "-16 tap.
g. Thread the 3/8 "-16 adaptor J 6471-2 into the plug. Then attach the slide hammer J 2619-5 to the adaptor. Remove the plug by striking the weight against the handle.
h. Insert a .375" diameter steel rod into the camshaft oil gallery and drive the remaining plug out.

NOTE:

If a steel rod is not available, remove the

remaining plug as outlined in steps "a" through "g".

Inspection

Soak the camshaft in clean fuel oil. Then, run a wire brush through the oil gallery to remove any foreign material or sludge. Clean the exterior of the camshaft and blow out the gallery and the oil holes with compressed air. Clean the gears, camshaft hearings and related parts with fuel oil and dry them with compressed air.

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam followers as outlined on Page 10-2-31. 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 gages (.0015 " .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 (Fig. 8).

2. If the flats measure less than .003 " in depth and there are no other defects the camshaft is satisfactory for service.

3. A slightly worn 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 .002 ".

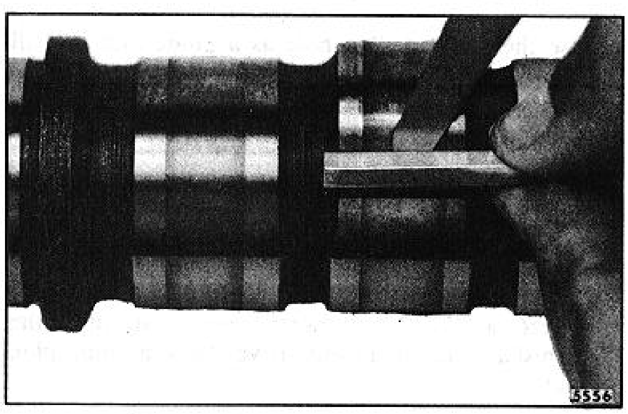


Fig. 8. Checking Cam Lobe Wear

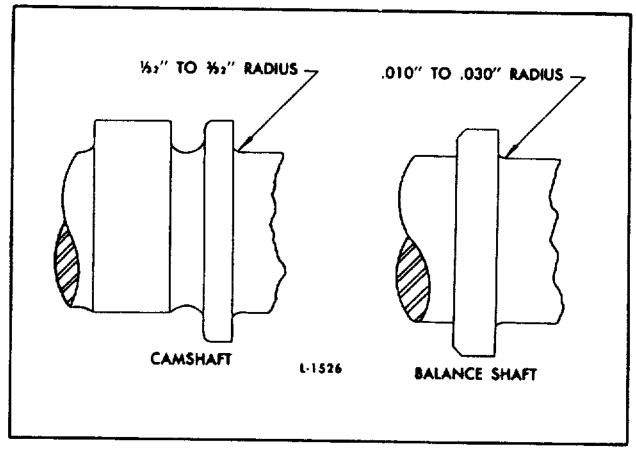


Fig. 9. Camshaft and Balance Shaft Journal Fillets

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 preventive and blow out the oil passages with compressed air.

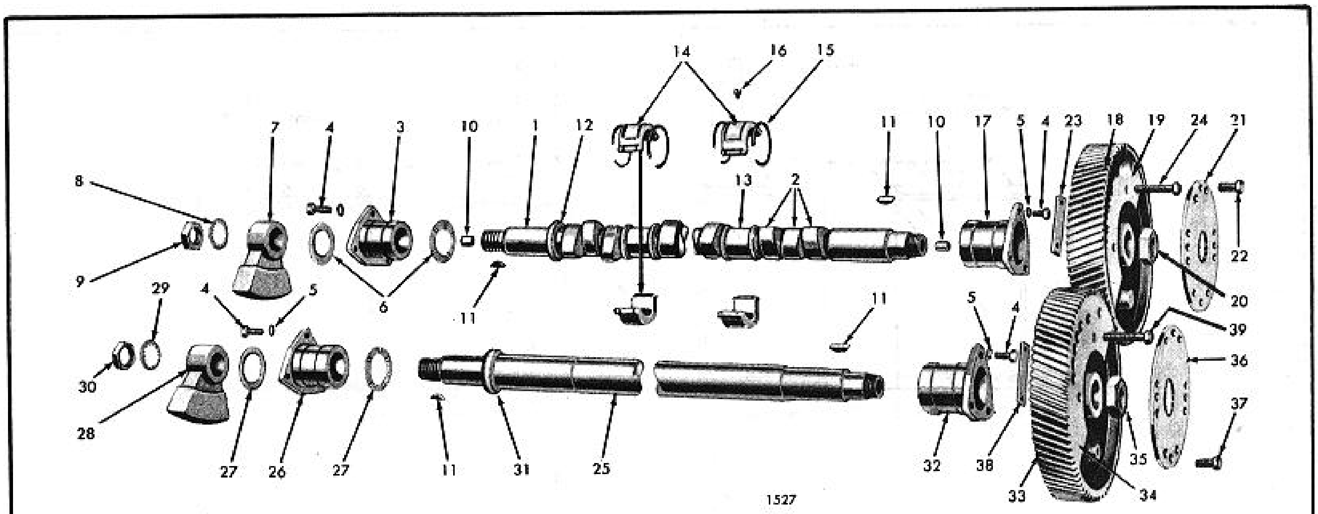
New standard size-thrust washers are .120 " to .122" thick. The clearance between the thrust washer and the thrust shoulder of the camshaft is .004 " to .012 " with new parts, or a maximum of .018" with used parts. Excessive clearance may be reduced by using thrust washers which are .005 " or .010 " oversize.

When the thrust surfaces of a camshaft or balance shaft are ground undersize, special care must be taken as follows:

1. Leave a .031 " to .094 " radius between the bearing surface of the thrust collar shoulder and the bearing surface of the camshaft (Fig. 9).

2. Leave a .010 " to .030 " radius between the bearing surface of the thrust collar shoulder and the bearing surface of the balance shaft (Fig. 9).

Use a fillet radius gage to measure the specified radii.



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

Fig. 10. Typical Camshaft and Balance Shaft Details and Relative Location of Parts

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 replaced; 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 preventive 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 a 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 .0015" total indicator reading and concentric with the outside diameter of the bearing retainer within .002" total indicator reading. The bushings must project from .045 " to .055 " from each end of the bearing (Fig. 11).

The clearance between the camshaft and balance shaft end journals and the end bearing bushings is .0025 " to .004 " with new parts or a maximum of' .006 " with used parts. End bearings are available in .010 " or .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 .0025 " to .005 " with new parts or a maximum of .009" with worn parts. Camshaft intermediate bearings are available in .010 " and .020 " undersize for use with worn or reground 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 plugged,

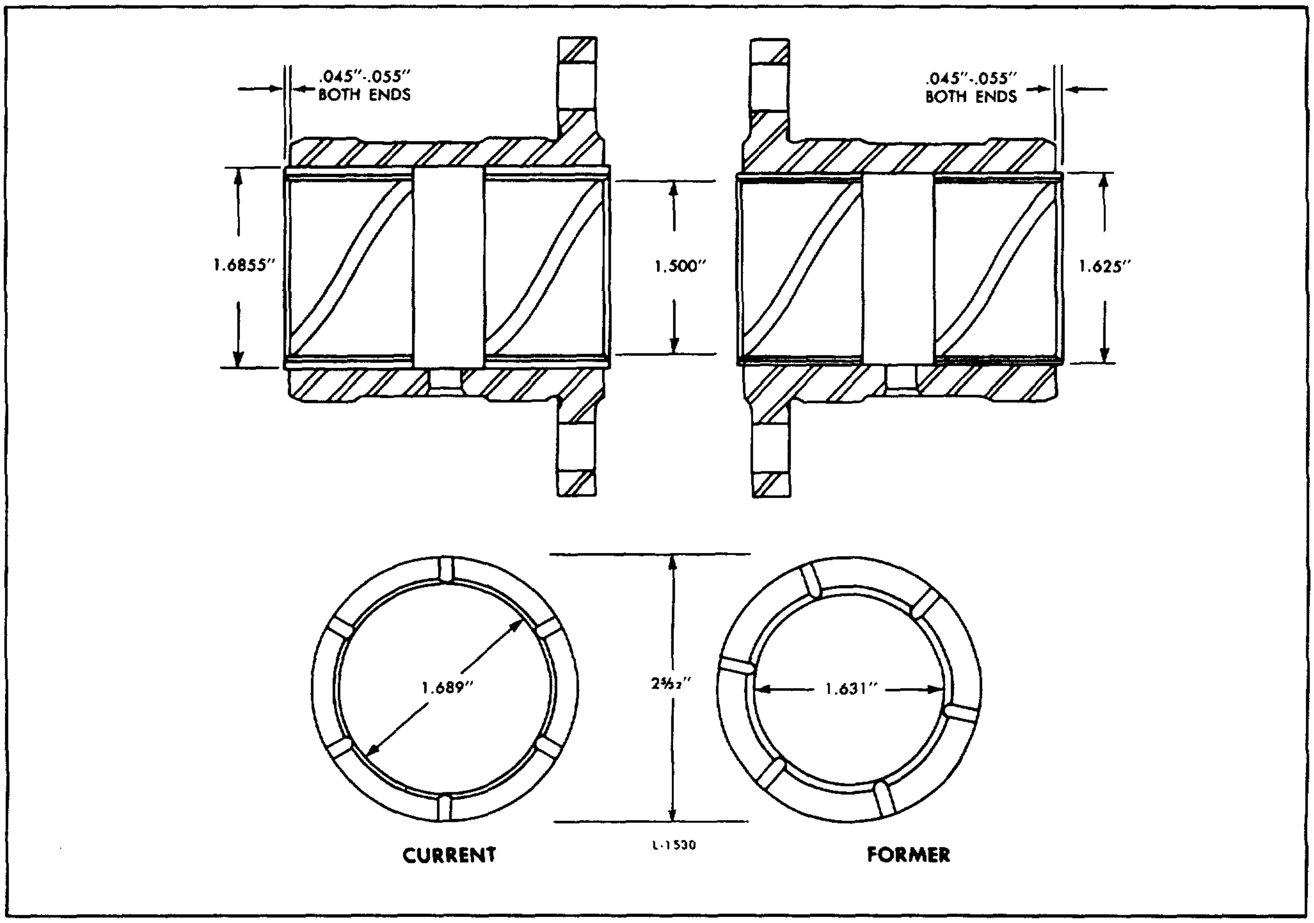


Fig. 11.· Comparison of End Bearings and Thrust Washers

redrilled and tapped. Discard lock screws with damaged threads.

Assemble Camshaft and Balance Shaft

Refer to Fig. 10 and assemble the camshaft and balance shaft as follows:

1. Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940 " to 2.060 " (Fig. 12).

2. Lubricate the rear camshaft and balance shaft bearing journals and slide the rear end bearings on each shaft, with the bolting flange of the bearing toward the outer (gear) end of the shaft.

3. Install the gears on the shafts.

4. Lubricate the camshaft intermediate bearing journals. Then place the two halves of each intermediate bearing on a camshaft journal and lock the halves together with two lock rings. Assemble each lock ring with the gap over the upper bearing and the ends an equal distance above the split line of the bearing.

NOTE:
Two intermediate bearing lock rings are used. The current ring can be identified by the wider gap. The wide gap ring MUST be used with the grooved type lower half bearings and can also be used with the former intermediate bearings.

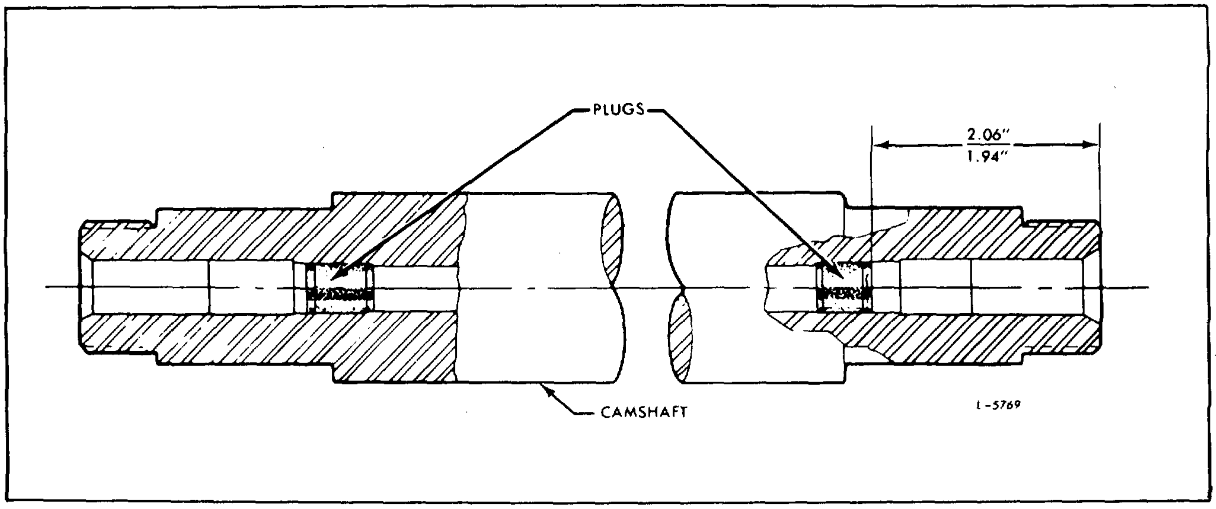


Fig. 12. Camshaft Plug Installation

Install Camshaft and Balance Shaft

1. Insert the front end of the camshaft into the opening on the blower side of the engine. Push the camshaft into the cylinder block until the camshaft gear teeth almost engage the teeth of the mating gear. Use care when installing the camshaft to avoid damaging the cam lobes.

NOTE:
The right-hand gear (viewing the engine from the flywheel end), has left-hand helical teeth.

2. Align the timing marks on the mating gears as shown in Fig. 1 on Page 10-2-103 and slide the camshaft gear in place.

3. Secure the camshaft rear end bearing to the cylinder block with the three bolts and lock washers. Rotate the camshaft gear as required to install the bolts through the hole in the gear web (Fig. 5). Tighten the bolts to 35-40 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 Fig. 1 on Page 10-2-103 and slide the balance shaft gear into place.

6. Secure the balance shaft rear end bearing. Use the same procedure as outlined for the camshaft rear end bearing (Step 3).

7. Apply grease to the steel face of each thrust washer. Then place a thrust washer against the inner end of the camshaft and balance shaft front end bearing. The steel face of the thrust washer must be against the bearing.

8. Install the camshaft and balance shaft front end bearings with the bolts and lock washers. Tighten the bolts to 35-40 lb-ft (47-54 Nm) torque.

NOTE:
Install the front bearings with care to avoid dislodging the thrust washers. Do not hammer the bearings into the cylinder block.

9. Apply grease to the steel face of each thrust washer and place them so that the steel faces are against the outer end of the camshaft and balance shaft front bearings.

10. Turn the camshaft intermediate bearings until the holes in the bearings are in alignment with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15-20 lb-ft (20-27 Nm) torque.

NOTE:
The current "high" cylinder blocks incorporate longer lock screws than were used formerly on the "low" blocks (Fig. 13).

IMPORTANT:
When the intermediate bearings are locked into position with the lockscrew, the bearing must have slight movement in the block bore.

11. Install the front balance weights on the shafts.

12. Place an internal tooth lock washer on the end of each shaft and start the nuts on both shafts.

13. Use a wood block (Fig. 4) between the balance weights or wedge a clean cloth between the camshaft

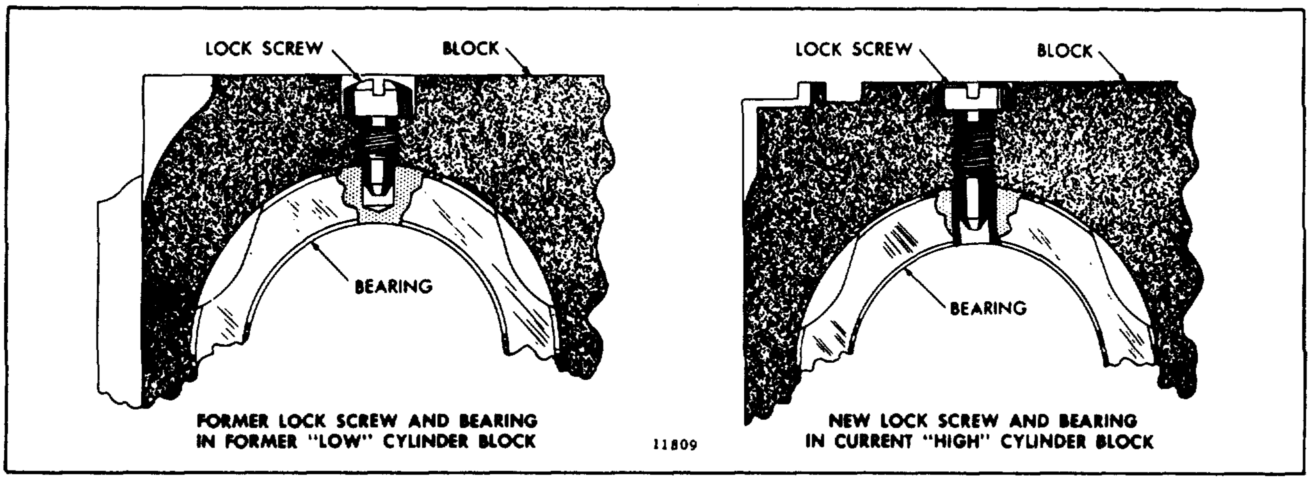


Fig. 13. Camshaft Intermediate Bearing Lock Screws

and balance shaft gears to prevent their turning. Tighten the nuts to 300-325 lb-ft (407-441 Nm) torque.

14. Install the camshaft and balance shaft gear nut retainers with bolts and lock washers. Tighten the bolts to 35-39 lb-ft (47-53 Nm) torque.

15. Check the clearance between the thrust washer and the thrust shoulder of both the camshaft and balance shaft. The specified clearance is .004 " to .012 " with new parts or a maximum of .018 " with used parts.

16. Check the backlash between the mating gears. The specified backlash between new gears is .003 " to .008 " or a maximum of .010 " between worn gears.

17. Install the flywheel housing and other parts or assemblies that were removed from the engine as outlined in their respective chapters of this manual.

18. Refill the cooling system.

Install Camshaft (Flywheel Housing and Transmission in Place)

1. Install a Woodruff key in the drive gear end of the camshaft and insert this end into position from the front end of the engine. Push the 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.

IMPORTANT:
Install the woodruff keys in the current advanced timed camshafts as outlined in the service note under Advanced Timed Camshaft.

2. Align the key in the shaft with the keyway in the camshaft drive gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.

3. Remove the camshaft gear puller, spacers and adaptor plate. Finger tighten the gear retaining nut on the shaft.

4. Install the front end bearing and thrust washers with the bolts and lock washers. Tighten the bolts to 35-40 lb-ft (47-54 Nm) torque.

NOTE:
Apply grease to the steel faces of the thrust washers and insure that the steel faces are towards the bearing.

5. Install the balance weight on the front end of the camshaft.

6. Start the balance weight retaining nut and lock washer on the camshaft (Fig. 8). Place a wood block between the balance weights (Fig. 4). Tighten the gear retaining nut and the balance weight nut to 300-325 lb-ft (407-441 Nm) torque.

7. Align the holes in the camshaft intermediate bearings with the tapped holes in the top of the cylinder block (Fig. 13). Install and tighten the lock screws to 15-20 lb-ft (20-27 Nm) torque.

8. Reinstall the parts, accessories and assemblies that were removed from the engine as outlined in their respective chapters in this manual.

9. Refill the cooling system.

CAMSHAFT AND BALANCE SHAFT GEARS

The camshaft and balance shaft gears, located at the flywheel end of the engine, mesh with each other and run at the same speed as the crankshaft (Fig. 1). Viewing the engine from the flywheel or gear train end, the right-hand gear, (camshaft) has left-hand helical teeth and the left-hand gear has right-hand helical teeth. The idler gear mates with the left-hand gear.

Since the camshaft and balance shaft gears must be in time with each other, the letter "O" is stamped on one tooth of one of the gears with a corresponding mark at the root of the mating tooth of the other gear. Also, since these two gears as a unit must be in time with the crankshaft, identification marks (letter "R") are located on the camshaft gear and the mating idler gear, (refer to Page 10-2-103).

The camshaft and balance shaft gears are keyed to their respective shafts and held securely against the shoulder on the shaft by a nut. A gear nut retainer, with a double hexagon hole in the center, fits over the nut and prevents loosening of the nut. The retainer is attached to the gear by bolts 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. The weight is secured with two 3/8"-24 x 1-3/8" bolts. 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 on Page 10-2-108.

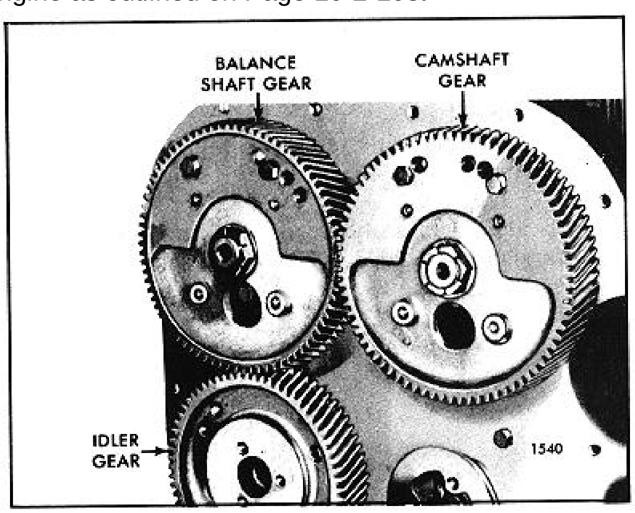


Fig. 1. Camshaft and Balance Shaft Gears

2. Support the camshaft suitably in the soft jaws of a bench vise, being careful not to damage the cams.

3. Remove the nut retaining the gear on the camshaft.

4. Back out the puller screw of tool J 1902-01 and attach the puller to the outer face of the gear with four bolts (Fig. 2).

5. Turn the puller screw down against the end of the shaft to remove the gear.

6. Remove the gear from the balance shaft in a similar manner.

7. If necessary, remove the two weight retaining bolts and remove the balance weights from each gear.

8. If necessary, remove the keys from the camshaft and balance shaft.

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.

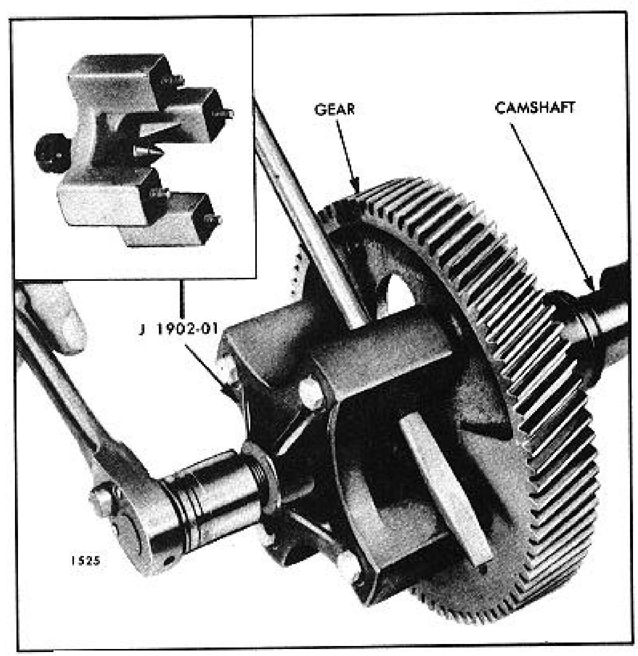


Fig. 2. Removing Gear (Camshaft or Balance Shaft)

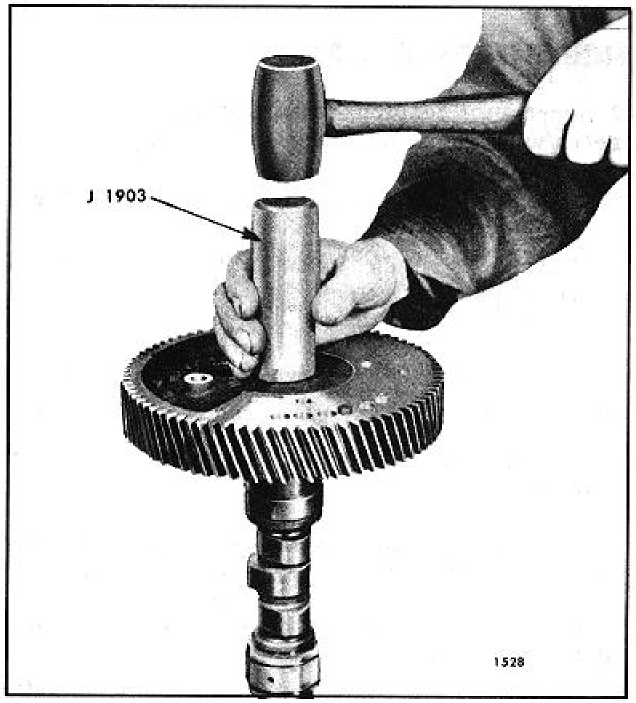


Fig. 3. Replacing Gear (Camshaft Shown)

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.

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 right-hand helical teeth is located on the left-side and the gear with left-hand helical teeth is located on the right-side of the engine. With this in mind, rest the non-gear end of the camshaft on a wood block and start the gear on the other end of the shaft by hand so the keyway aligns with the key and with the flat finished face of the gear away from the bearing.

5. Use gear installer J 1903 as shown in Fig. 3 to drive the gears on the camshaft and balance shaft.

6. Start the gear retaining nuts on their respective shafts by hand. Tighten the nuts after the shafts have been installed in the cylinder block.

7. Install the camshaft and balance shaft in the engine as outlined on Page 10-2-113.

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 (407-441 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 .003 "-.008 " with new parts or.010 " maximum with used parts.

IDLER GEAR AND BEARING ASSEMBLY

Figure 1 illustrates the mounting of the roller bearing type idler gear. The early flanged type idler gear and the former single spacer type idler gear are no longer serviced. When replacing any part of the gear assembly a complete current roller bearing type idler gear assembly must be used.

The idler gear is mounted on a double row, tapered roller bearing which, in turn, is supported on a stationary hub. This hub is secured directly to the cylinder block by a bolt which passes through the hub and rear end plate. A hollow dowel serves a two-fold purpose; first, as a locating dowel it positions the hub and prevents it from rotating and, second, conducts oil under pressure from an oil gallery in the cylinder block through a passage in the gear hub to the roller bearing.

The current idler gear bearing consists of two cups, two cones and an outer and inner spacer ring. The former idler gear bearing consists of a cup, two cones and a 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. No spacer was used on early design bearings. 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.

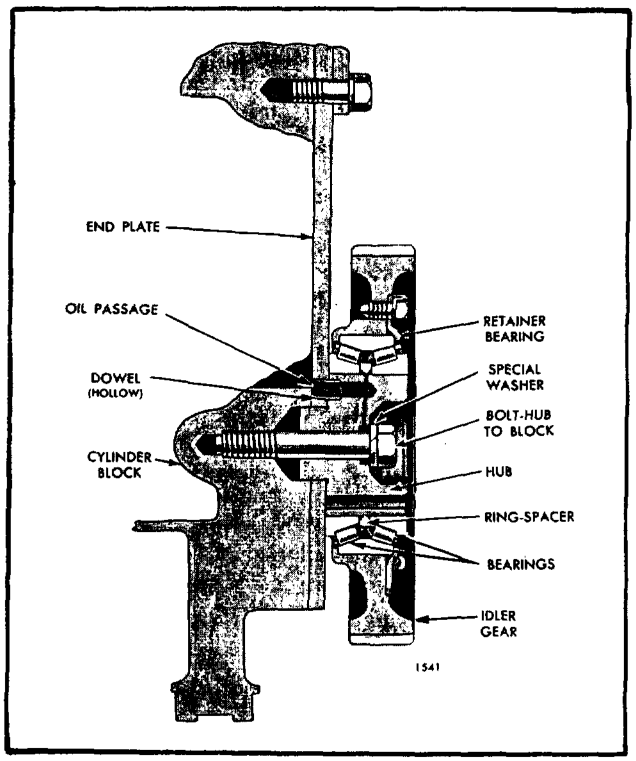


Fig. 1. Idler Gear Mounting Typical

A right-hand helix gear is provided for left-hand rotation engines, and a left-hand helix gear is provided for right-hand rotation engines. Since the engine is right hand rotation a left-hand helix gear is used. (Fig. 1 on Page 10-2-103).

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, Hub and Bearing Assembly and Idler Gear Hole Spacer (Flywheel Housing Previously Removed)

1. Remove the idler gear hub to cylinder block bolt and washer (Fig. 1) 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 (Fig. 1 on Page 10-2-103) in the same manner if the engine is being completely reconditioned.

Disassemble Idler Gear, Hub and Bearing Assembly

While removing or installing an idler gear bearing, the bearing MUST be rotated to avoid the possibility of damaging the bearing by brinelling the bearing cones. Brinelling refers to the marking of the cones by applying a heavy load through the rollers of a non-rotating bearing in such a way that the rollers leave impressions on the contact surfaces of the cones. These impressions may not be easily discerned during normal inspection. For example, a bearing may be brinelled if a load were applied to the inner cone of the bearing assembly in order to force the outer cone into the idler gear bore, thus transmitting the force through the bearing rollers. A brinelled bearing may have a very short life.

Refer to Fig. 3 for the location and identification of parts and disassemble the bearing as follows:

1. Remove the six bolts and three bolt locks which secure the bearing retainer to the idler gear, and remove the bearing retainer.

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 press with the bearing cone or inner race supported on steel blocks as shown in Fig. 2. While rotating the gear assembly, press the hub out of the bearing. Remove the gear assembly from the arbor press and remove the bearing cones and spacers.

4. Tap the bearing cups and spacer rings from the idler gear by using a brass drift alternately at four notches provided around the shoulder of the gear.

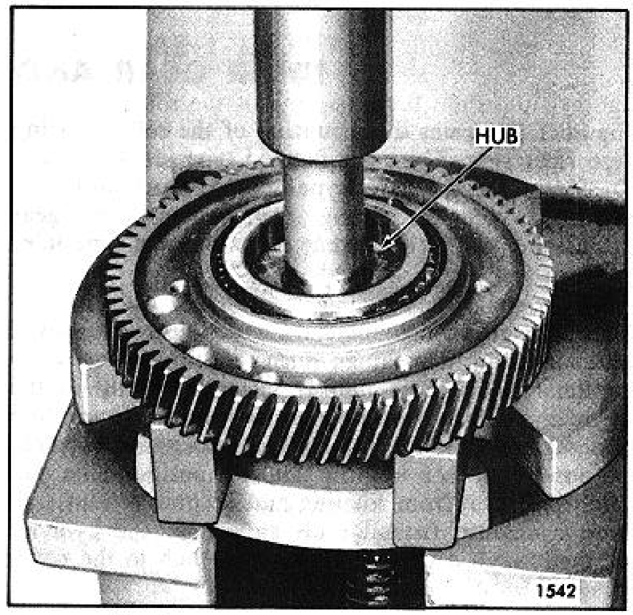


Fig. 2. Pressing Hub Out of Bearing

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.

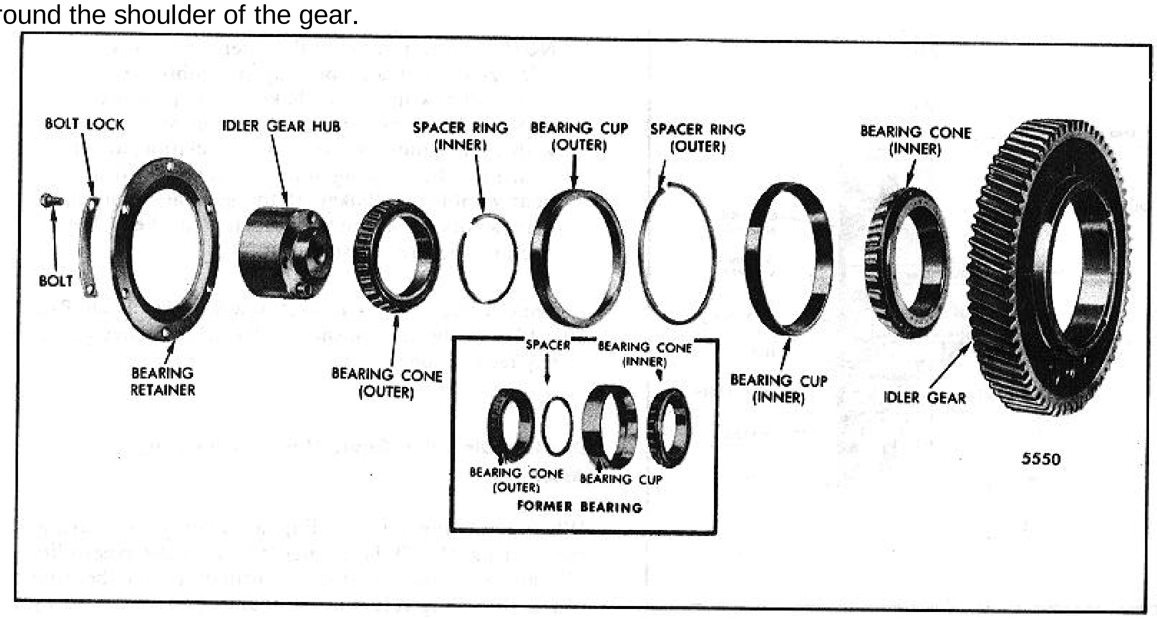


Fig. 3. Idler Gear Details and Relative Locating Parts (Current Bearing)

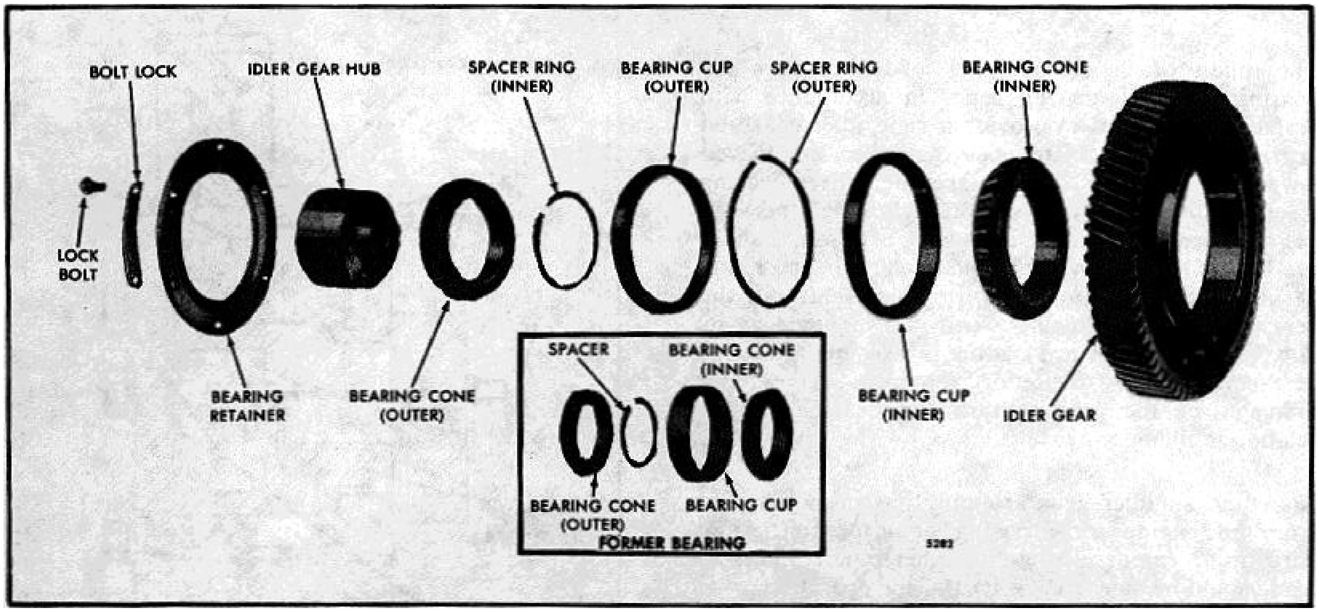


Fig. 4. Idler Gear Details and Relative Location of Parts

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, Hub and Bearing

Refer to Fig. 4 and assemble the bearing components in their *original positions* (refer to identification marks made during disassembly) as outlined below:

> **NOTE: The current idler gear bearing is a matched assembly. *Do not* mix components.**

1. Support the idler gear, shoulder down, on the bed of an arbor press. Start one of the bearing cups, numbered side up, squarely into the bore of the gear. Then press the bearing cup against the shoulder of the gear. Use a flat steel plate (pre-load test plate) between the ram of the press and the bearing cup.

2. Lay the outer spacer ring on the face of the bearing cup.

3. Start the other bearing cup, numbered side down, squarely into the bore of the gear. Then press the cup tight against the spacer ring. Use a flat steel plate (pre-load test plate) between the ram of the press and the bearing cup.

4. Press the inner bearing cone (numbered side up) on the idler gear hub, flush with the inner hub mounting face. Use the pre-load test plate (with the large center hole) between the ram of the press and the bearing.

5. Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 180° from the gap in the inner spacer ring.

6. Position the gear with both cups over the hub and the inner bearing cone.

7. Press the outer idler gear bearing cone over the hub while rotating the gear to seat the rollers properly between the cones. The bearing cones must be supported so as not to load the bearing rollers during this operation (Fig. 5).

8. Before installing the gear and bearing assembly, check the pre-load.

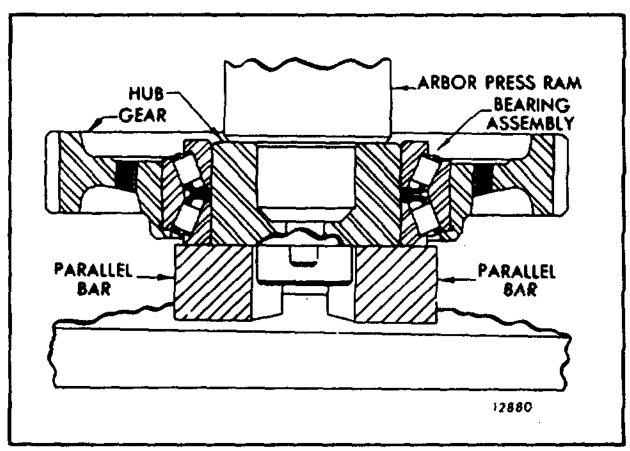


Fig. 5. Pressing Hub into Bearing

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 *pounds-pull*, by the effort required at the outer diameter of the gear to turn the bearing cup in relation to the bearing cones.

Any time an idler gear assembly has been removed from an engine for servicing or inspection, while performing engine overhaul or other repairs, the preload should be measured as part of the operation.

The idler gear bearing must be clean and lubricated with light engine oil prior to the pre-load test. Idler gear assemblies which include new bearings should be *worked in* by grasping the gear firmly by hand and rotating the gear back and forth several times.

After the idler gear, hub, and bearing are assembled together, the bearing should be checked to ascertain that the gear may be rotated on its bearing without exceeding the maximum torque specifications, nor be so loose as to permit the gear to be moved in relation to the hub by tilting, wobbling or shaking the gear.

If the mating crankshaft and balance shaft gears are not already mounted on the engine, the torque required to rotate the idler gear may be checked by mounting the idler gear in position on the engine, using a steel plate 4 " square (pre-load test plate) against the hub and cone as outlined below.

1. Mount the idler gear assembly on the engine.

2. Install the center bolt and washer through the gear hub and into the cylinder block. Tighten the bolt to 8090 lb-ft (108-122 Nm) torque.

3. Place steel plate (lower plate shown in Fig. 7) against hub and bearing. Insert three 3/8 "-16 bolts through the plate and thread them into the hub. Tighten the bolts to 24-40 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 cord around the periphery of the gear several times. Attach the other end of the cord to spring scale, J 8129 (Fig. 8). Maintain a straight, steady pull on the cord and scale, 90 ° to the axis of the hub, and note

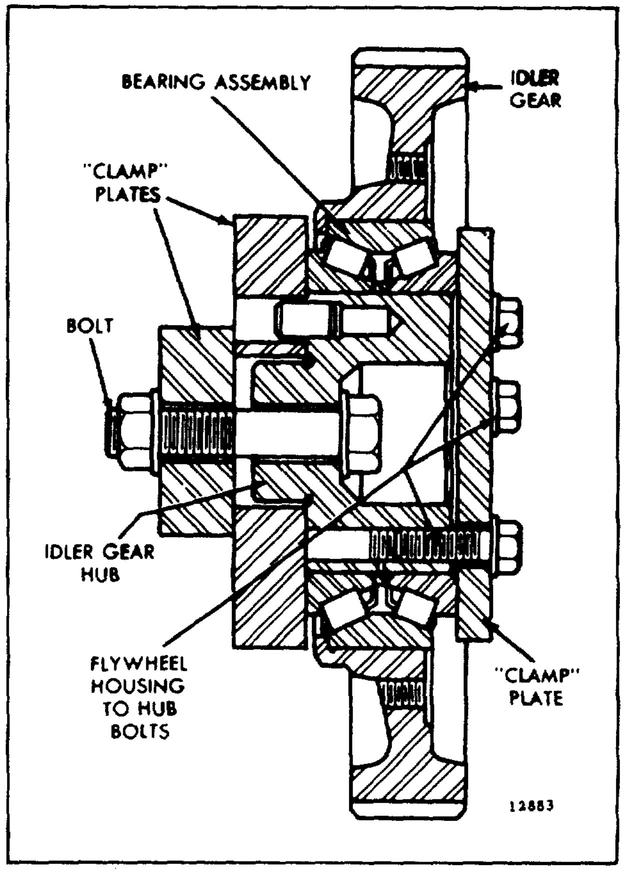


Fig. 6. Fixture for Testing Bearing Pre-Load

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.

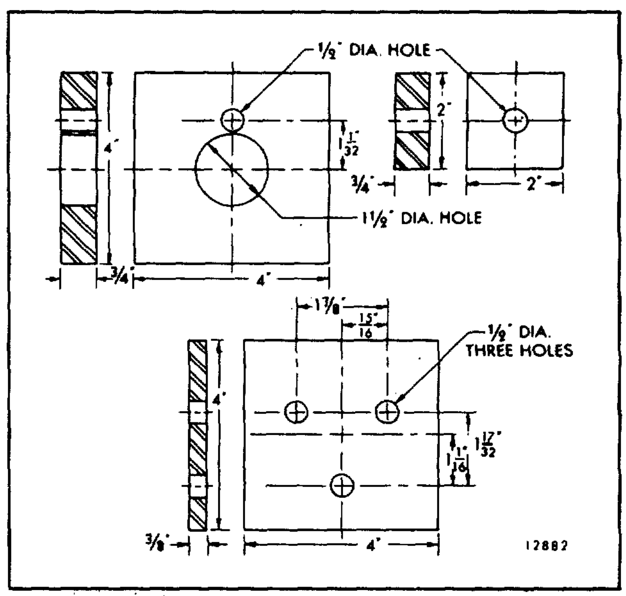


Fig. 7. Plates for Bearing Test Fixture

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture, which may be held in a vise, can be made as shown in Fig. 6. Three plates (shown in Fig. 7) a 1/2"-13 x 2 3/4" bolt and a plain washer are used with a 1/2 "-13 nut and plain washer for mounting. One of the plates is used to take the place of the flywheel housing, and the other two plates, the cylinder block, *Engine-mounted* conditions are simulated by tightening the nut to 80-90 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:

1. Attach the plates (two upper plate shown in Fig 7) to the idler gear with 1/2"-13 bolt, washers and nuts as shown in Fig. 6. Tighten the bolt to 80-90 lb-ft (108122 Nm) torque.

2. 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.

3. Clamp the idler gear assembly and fixture in vise (Fig. 8).

4. Attach the cord to the idler gear and spring scale and check the pre-load as outlined in step 4 of the previous method.

If the scale reading is within the specified 1/2 to 4 lbs., but fluctuates more than the permissible 2 lbs. 11 ounces, the idler gear and bearing assembly must NOT be installed on the engine. Fluctuations in scale reading may be caused by the cones or races not being concentric to each other, damaged cones or races or rollers, or dirt or foreign material within the bearings. In these cases, the bearing should be inspected for the cause of fluctuation in the scale readings and corrected or a new bearing installed.

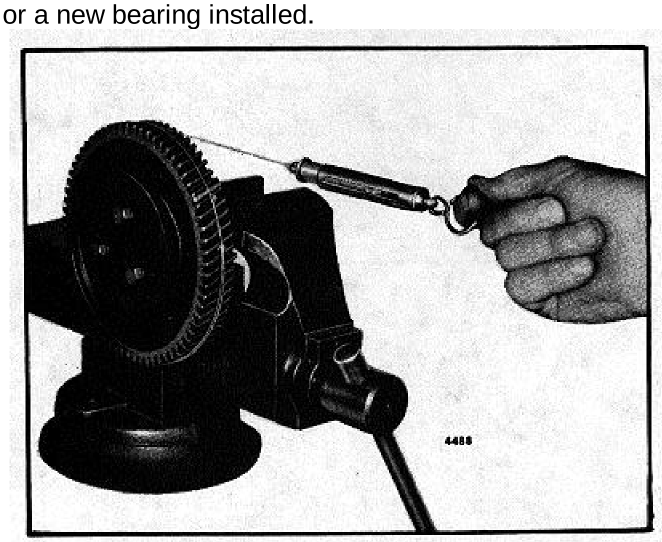


Fig. 8. Checking Pre-Load of Idler Gear Bearing

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.

> **IMPORTANT: 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, Hub and Bearing Assembly

1. Position the crankshaft gear and the balance shaft gear so that the timing marks will align with those on the idler gear (refer to Fig. 1 on Page 10-2-103).

2. With these marks in alignment, start the idler gear into mesh with the crankshaft gear and the balance shaft gear, and simultaneously rotate the gear hub so that the hollow dowel at the inner face of the hub registers with the oil hole in the end plate.

3. Roll the idler gear into position, align the hollow dowel with the hole in the end plate, and gently tap the hub until it seals against the end plate. Thus the hollow dowel in the hub will conduct oil through the end plate and into the hub where it flows through a drilled passage to the roller bearing.

4. After making sure that the hub is tight against the end plate, secure the idler gear assembly with a 1/2 "13 bolt and special washer. Tighten the bolt to 80-90 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.

> **NOTE: Current engines use a new idler gear hub and idler gear hole spacer (dummy hub) which requires 1/2 "-13 x 2-1/2" retaining bolts, replacing the 1/2"-13 x 2" bolts formerly used.**

6. Lubricate the idler gear and bearing liberally with clean engine oil.

7. Check the backlash between the mating gears. The backlash must be .002 " to .008 " between new gears and must not exceed .010 " between used gears.

8. No gasket is used between the roller bearing type idler gear assembly and the flywheel housing.

NOTE: Make sure the oil passage in the cylinder block is plugged at the dummy hub location.

Install the flywheel housing as outlined on Page 10-2-76

CRANKSHAFT TIMING GEAR

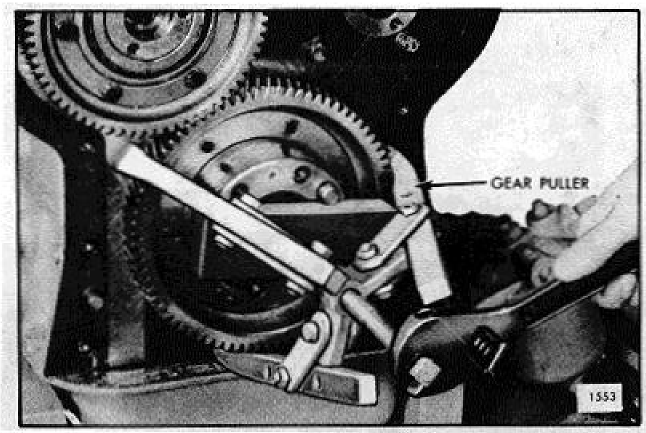


Fig. 1. Removing Crankshaft Timing Gear

The crankshaft timing gear is bolted to the flange at the rear end of the crankshaft and drives the balance shaft gear through an idler gear.

Since the camshaft must be in time with the crankshaft, timing marks are located on two teeth of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft and balance shaft gears (refer to Page 10-2-103).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft gear is a 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. Then remove the gear with a suitable puller as shown in Fig. 1.

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 end of the crankshaft with the flat finished hub of the gear facing toward the cylinder block and with all six bolt holes in the gear aligned with the tapped holes in the crankshaft. One bolt hole is offset so the gear can be attached in only one position.

2. Align the proper timing mark ("R") on the crankshaft gear tooth with the corresponding mark on the idler gear (refer to Page 10-2-103).

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 .003 " to .008" with new gears or .010 " maximum with used gears.

5. Install a new crankshaft rear oil seal sleeve, as outlined on Page 10-2-58.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

The blower drive gear is mounted on the blower drive gear support and in addition to driving the blower, drives the governor, water pump and fuel pump. The drive is cushioned by a spring-loaded flexible coupling, see Figs. 1 and 5 which insures a uniform rotation of the blower rotors.

The right-hand helix blower drive gear is driven by the camshaft gear. See Fig. 1 on Page 10-2-106.

The ratio of blower speed to engine speed is 2.00:1.

A new blower drive support assembly has replaced the former assembly (Fig. 2). The new and former blower drive assemblies are different in that the flanged bearing, which also served as a thrust surface, has been replaced by a new bearing. The inner bearing of the new assembly protrudes slightly from the inner face of the support to facilitate installation of and to serve as a pilot for the thrust washer.

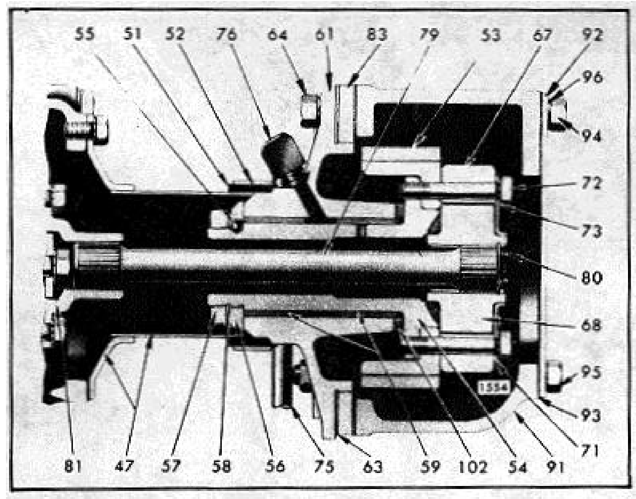


Fig. 1. Typical Blower Drive Gear and Support Assembly

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

Remove and Install Blower Drive Shaft

If the blower drive shaft is not broken, it may be removed as follows:

1. Remove the six bolts (94 and 95) that secure the flywheel housing small hole cover (92), see Fig. 1.

2. Refer to Fig. 4 and remove the snap ring and pull the blower drive shaft out of the drive assembly.

NOTE: Some shafts have a tapped hole in the end which can be used as an aid in removing the shaft.

If the blower drive shaft is broken and it is not possible to remove all of the pieces, it will be necessary to remove the blower, see Page 10-49.

A broken drive shaft indicates an unusual loading which may have been caused by a bearing failure or other malfunction. Inspect the blower drive, blower rotors and the housing before replacing the drive shaft. See the blower inspection procedure on Page 10-4-7.

Reverse Steps 1 and 2 for the installation of the blower drive shaft.

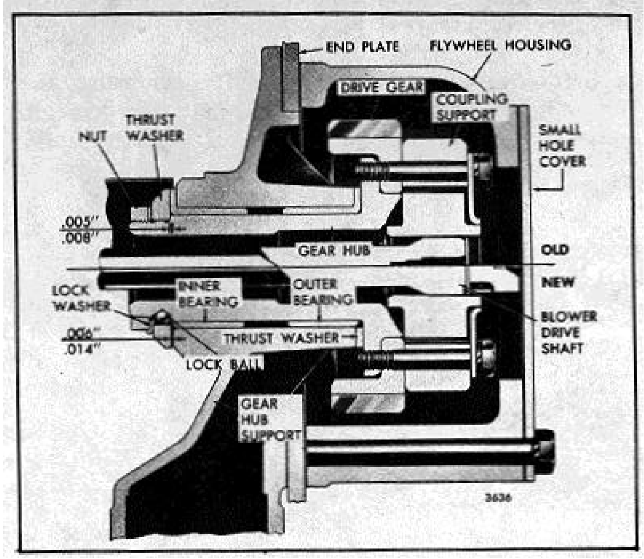


Fig. 2. Blower Drive Support Assembly

Remove Blower Drive Gear and Support Assembly (Flywheel Housing Removed)

Removal of the flywheel housing is not necessary when removing the blower drive gear, however, an inspection of the gear train is advisable when any one of the gears requires service. The procedures for the removal of the flywheel and flywheel housing are found on Pages 10-2-71 and 10-2-75.

Before removing the blower drive gear, the blower drive shaft must be removed as previously outlined.

1. Remove the blower as outlined on Page 10-4-9.

2. Remove the blower drive oil line, see Fig. 3.

3. Straighten the ears on the lock washer (58) and loosen the drive gear hub nut (57), Fig. 5.

4. Remove the blower drive support attaching bolts.

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 Assembly

1. Secure the blower drive gear and support assembly in a vise with soft jaws.

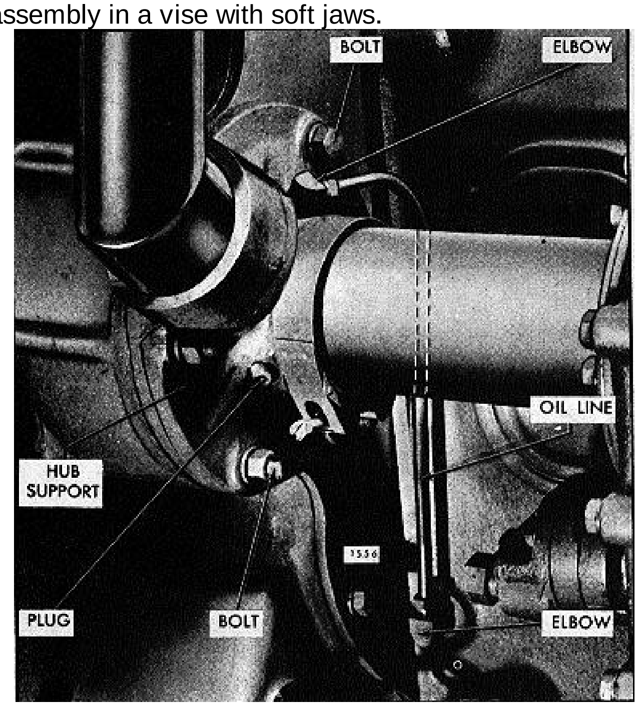


Fig. 3. Blower Drive Gear and Support Assembly Mounting

2. Take out the drive coupling bolts (72) and remove the retainer (71) and coupling support (67), see Fig. 5.

3. Remove the drive gear hub nut (57), lock washer (58), lock ball (55) and thrust washer (56) and withdraw the blower drive gear hub.

4. Remove the thrust washer (Fig. 2) from the blower drive gear hub.

5. Press the gear hub out of the blower drive gear.

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 .0010" to .0025" with new parts and a maximum of .0050" with used parts.

The current bearing on the gear end protrudes .045" to .055" above the surface of the face to facilitate the installation of the blower drive thrust washer (102) Fig. 5. The other bearing is installed with the end flush to .030" below the surface of the face of the support. Each of the former bearings were flanged. Replacement bearings must withstand a 2000 lb end load without moving, also the bearing bores must be square with the inner and outer faces of the support within .001" total indicator reading.

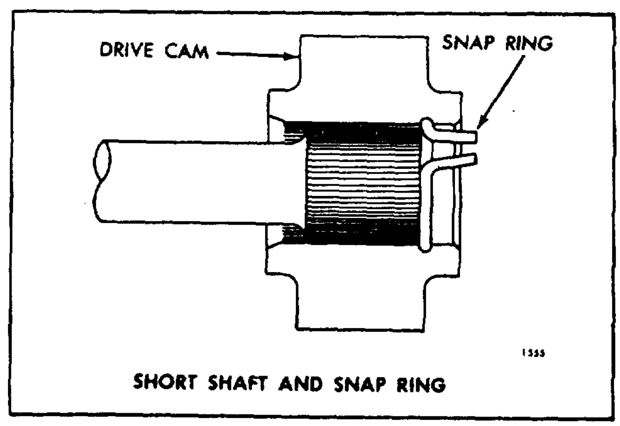


Fig. 4. Bower Drive Shaft Mounting

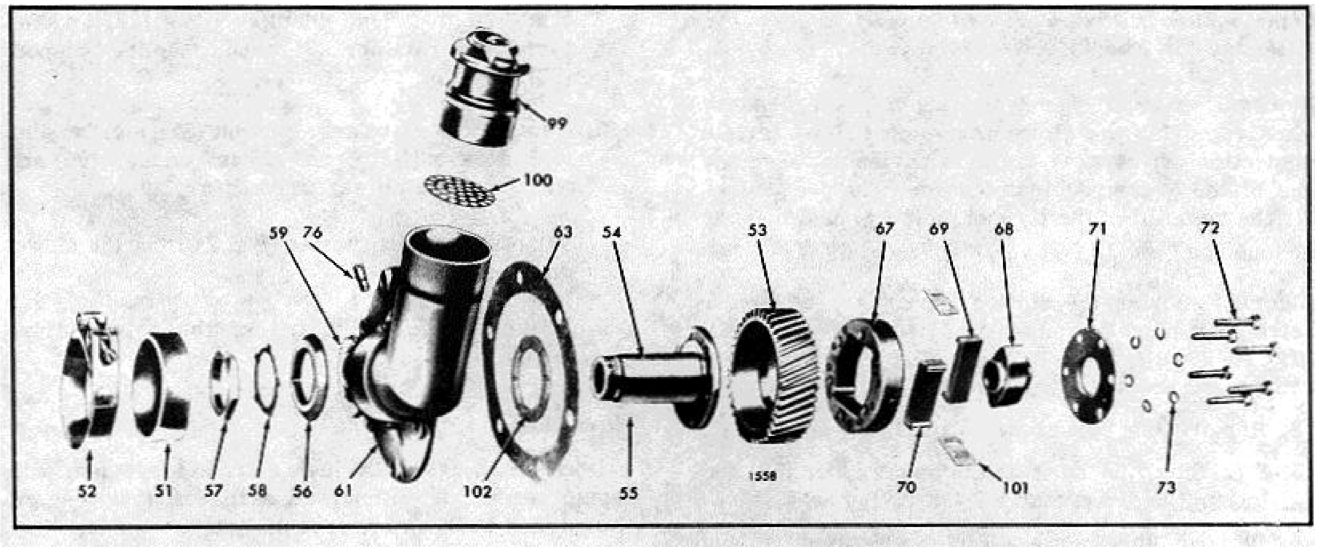


Fig. 5. Typical Blower Drive Gear Details and Relative Location of Parts

51.	Seal-Drive Cover	57.	Nut-Drive Gear Hub	68.	Cam-Drive Coupling	73.	Lock Washer
52.	Clamp-Cover Seal	58.	Lock Washer	69.	Spring (Pack)-Drive Coupling	76.	Elbow-Oil Pipe
53.	Gear-Blower Drive	61.	Support-Drive Gear Hub	70.	Seat-Coupling Spring	99.	Cap-Oil Filler
54.	Hub-Drive Gear	63.	Gasket	71.	Retainer-Drive Coupling	100.	Strainer-Oil Filler
55.	Lock Ball	67.	Support-Drive Coupling	72.	Bolt-Drive Coupling	101.	Seat-Coupling Spring End
56.	Washer-Drive Gear Hub Thrust					102.	Washer-Thrust

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 current blower drive couplings incorporate spring seats which prevent pressure and 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 Assembly

The relative location of the parts is shown in Fig. 5.

1. Secure the blower drive gear support (61) in a vise with soft jaws.

2. Press the drive gear hub (54) into the 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 the 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 the lock ball (55) in its place on the drive gear hub and slide the 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 the nut (57) on the hub. Install two bolts into the threaded holes in the drive gear hub. Place a suitable holding bar across the bolts to keep the hub from rotating and tighten the hub nut to 50-60 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.

   a. Place the drive coupling support (67) on wood blocks as shown in Fig. 6.
   b. Install the spring end seats (101) and place the spring seats (70) in each corner of the drive coupling support.

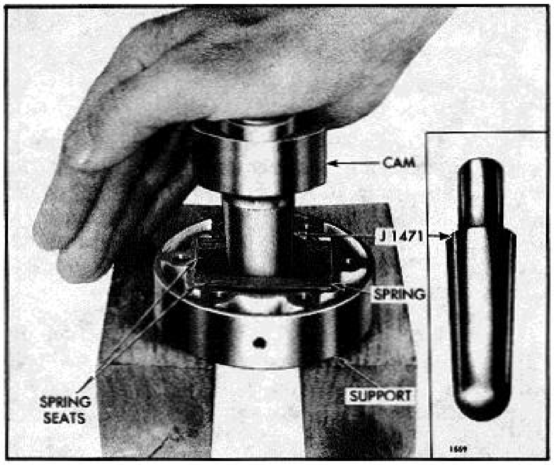


Fig. 6. Inserting Blower Drive Cam

c. Apply engine oil to the drive coupling springs (there are 21 leaves in each spring pack) and insert them in the coupling support.

d. Place the blower drive cam (68) on the installer J 1471, insert the round end of the tool between the spring packs (69) and press the cam into position. See Fig. 6.

8. Place the coupling support against the drive gear with the blower drive shaft ring groove in the cam facing away from the drive gear. Then, place the drive coupling retainer (71) against the coupling support with the flared edge away from the support. Revolve the coupling assembly on the hub flange until the cam lobes are in line with the oil grooves in the gear hub (Fig. 7) to ensure proper lubrication.

9. Install the drive coupling bolts.

Install Blower Drive Gear and Support Assembly

1. Check the clearance (Fig. 2) between the drive support gear hub thrust washer, before installing the blower

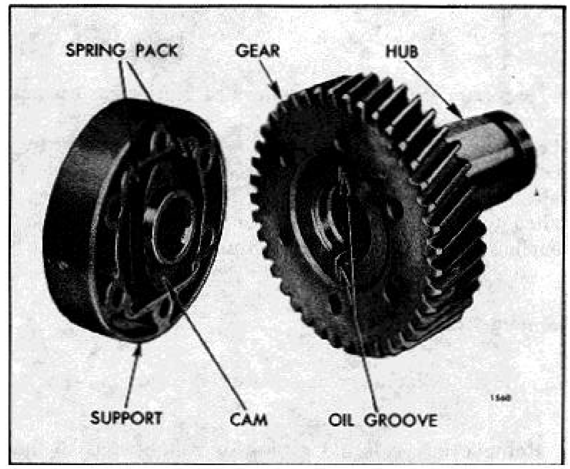


Fig. 7. Relation of Blower Drive Cam to Oil Grooves in Gear Hub

drive gear support assembly. The clearance must be .006" to .014".

2. Place a new gasket (63) on the mounting face of the hub support (Fig. 5).

3. Attach the blower drive gear and support assembly to the cylinder block rear end plate with the two 3/8"-24 x 7/8 bolts.

4. Connect the oil line (Fig. 3).

5. Install the blower a s outlined on Page 10-4-15 and secure the seal (61) and clamp (52) shown in Fig. 5.

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 as described on Pages 10-2-72 and 10-2-76 and install the remaining bolts that secure the blower drive gear and support assembly.

ACCESSORY DRIVE

An accessory drive has been provided at the rear of the engine to accommodate the gear driven hydraulic pump. The drive for the pump is made up of an accessory drive plate and drive coupling. The accessory drive plate is bolted to the balance shaft gear. The hydraulic pump is bolted to the flywheel housing and driven by the drive coupling which is splined to the accessory drive plate.

Remove Accessory Drive

Remove the hydraulic pump accessory drive as follows:

1. Remove any external piping or connections to the pump.

2. Remove the five bolts and lock washers attaching the pump to the flywheel housing. Pull the pump 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. Then remove the four bolts attaching the accessory drive plate and remove the plate.

Inspection

Clean the accessory drive parts with clean fuel oil 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.

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.

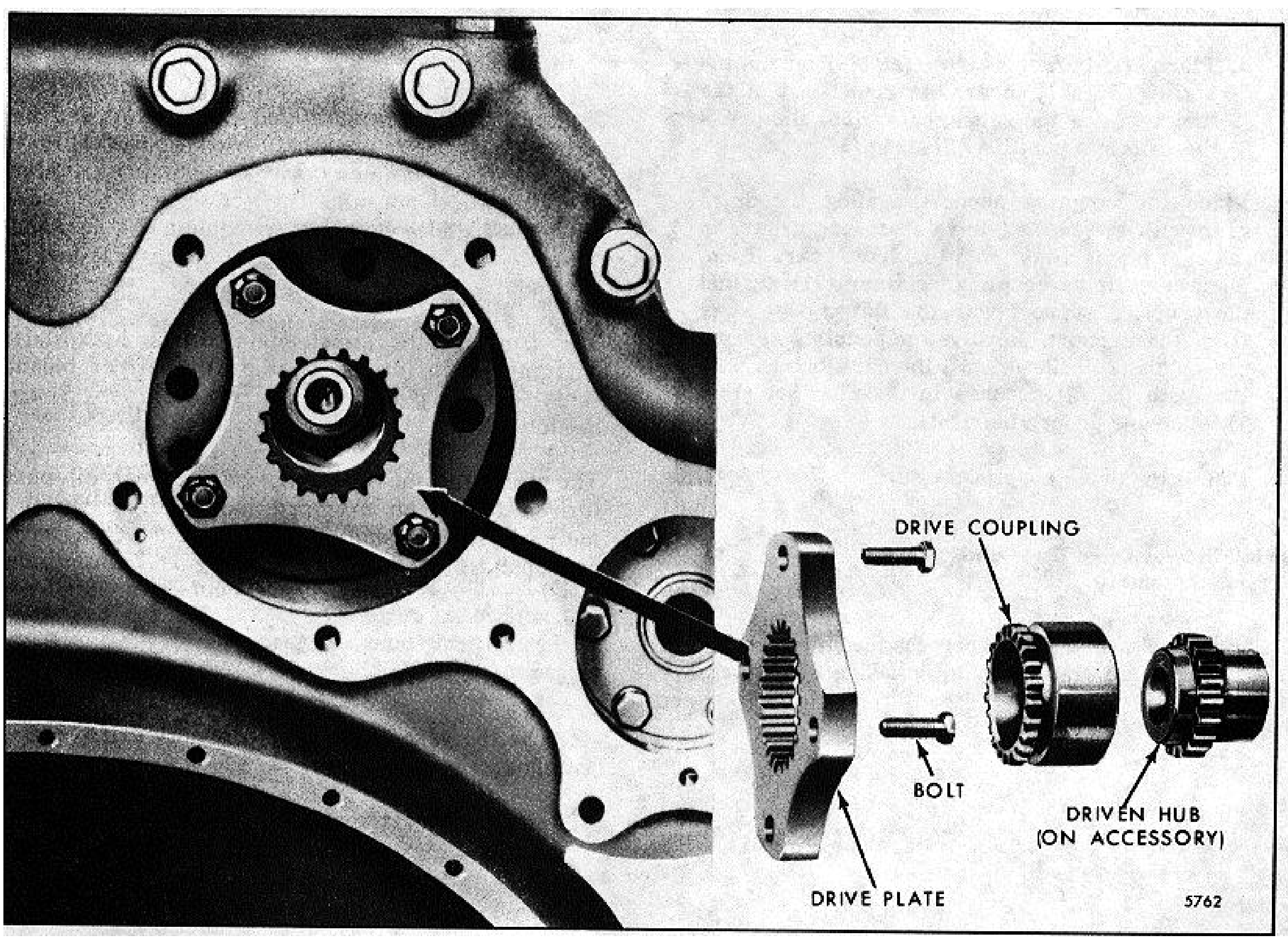


Fig. 1. Typical Components of Accessory Drive For Direct-Driven Accessories

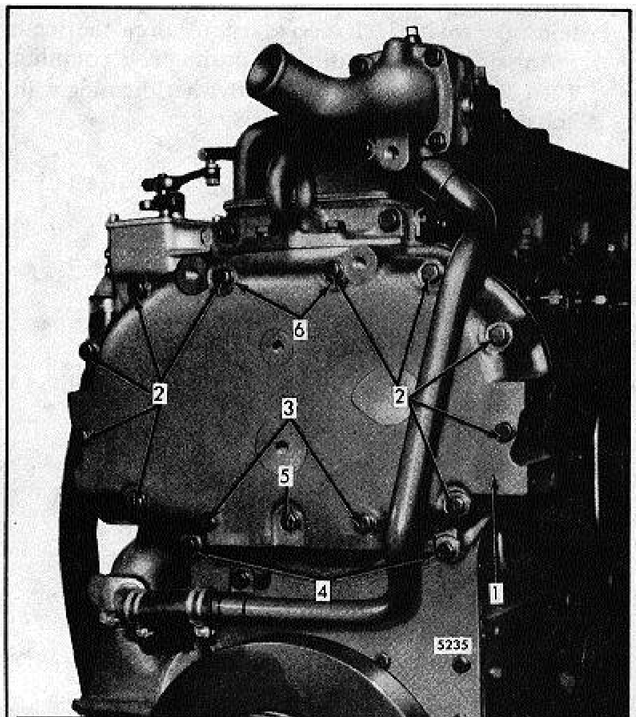
2. Insert a clean, lintless cloth in the flywheel housing opening to prevent bolts from accidentally falling in the gear train. Align the bolt holes in the accessory drive plate with the tapped holes in the balance gear. Then secure the plate with four bolts.

3. Install the drive coupling (Fig. 1) and proceed as follows:

a. Affix a new gasket to the mounting flange on the accessory.

b. Place the pump 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 pump to the flywheel housing with bolts and lock washers.

BALANCE WEIGHT COVER



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

Fig. 1. Balance Weight Cover Mounting

The front balance weight cover (Fig. 1) encloses the front engine balance weights and also serves as a support for various equipment such as the cooling fan support bracket or heat exchanger.

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.

Remove Cover

1. Drain the cooling system.

2. Loosen the hose connections between the radiator and the engine.

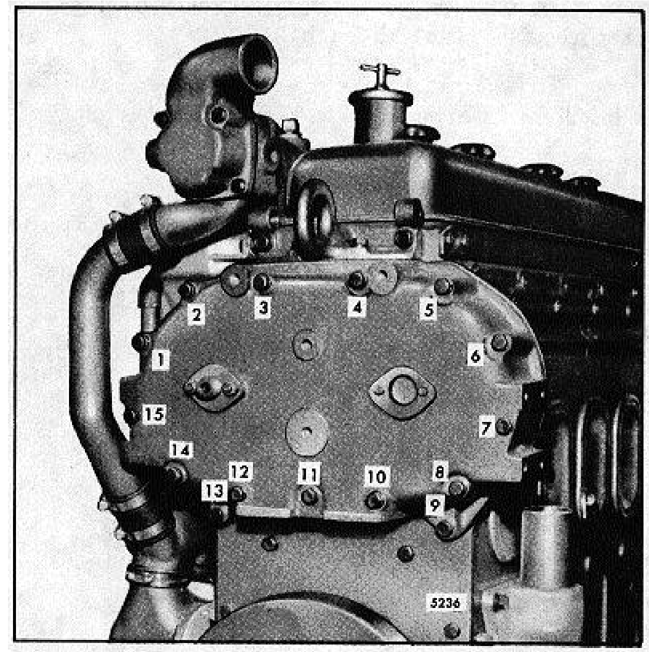


Fig. 2. Balance Weight Cover Bolt Tightening Sequence

3. Remove the radiator.

4. Remove the fan, fan hub and adjusting bracket.

5. Remove the fifteen bolts, lock washers and plain washers (Fig. 1) which secure the balance weight cover to the cylinder block and the front end plate. Remove the cover and gasket.

6. Remove all traces of the old gasket material from the cover and the end plate.

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 Fig. 2 and tighten the bolts to 25-30 lb-ft (34-41 Nm) torque.

4. Install the various sub-assemblies that were previously removed.

SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

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 together with an overlap of approximately 1/8"

3. Wrap the tape tightly in the same direction as you would turn a nut. The tape must 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

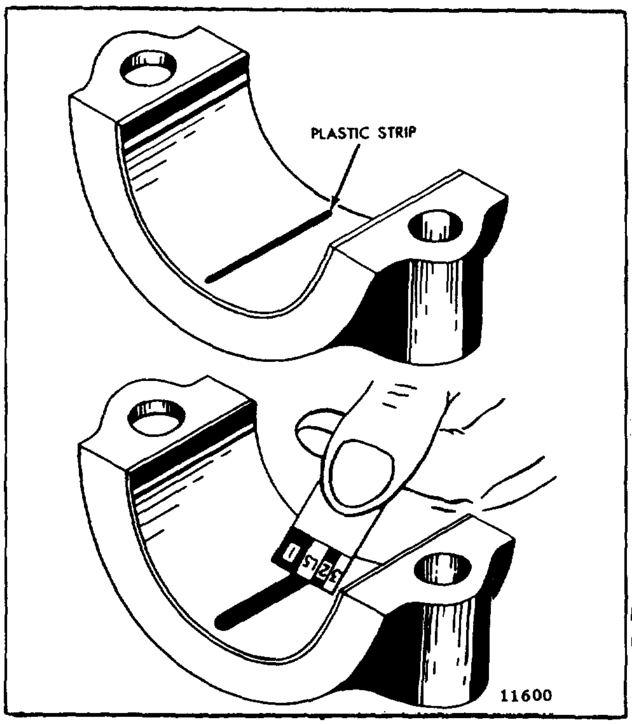


Fig. 1. Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially and is available in three sizes and colors. Type PG-1 (green) has a clearance range of .001" to .003", type PR-1 (red) has a range of .002" to .006" and type PB-1 (blue) has a range of .004" to .009".

The plastic strip may be used for checking the bearing clearances as follows:

1. Remove the bearing cap and wipe the oil from the bearing shell and the crankshaft journal.

NOTE: 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.

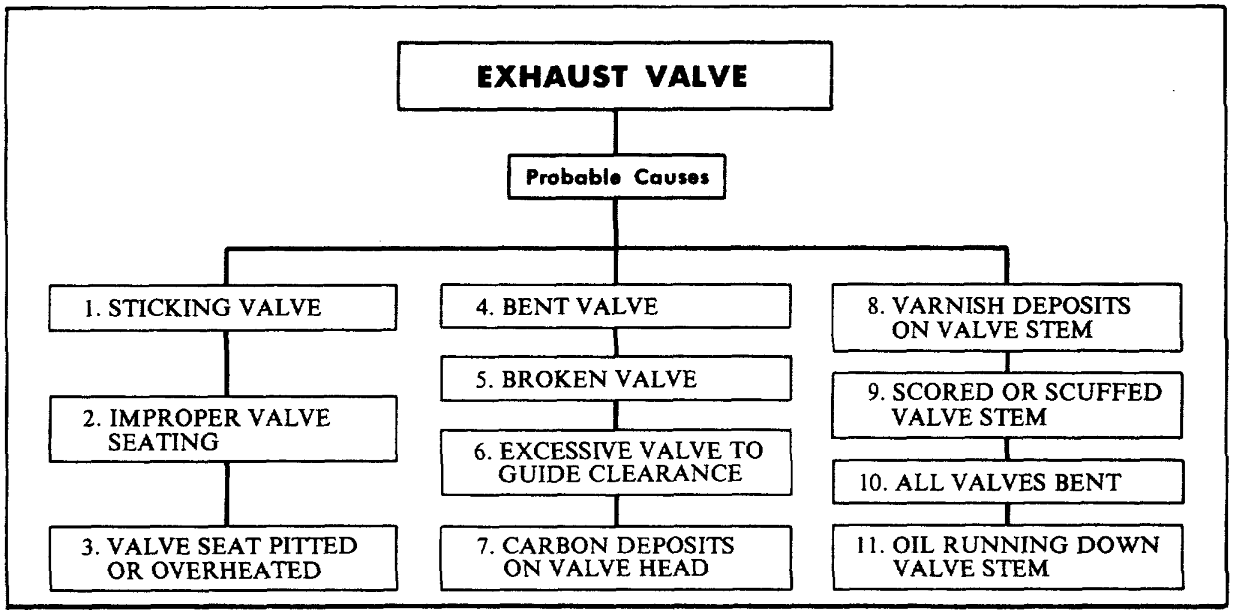
2. Place a piece of the plastic strip the full width of the bearing shell, about 1/4" off center (Fig. 1).

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 (Fig. 1). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

TROUBLE SHOOTING



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, 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. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Cylinder Block			
Block bore:			
Diameter	4.6256	4.6270"	
Out-of-round		.0010"	.0020"
Taper		.0010"	.0020"
Cylinder liner counterbore:			
Diameter	5.460"	5.0485"	
Depth	.4770"	.4795"	
Main bearing bore:			
Inside diameter (vertical axis)	3.8120"	3.8130"	
Top surface of block:			
Centerline main bearing bore to block top	16.1840"	16.1890"	16.176" min.
Flatness -transverse			.0030"
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	4.2489"	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 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			
71N Engines			
Piston crown:			
Saddle-to-crown distance:			
N piston (18.7:1 compr. ratio)	2.7030"	2.7100"	
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 (two rings in upper groove)	.0080"	.0230"	.0430"
Clearance (lower groove)	.0015"	.0055"	.0080"
Clearance (upper groove)	.0010"	.0035"	.0060"

*Measured with Keystone fire ring flush with outside diameter of piston crown.
† Diameter above and below the piston pin may be 4.2414".

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Piston Pins (Cross-Head Piston)			
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"
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"	

§ 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 (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
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"
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	.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 ° (2-valve)	.0625"	.0937"	.0937"
Valve seat runout		.0020"	.0020"

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Exhaust Valves			
Stem diameter (2-valve)	.3417"	.3425"	.3405"
Valve head-to-cylinder head:			
30 ° (current 2-valve)	.023 "recess.	006 "protr.	.038 " recess.
Valve Guides			
Height above cylinder head:			
2-valve	1.5938 "	1.5938"	
Diameter-inside (2-valve)	.3445"	.3455"	.3465"
Clearance-valve-to-guide (2-valve)	.0020"	.0038"	.0060"
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)	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		GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None		GM 255-M	1	No. 6 thru 1 1/2	60,000
None		GM 260-M	2	No. 6 thru 3/4	74,000
				over 3/4 to 1 1/2	60,000
	Bolts and Screws	GM 280-M	5	No. 6 thru 1	120,000
				over 1 to 1 1/2	105,000
	Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
	Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
	Bolts and Screws	GM 300-M	8	1/4 thru I 1/2	150,000
	Bolts and Screws	GM 455-M	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)
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
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
§ Idler gear hub and spacer bolts	3/8 -16	25-40	34-54
Injector clamp bolts	3/8 -16	20-25	27-34
Accessory drive to gear bolt (steel disc)	3/8 -24	45-50	61-68
Balance weight cover bolts	3/8 -24	25-30	34-41
Balance weight to hub bolt	3/8 -24	25-30	34-41
Balance weight to timing gear bolt	3/8 -24	25-30	34-41
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
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) (see Sect. 1.3.4)	5/8 -11		
**Main bearing bolts (boring)	5/8 -11	165-175	224-238
**Flywheel bolts (see Sect. 1.4)	9/16-18		
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

*Self-locking only.
§ Wired head only.
@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 ")
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 1/2 coils - .162 "wire)	133 lbs. @ 2.1094"
Exhaust valve (two-valve cylinder head)	25 lbs. @ 2.2000"

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 (.0015 " to .015 ")	J 3172
Feeler Stock (.0015 ")	J 23185
Guide Studs	J 9665
Push Rod Remover (set of 3)	J 3092-01
Slide Hammer	J 2619-01
Socket (Fuel Line Nut)	J 8932-01
Spring Tester	J 22738-02
Valve Guide Cleaner	J 5437
Valve Guide Installer (2-Valve Head)	J 4144
Valve Guide Remover (2-Valve Head)	J 267
Valve Seat Dial Gage	J 8165-2
Valve Seat Grinder	J 8165-1
Valve Seat Grinder Adaptor Set (2-Valve Head)	J 8165-8
Valve Seat Insert Installer (2-Valve Head)	J 1736
Valve Seat Insert Remover (31 ° 2-Valve Head)	J 4824-03
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 1686D
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 (cross-head piston)	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 (Cross-head piston)	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 (cross-head piston)	J 23453
Camshaft	
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

FUEL SYSTEM AND GOVERNOR CHAPTER 3

CONTENTS

FUEL SYSTEM

The fuel system (Fig. 1) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter and fuel lines.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter and into the inlet fuel manifold, then through fuel pipes into the inlet side of each fuel injector.

The fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage) which are cast in several places in the side of the cylinder head. This aids installation of the fuel lines.

Surplus fuel returns from the outlet side of the injectors to the fuel return manifold and then back to the supply tank.

All engines are equipped with a restrictive fitting in the fuel outlet manifold to maintain the fuel system pressure. Refer to Page 10-9-1 for the size fitting required.

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.

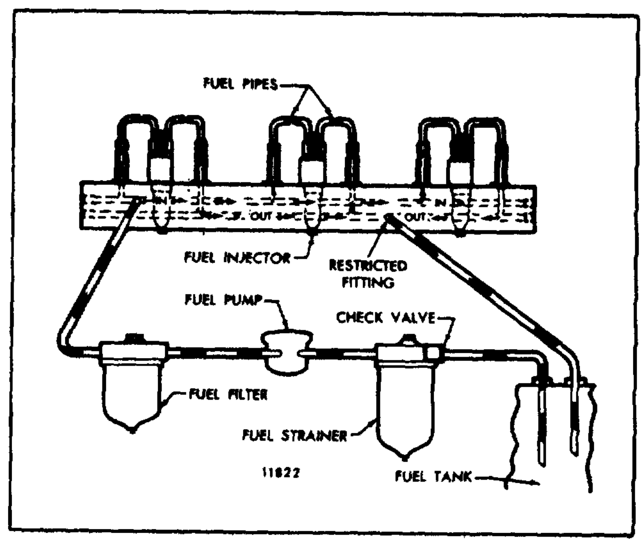


Fig. 1. Schematic Diagram of Typical Fuel System

FUEL INJECTOR (Needle Valve)

The fuel injector (Figs. 1 and 2) is a lightweight compact unit which enables quick, easy starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air-fuel mixing or vaporizing devices are required.

The fuel injector performs four functions:

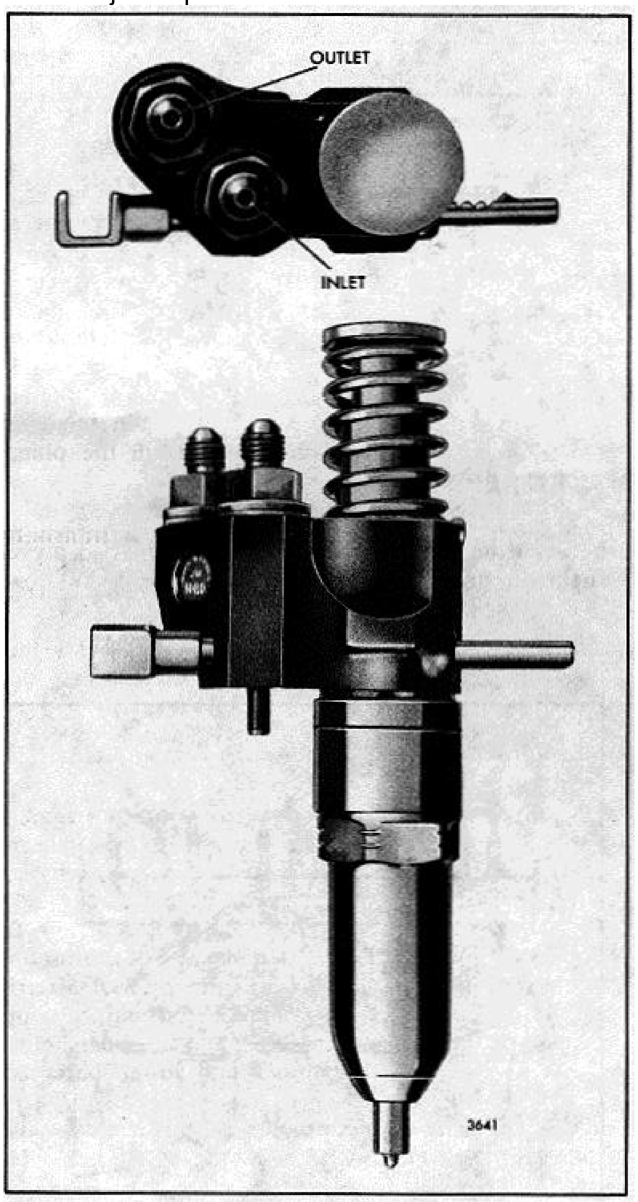


Fig. 1. Fuel Injector Assembly

1. Creates the high fuel pressure required for efficient injection.

2. Meters and injects the exact amount of fuel required to handle the load.

3. Atomizes the fuel for mixing with the air in the combustion chamber.

4. Permits continuous fuel flow.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder.

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 3 illustrates the fuel metering from no-load to full-load by rotation of the plunger in the bushing.

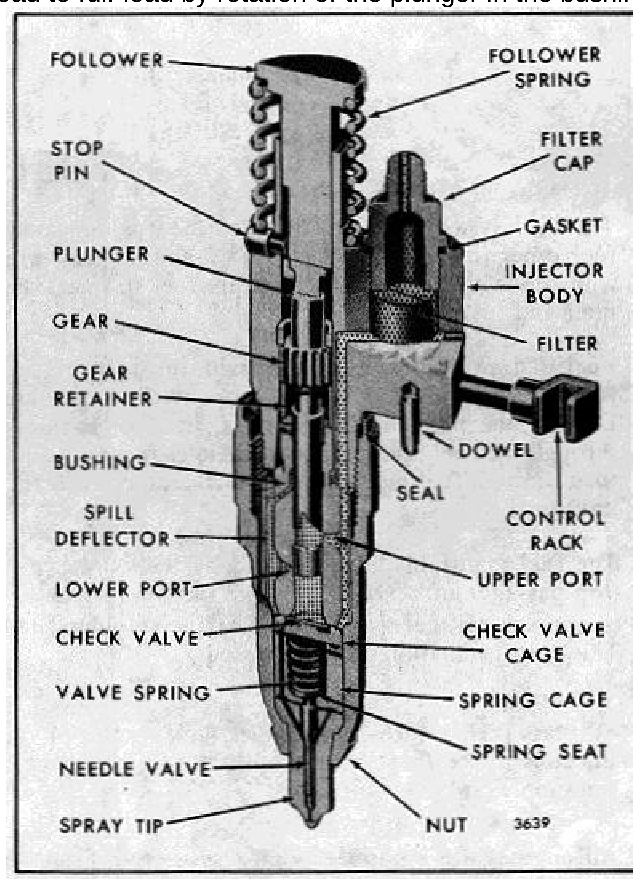


Fig. 2. Cutaway View of Fuel Injector

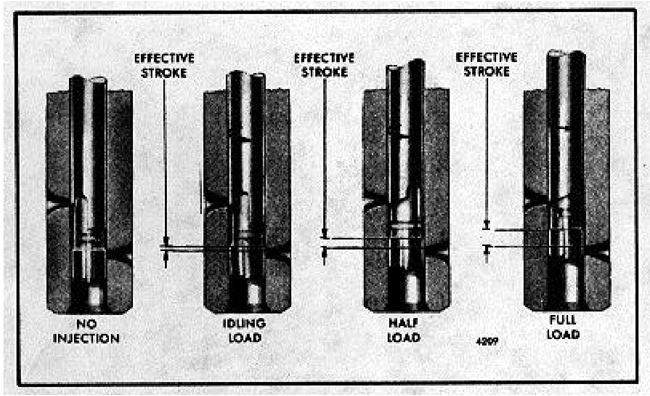


Fig. 3 · Fuel Metering from No-Load to Full-Load

Figure 4 illustrates the phases of injector operation by the vertical travel of the injector plunger.

The continuous fuel flow through the injector serves, in addition to preventing air pockets in. the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

NOTE: Do not intermix the needle valve

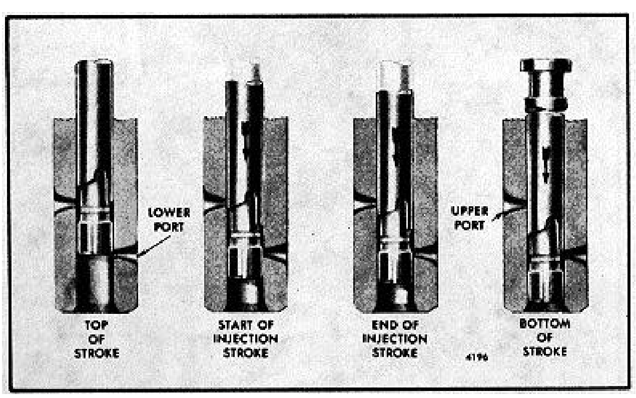


Fig. 4. Phases of Injector Operation Through Vertical Travel of Plunger

injectors with other types of injectors in an engine.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 5). The identification tag indicates the nominal output of the injector in cubic millimeters.

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting of all injector racks.

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

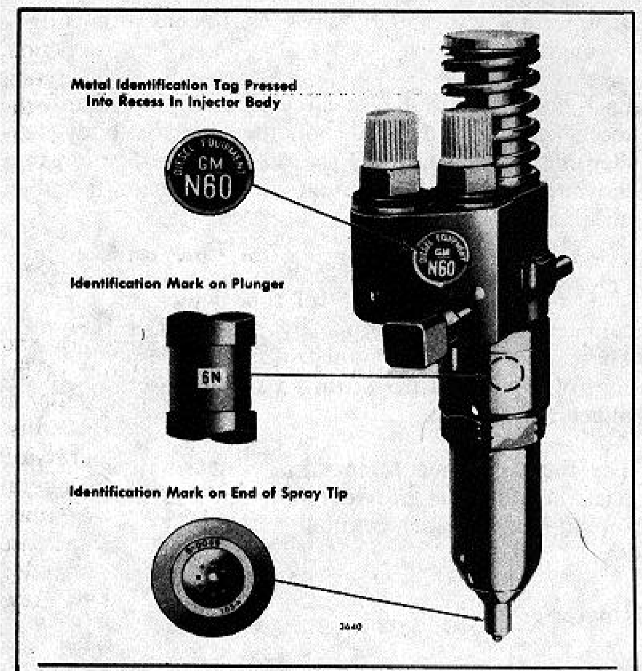
Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (Fig. 2). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat, non-return check valve. The fuel in the check valve



INJECTOR	SPRAY TIP*	PLUNGER
N65 (white tag)	8 — 0055 — 165A	75N

*First numeral indicates number of spray holes, followed by size of holes and angle formed by spray from holes.

Fig. 5 Injector Identification Chart

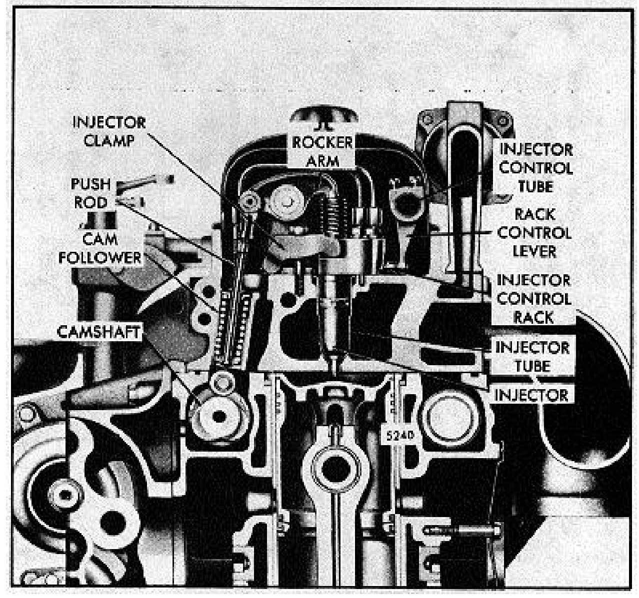


Fig. 6 Fuel Injector Mounting

cage, spring cage, tip passages and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection.

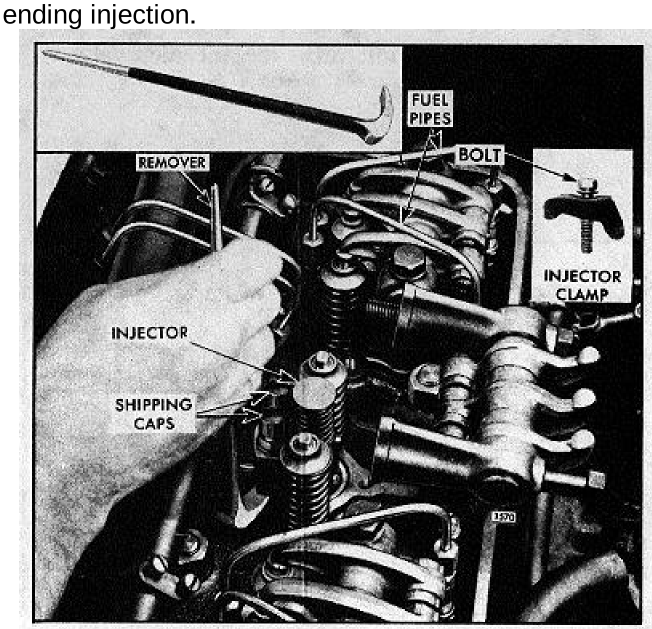


Fig. 7. Removing Injector from Cylinder Head

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 4 shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel. The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. Figure 3 shows the various plunger positions from no-load to full-load. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection.

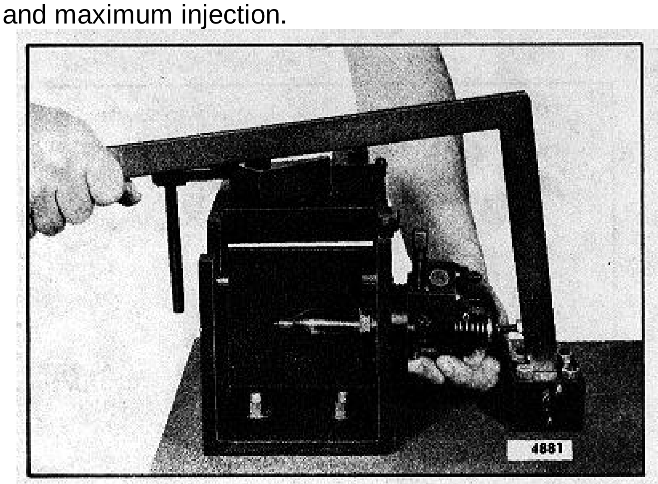


Fig. 8. Checking Rack and Plunger for Free Movement with J 22396

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 amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air. Also provide a source for 110 volt alternating current electric power.

Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust-proof material and deep enough to permit

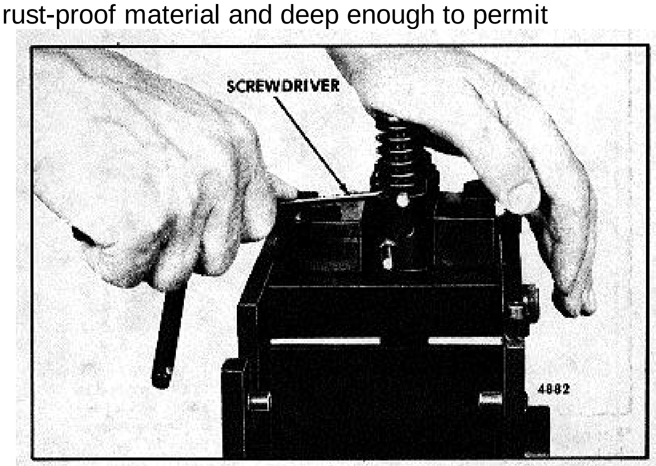


Fig. 9. Removing Injector Follower Stop Pin

all of the injector parts to be completely covered by the cleaning agent, usually clean fuel oil, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free cleaning tissue is a good, inexpensive material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors. Also protect the fuel pipes and fuel connectors from the entry of dirt or other foreign material.

2. After an injector has been operated in an engine, do not remove the filter caps or 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 (Fig. 34).

3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined on Page 10-10-3.

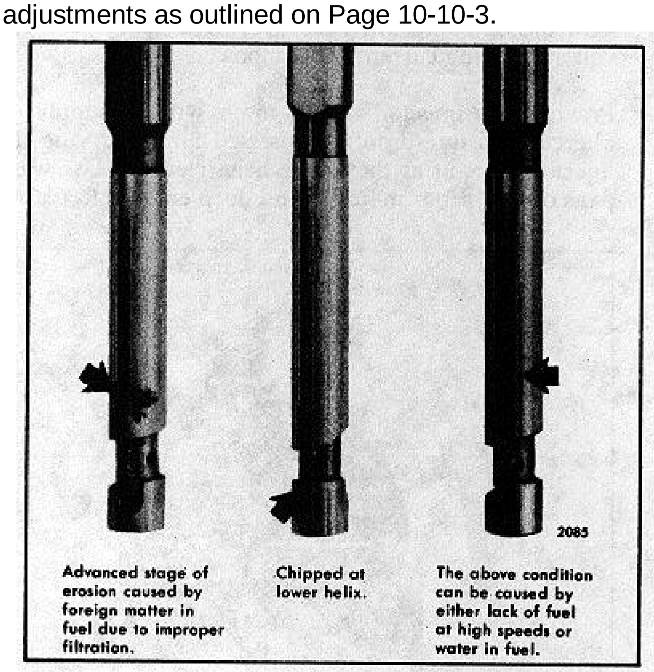


Fig. 10. Unusable Injector Plungers

a. Time the injector.
b. Position the injector control rack.

4. Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive.

5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an upright position to prevent test oil leakage.

NOTE:
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 (Fig. 6).

NOTE:
Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also protect the fuel pipes and fuel connectors from entry of dirt or foreign material.

3. Crank the engine to bring the outer ends of the push rods of the injector and valve rocker arms in line horizontally.

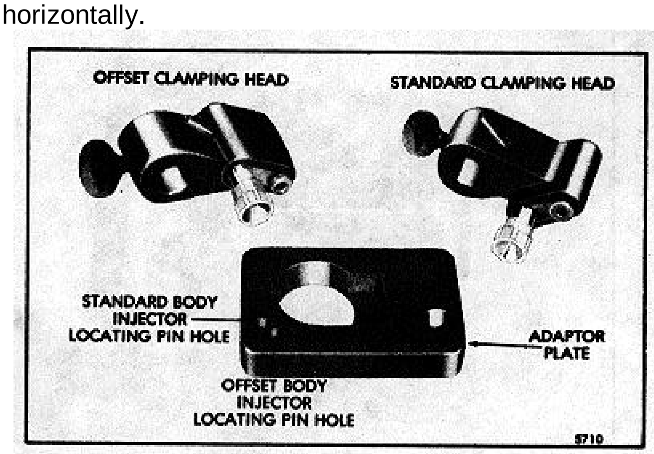


Fig. 11. Injector Tester J 23010 Clamping Heads

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).

5. Remove the injector clamp bolt, special washer and clamp.

6. Loosen the inner and outer adjusting screws 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

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.

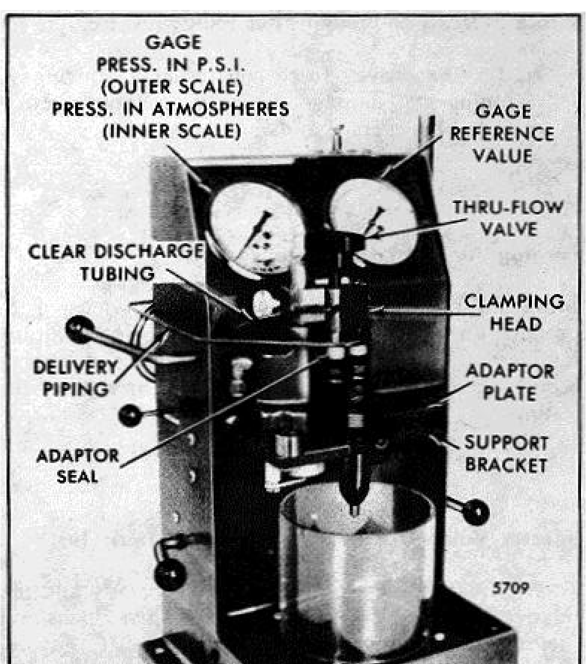


Fig. 12. Injector Installed in Tester J 23010 with clamping Head

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 Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center of the follower when the follower spring is compressed.

With the injector control rack held in the no-fuel position, push the handle down and depress the follower to the bottom of its stroke. Then very slowly release the pressure on the handle while moving the control rack up and down as shown in Fig. 8 until the

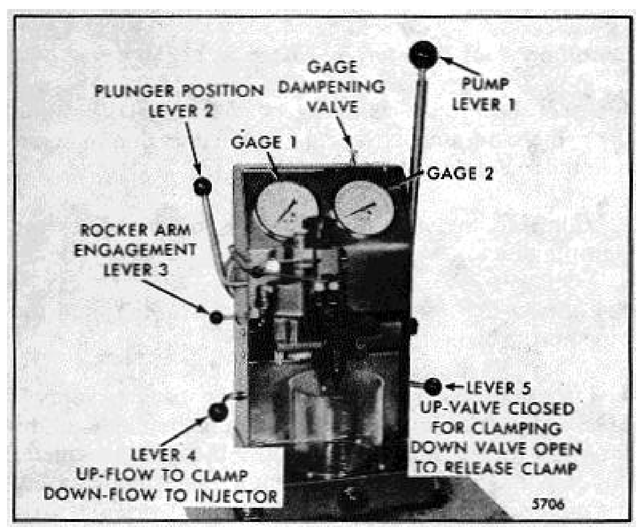


Fig. 13. Injector in Position for Testing with Tester J 23010

follower reaches the top of its travel. If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times if necessary. Generally this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts.

Visual Inspection of Plunger

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests.

Remove the plunger from the injector as follows:

1. Support the injector, right side up, in holding fixture J 22396.

2. Compress the follower spring. Then raise the spring above the stop pin with a screw driver and withdraw the pin (Fig. 9). Allow the spring to rise gradually.

3. Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.

4. Inspect the plunger. If the plunger is chipped (Fig. 10), replace the plunger and bushing assembly.

5. Reinstall the plunger, follower and spring.

Installing Fuel Injector in Tester J 23010

1. Select the proper clamping head (Fig. 11). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 12).

2. Connect the test oil delivery piping into the clamping head.

3. Connect the test oil clear discharge tubing onto the pipe on the clamping head.

4. Locate the adaptor plate on top of the support bracket by positioning the 3/8 " diameter hole at the far right of the adaptor plate onto the 3/8 " diameter dowel pin. This allows the adaptor plate to swing out for mounting the fuel injector.

5. Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. II 1).
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

1. Refer to Fig. 13 and position the injector tester levers as follows:

Lever 2 up and to the rear
Lever 3 in the rear detent
Lever 4 up (horizontal)
Lever 5 up (horizontal)

2. Align the clamping head nylon seals over the injector filter caps (Fig. 12).

3. Back off the Thru-Flow valve about half-way to allow the self-aligning nylon seals to seat properly during the clamping operation.

4. Hold the clamping head in position over the filter caps and, with the left hand, operate pump lever 1 evenly to move the clamping head down to seal the filter caps. The Thru-Flow valve should still turn freely. If it does not, turn the valve counterclockwise until it rotates freely and reapply clamping pressure.

NOTE:
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 I to produce a test oil flow through the injector. When air bubbles no longer pass through the clear discharge tubing, the system is free of air and is now ready for testing.

Injector Volvo 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.

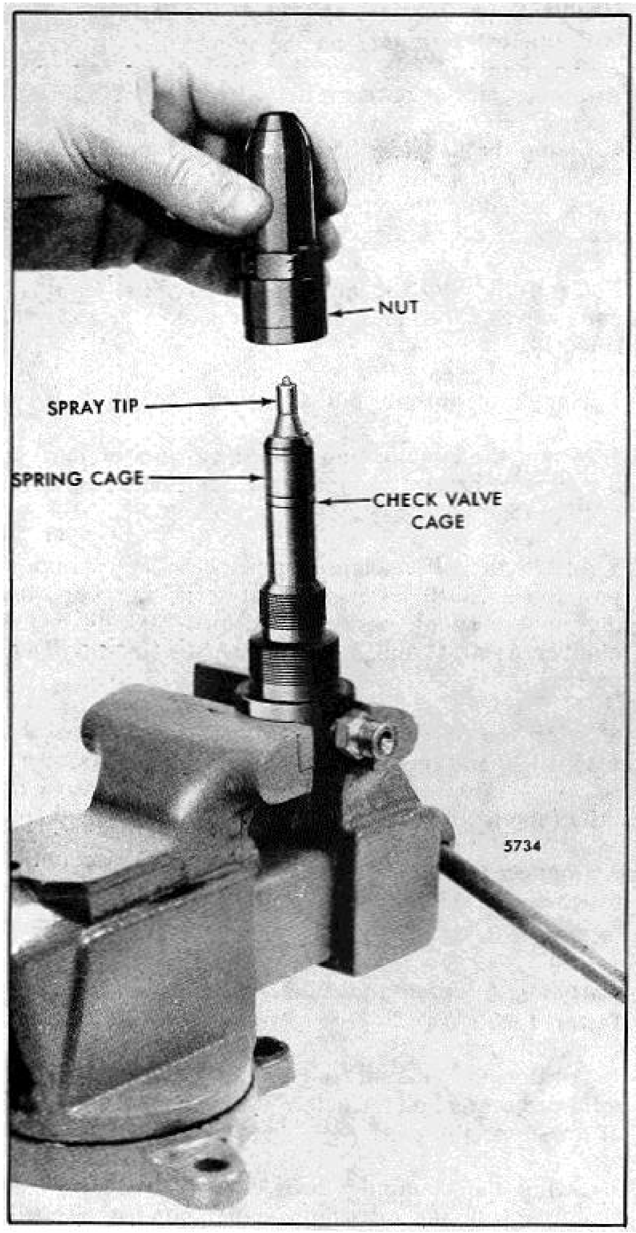


Fig. 14 Assembling Injector Valve Parts on Tip Tester Adaptor J 23010-129

3. Position the injector rack in the full-fuel position.

4. Place pump lever I 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 gage 2 will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector. Reference values for Series 71 injectors, are from 127 minimum to 146 maximum.

NOTE:

The reference value obtained when pop testing the needle valve injectors is to be used as a trouble shooting and diagnosis aid. This allows comparative testing of injectors without disassembly. Exact valve opening pressure values can only be determined by the Needle Valve Tip Test using tester J 23010 and tip test adaptor J 23010-129 or auxiliary tester J 22640.

Injector High Pressure Test

This test checks for leaks at the filter cap gaskets, body plugs and nut seal ring.

1. Clamp the injector properly and purge the air from the system.

2. Close the Thru Flow valve. but do not overtighten.

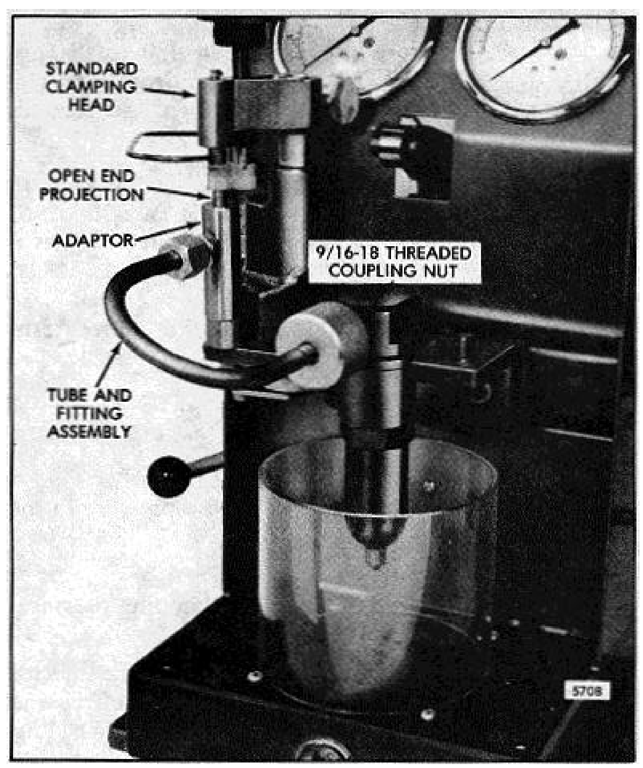


Fig. 15. Adaptor and Tube Assembly on Injector Tester J 23010

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 (I1 024-13 780 kPa) on gage 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 gage 1 reads approximately 700 psi (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 (fixture J 23010) or 40 seconds (fixture J 9787), leakage is excessive.

Refer to the Trouble Shooting Charts on Page 10-3-59 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.

Unclamping the Injector

1. Open the Thru-Flow valve to release pressure in the system.

2. Move lever 5 down to release the clamping pressure.

3. Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clear of the injector filter caps.

4. Carefully return lever 5 to the up (horizontal) position.

Needle Valve Tip Test (Using J 23010 Tester and Tip-Test Adaptor)

Assemble injector parts on tip test adaptor as follows:

1. Clamp the flat sides of the tip test adaptor J 23010129 firmly in a vise and assemble the cleaned injector parts including the check valve cage, spring, spring seat, spring cage and spray tip assembly.

2. Carefully pilot the injector nut over the spray tip and valve parts and thread it onto the adaptor (Fig. 14).

3. Tighten the injector nut.

4. Mount the adaptor and assembled injector parts in the support bracket (adaptor plate not needed). Refer to Fig. 15.

5. Install the offset clamping head on the clamping post (on J 23010 testers without serial numbers, use the upper detent position and on J 23010 testers numbered 1051 and higher, use the lower detent position).

6. Select the (larger) 9/16 "-18 threaded coupling nut J 23010-20 and thread it on tubing J 23010-75. Install the tubing and fitting to adaptor J 23010-167.

7. Connect the tubing to tip test adaptor J 23010-129 by threading the coupling nut on the tip test adaptor.

Installing Adaptor and Tube Assembly on Tester J 23010

1. Position the adaptor and tubing assembly with the solid projecting end located in the hole on the left side of the support bracket.

2. Swing the clamping head over the adaptor and clamp it with the oil supply outlet aligned over the open projecting end of the adaptor (Fig. 15).

NOTE:
Use the fuel injector clamping procedure to clamp adaptor J 23010-167 in the injector tester. Spray Tip Test

1. Move lever 4 down and operate the pump lever I rapidly with smooth even strokes (40 strokes per minute) simulating the action of the tip functioning in the engine (Fig. 13).

2. Note the pressure at which the needle valve opens on gage 1. The valve should open between 2200 and

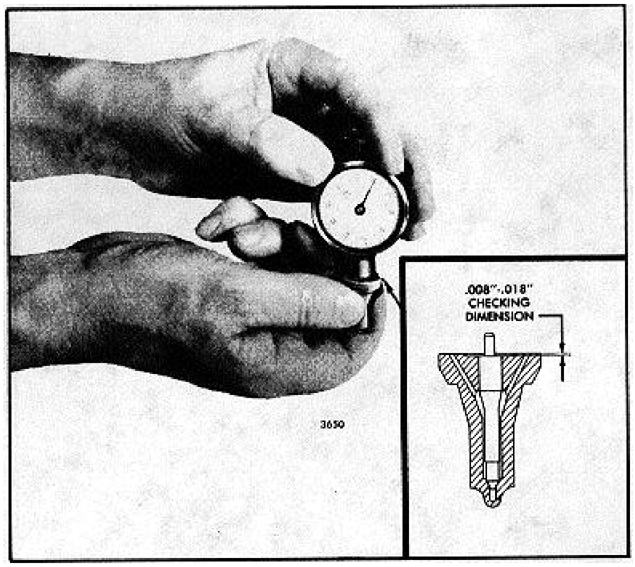


Fig. 16. Checking Needle Valve Lift

3300 psi (15 158 and 22 737 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 a poor needle valve seat.

If the valve opening pressure is within 2200-3300 psi (15 158-22 737 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 9462-02 (Fig. 16) as follows:

1. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

2. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

3. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. The lift should be .008 " to .018 ". If it exceeds .018 ", the tip assembly must be replaced. If it is less than .018", inspect for foreign material between the needle valve and the tip seat.
Meat

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 and check the injector output with calibrator J 22410.

Needle Valve Tip Test (Using Auxiliary Tester J 22640)

1. Connect the pipe from auxiliary tester J 22640 to the rear of the J 23010 tester at the connection located near the bottom of the tester (Fig. 17).

2. Assemble cleaned injector parts, including the check valve cage, spring, spring seat, spring cage and spray tip assembly, on the auxiliary tester J 22640 (Fig. 18).

3. Carefully pilot the injector nut over the spray tip and valve parts and thread it on the auxiliary tester.

4. Tighten the injector nut.

5. Open the valve on the auxiliary tester and place lever 4 in the up (horizontal) position.

6. Install the shield on the auxiliary tester and operate pump lever 1 until the needle valve has opened several times to purge the air from the system.

7. Operate pump lever 1 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 3300 psi (15 158 and 22 737 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 2200-3300 psi (15 158-22 737 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

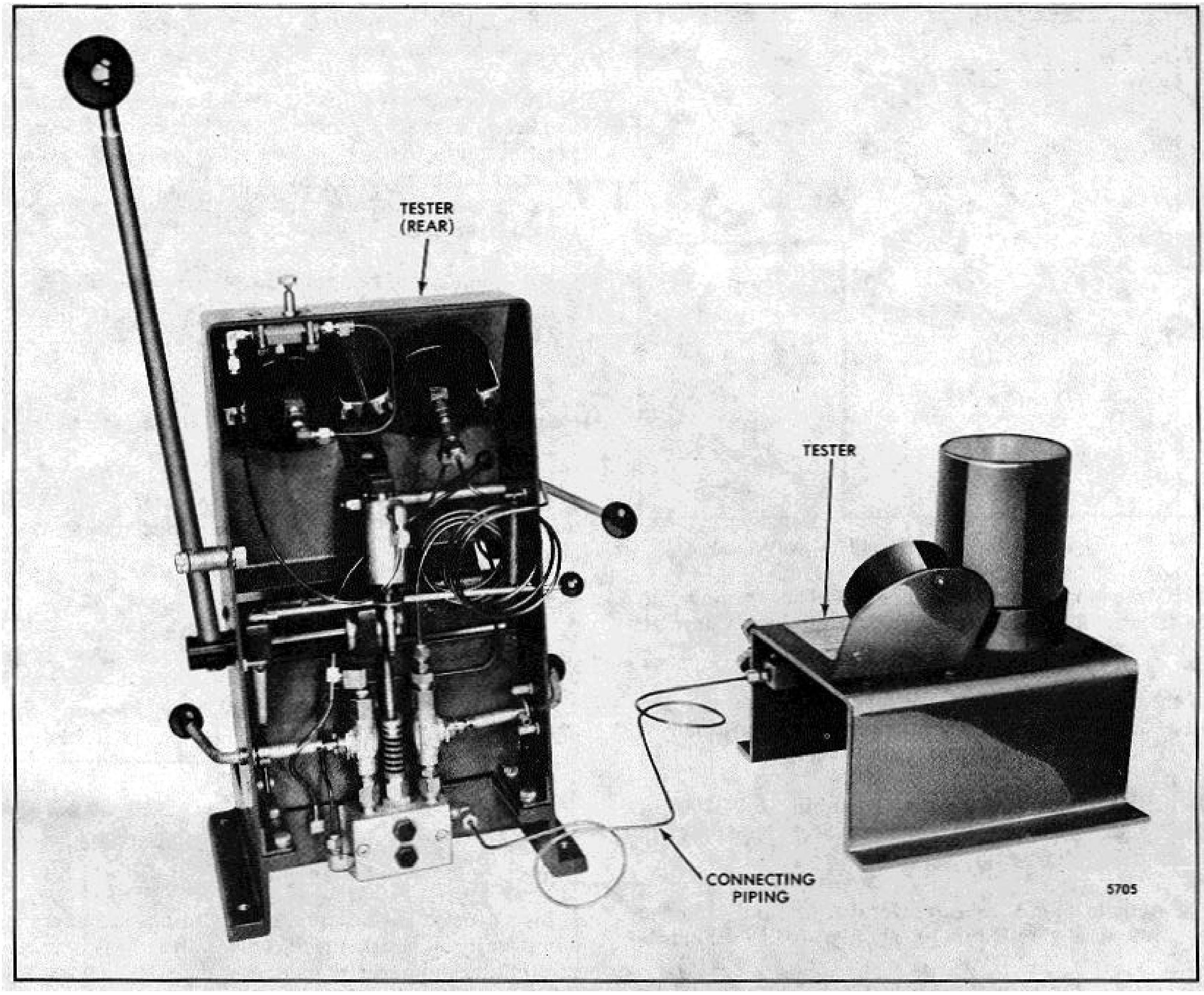


Fig. 17 - Injector Needle Valve Tester J 23010 with Auxiliary Tester J 22640

no fuel droplets although 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 testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

Before removing an injector from the engine. note the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the braided fuel inlet tube and the plastic fuel outlet tube on the calibrator (Fig. 20) depends on the adaptor being used and the direction of fuel flow through the injector.

Calibrator J 22410

To check the fuel output, operate the injector in calibrator J 22410 (Fig. 21) as follows:

NOTE:
Place the cam shift index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch and preheat the test oil to 95-105 °F (35-40 °C).

1. Place the proper injector adaptor between the tie

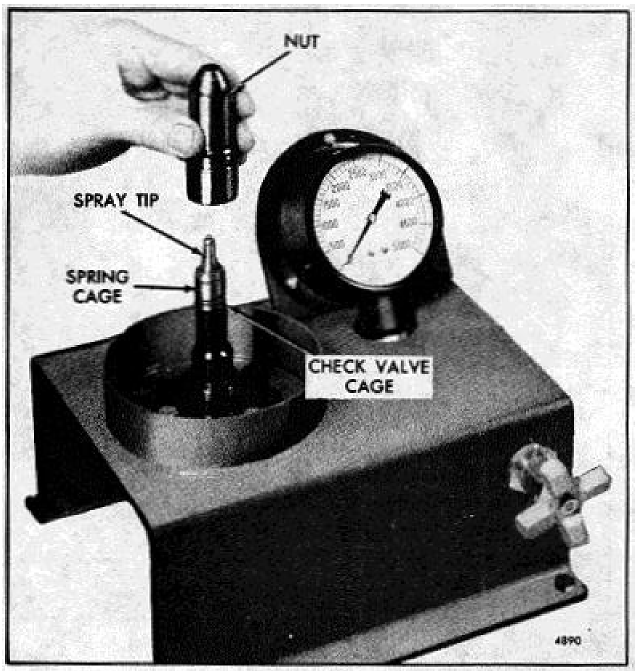


Fig. 18 - Installing Injector Valve Parts on Auxiliary Tester J 22640

INJECTOR	CALIBRATOR J 22410 Min.-Max.	INJECTOR	CALIBRATOR J 22410 Min.-Max.
N65 (white tag)	64 69	7A65	66 71

Fig. 19. Fuel Output Chart

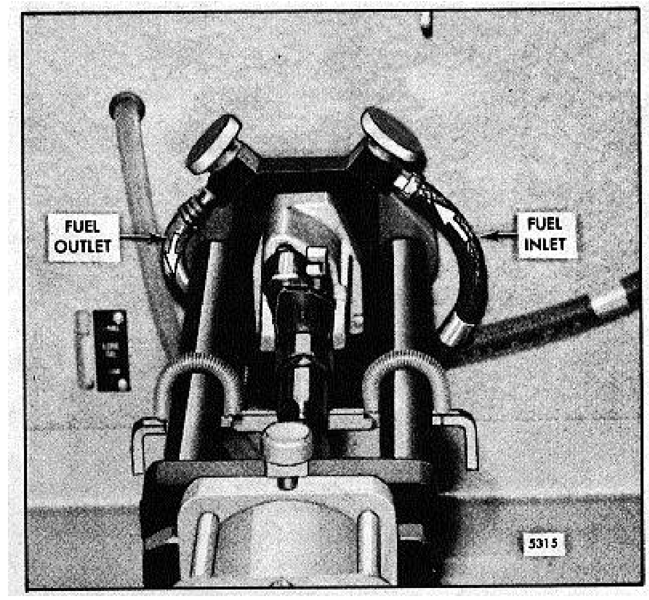


Fig. 20 - Position of Calibrator Fuel Flow Pipes

rods and engage it with the fuel block locating pin. Then slide the adaptor forward and up against the fuel block face.

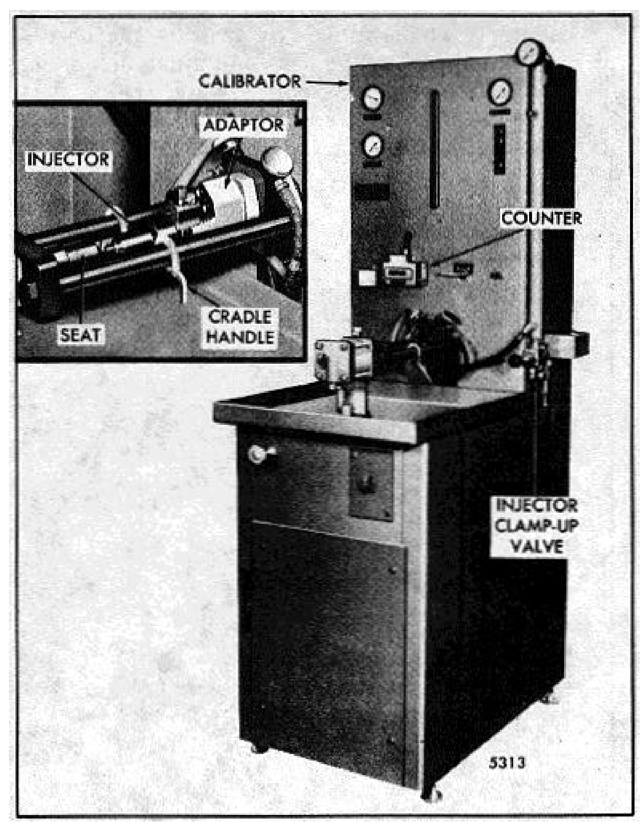


Fig. 21. Injector in Calibration J 22410

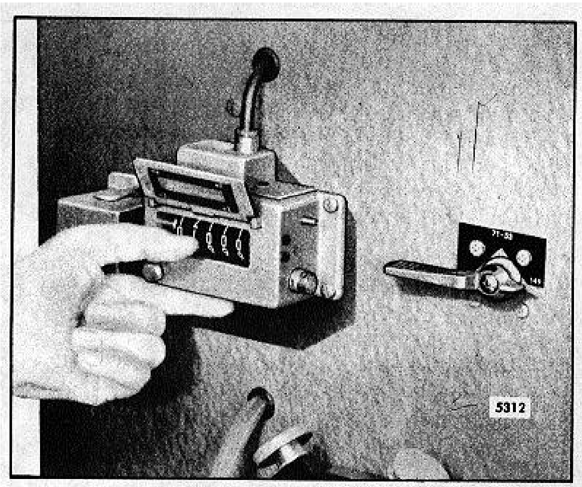


Fig. 22 Setting Calibrator Stroke Counter

2. Place the injector seat J 22410-226 into the permanent seat (cradle handle in vertical position). Clamp the injector into position by operating the air valve.

NOTE:

Make sure the counter (Fig. 22) on the calibrator is preset at 1000 strokes. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and hold the reset lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

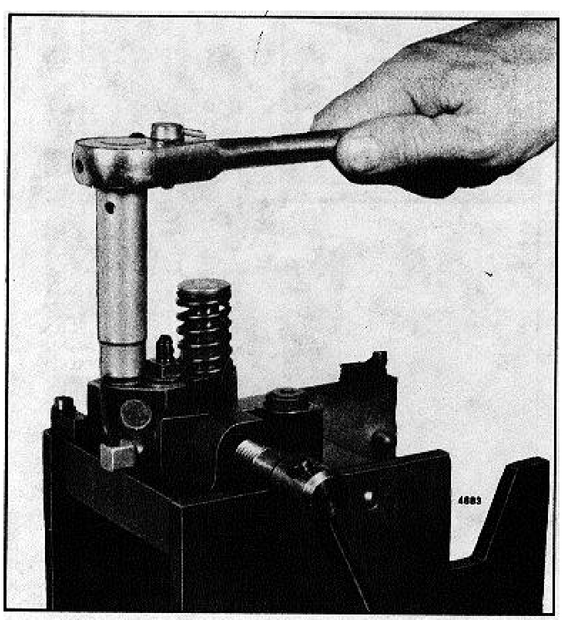


Fig. 23. Removing or Installing Filter Cap

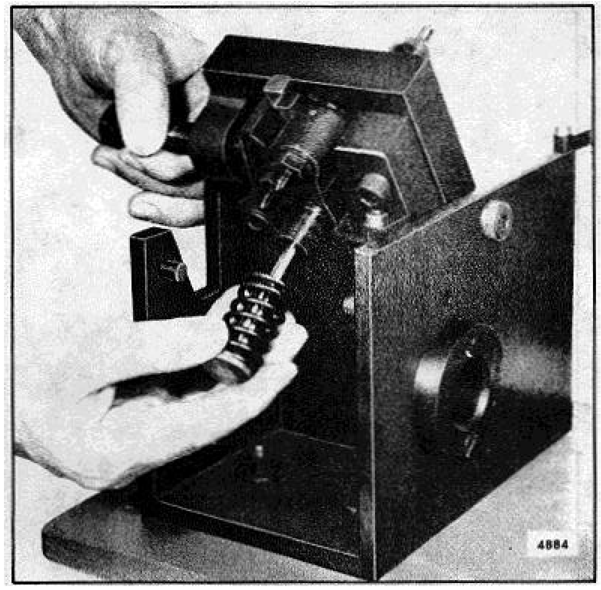


Fig. 24 Removing or Installing Plunger Follower, Plunger and Spring

3. Pull the injector rack out to the no-fuel position.

4. Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

NOTE:

The low oil pressure warning buzzer will

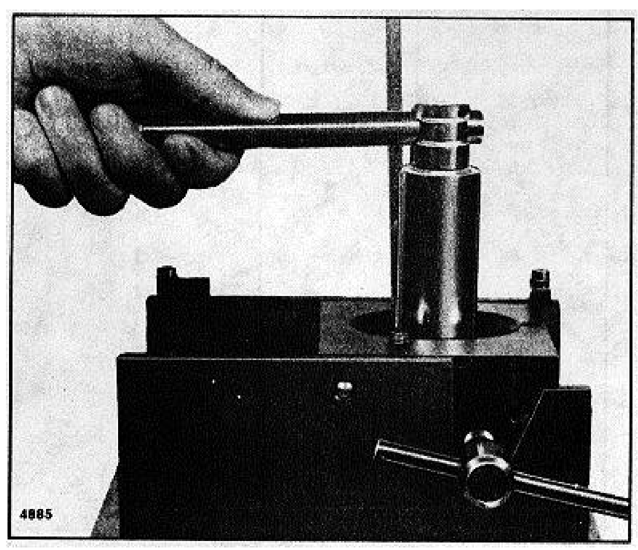


Fig. 25. Removing Injector Nut

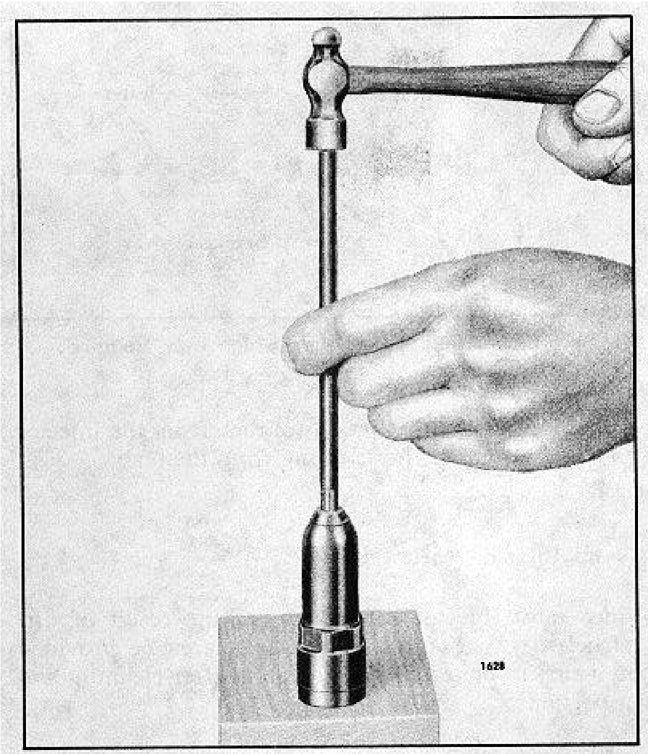


Fig. 26. Removing Spray Tip from Injector Nut
sound briefly until the lubricating oil reaches the proper pressure.

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.

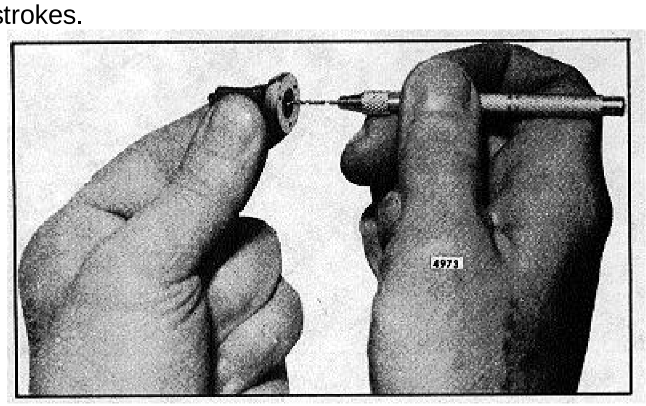


Fig. 27. Cleaning injector Spray Tip

7. Shut the calibrator off (the calibrator will stop in less time at full-fuel).

8. Observe the vial reading and refer to Fig. 19 to determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to *Trouble Shooting Chart 3* and *Shop Notes* on Page 10-3-61 for the cause and remedy.

NOTE:
Refer to Page 10-3-59 for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

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 (Fig. 23) and remove the filter caps, gaskets and filters.

NOTE:
Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. *In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. .34).*

2. Compress the follower spring as shown in Fig. 11.

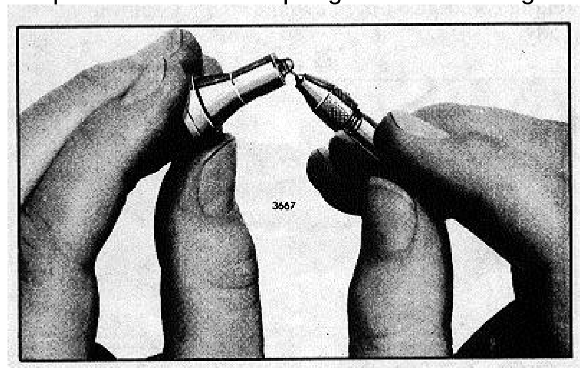


Fig. 28. Cleaning Spray Tip Orifices

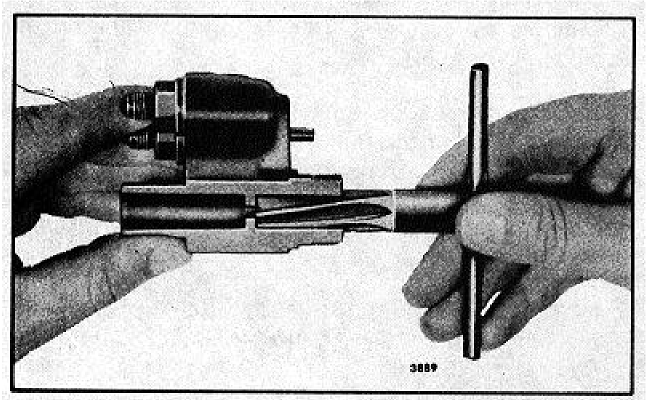


Fig. 29. Cleaning Injector Body Ring with Tool J 21089

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 Fig. 24 and remove the plunger follower, plunger and spring as an assembly.

4. Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (Fig. 25).

5. Lift the injector nut straight up, being careful not to dislodge 'the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly.

When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291-02 as shown in Fig. 26.

6. Refer to Fig. 36 and remove the spill deflector. Then lift the bushing straight out of the injector body.

7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

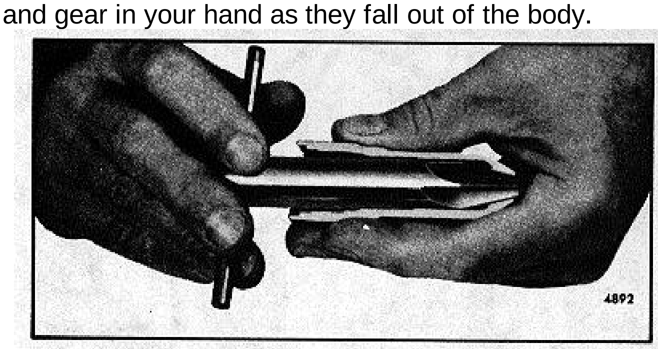


Fig. 30. Cleaning Injector Nut Spray Tip Seat with Tool J 9418-5

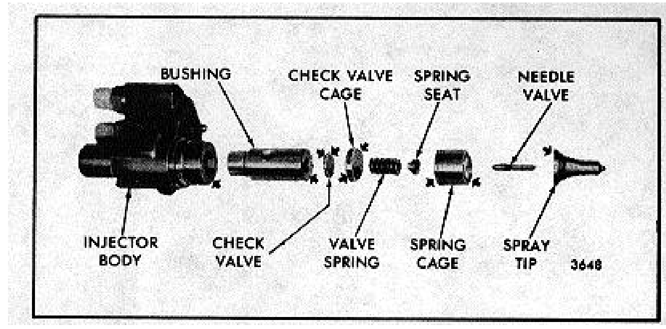


Fig. 31. Sealing Surfaces which may Require Lapping

8. Withdraw the injector control rack from the injector body. Also remove the seal ring from the body.

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.

Clean the spray tip with tool J 9464-01 (Fig. 27).

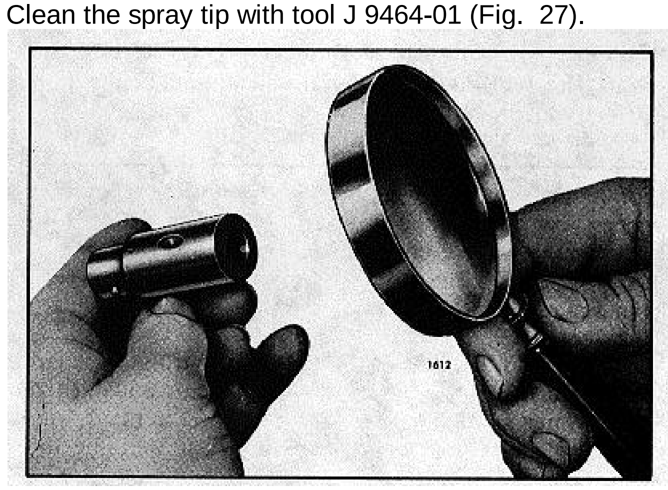


Fig. 32. Examining Sealing Surface with a Magnifying Glass

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.

Wash the tip in fuel oil and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1 and the proper size spray tip cleaning wire. Use wire J 21460 to clean .0055 " diameter holes and wire J 21461 to clean .006 " diameter holes (Fig. 28).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16 " with stone J 8170. Allow the wire to extend 1/8 " from tool J 4298-1.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

CAUTION:

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

When the body of the spray tip is clean, lightly buff the tip end in the same manner. This cleans the spray tip orifice area and will not plug the orifices.

Wash the spray tip in clean fuel oil and dry it with compressed air.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully insert reamer J 21089 in the injector body (Fig. 29). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a 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

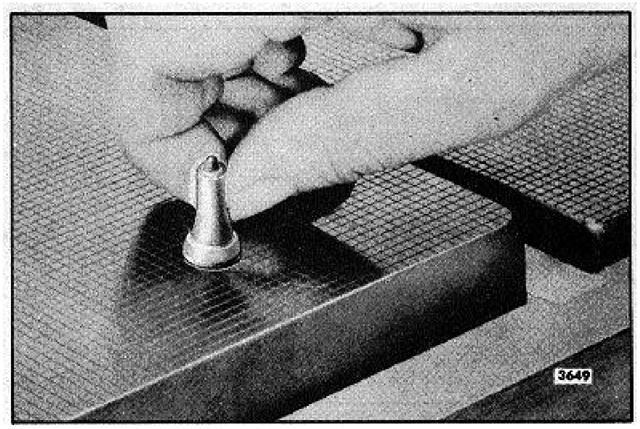


Fig. 33. Lapping Spray Tip on Lapping Blocks J 22090

J 9418-5 (Fig. 30). Use care to minimize removing metal or setting up burrs on the spray tip seat. Remove only enough metal to produce a clean uniform seat to prevent leakage between the tip and the nut. Carefully insert carbon remover J 9418-1 in the injector nut. Turn it clockwise to remove the carbon deposits on the flat spray tip seat.

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

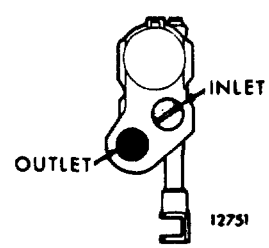


Fig. 34. Location of Filter in Injector Body

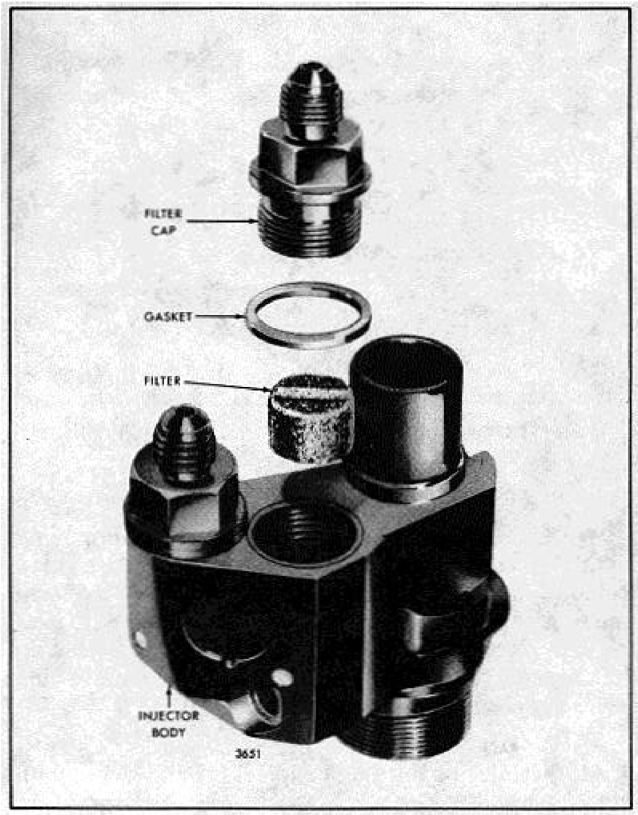


Fig. 35. Details of Injector Filters and Caps and Their Relative Location

operation, causing a serious oil dilution problem. *Keep the plunger and bushing together as they are mated parts.*

After washing, submerge the parts in a clean receptable containing clean fuel oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts

Inspect the teeth on the control rack and the control rack gear for excessive wear or damage. Also check for excessive wear in the bore of the gear and inspect the gear retainer. Replace damaged or worn parts.

Inspect the injector follower and pin for wear. Refer to Page 10-3-55.

Inspect both ends of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500 grit stone.

Inspect the follower spring for visual defects. Then check the spring with spring tester J 22738-02.

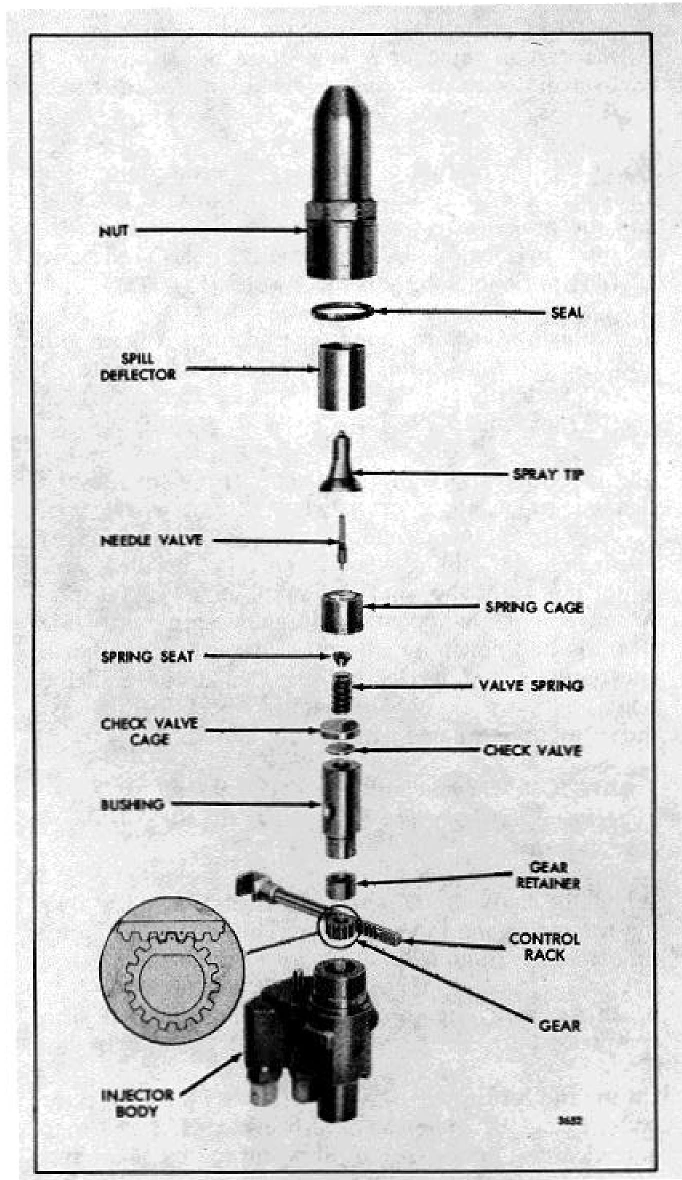


Fig. 36. Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

The current injector follower spring (.142 " diameter wire) has a free length of approximately 1.504 " and should be replaced when a load of less than 70 lbs. will compress it to 1.028 ".

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and check for free movement. *Replace the plunger and bushing as an assembly if any of the above damage is noted, since they are mated parts.* Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

Examine the spray tip seating surface of the injector nut and spray tip for nicks, burrs, erosion or brinelling. Reseat the surface or replace the nut or tip if it is severely damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

Inspect the sealing surfaces of the injector parts indicated by arrows in Fig. 31. Examine the sealing surfaces with a magnifying glass as shown in Fig. 32 for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. 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 Table 1.

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

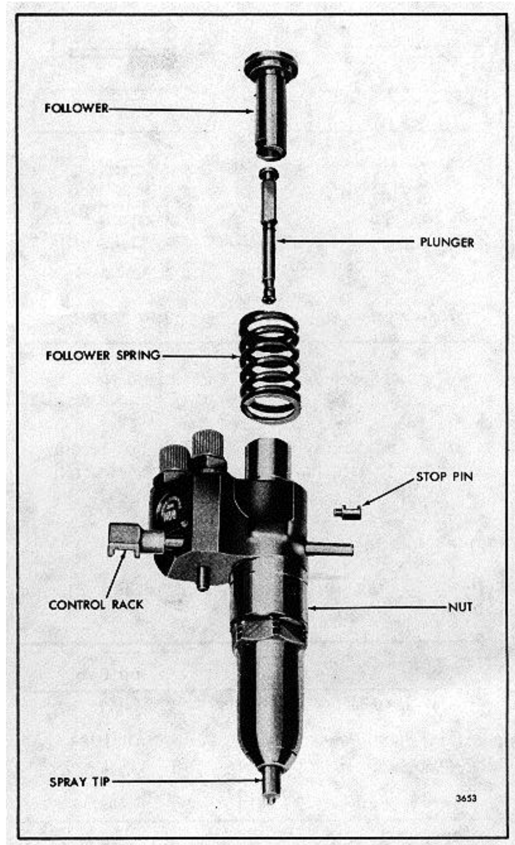


Fig. 37. Injector Plunger, Follower and Relative Location of Parts

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 arrows in Fig. 31. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

NOTE:
The sealing surface of current spray tips is precision lapped by a new process which leaves the surface with a dull satin-like finish; the lapped surface on former spray tips was

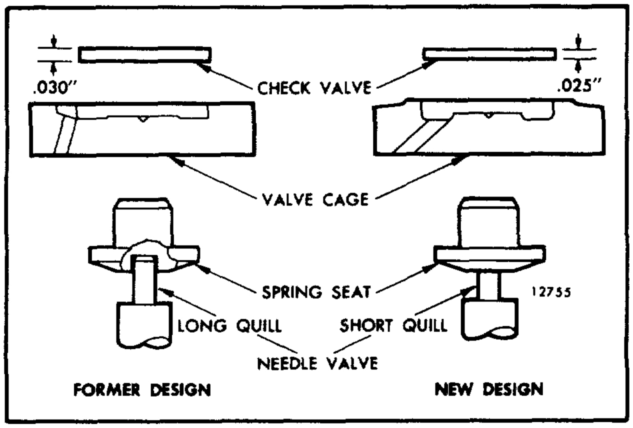


Fig. 38. Comparison of Former and New Design Injector Parts

bright and shinny (Fig. 39). It is not recommended to lap the surface of the new current spray tip.

Lapping Injector Parts

Lap the sealing surfaces indicated in Fig. 31 and Table I as follows:

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163" -.165"
Check Valve	.022"
Valve Spring Cage	.602"

TABLE 1. Minimum Thickness (Used Parts)

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.

2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.

3. Place the part to be lapped flat on the block as shown in Fig. 33 and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.

4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. Do not lap excessively (refer to Table 1).

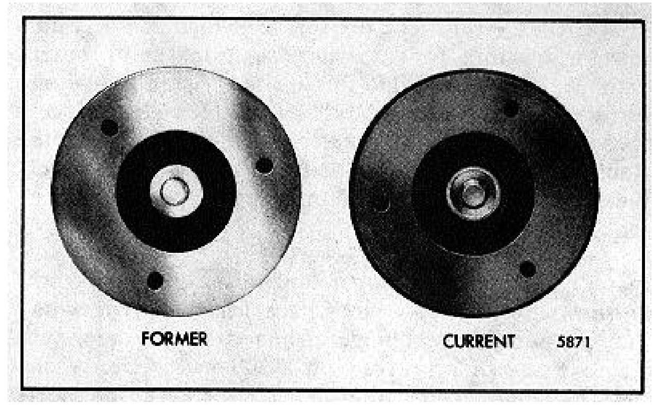


Fig. 39. Spray Tip Sealing Surface Identification

5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. Do not lap excessively. Again wash the part in cleaning solvent and dry it with compressed air.

7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and

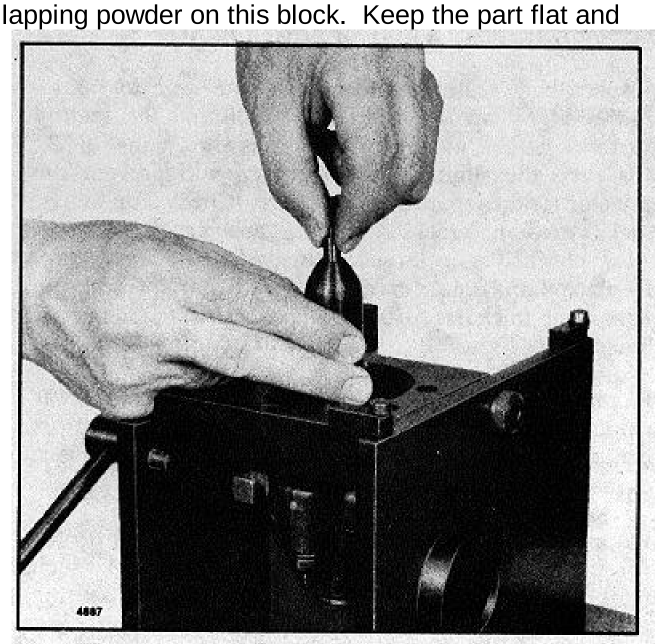


Fig. 40. Tightening Injector Nut by Hand

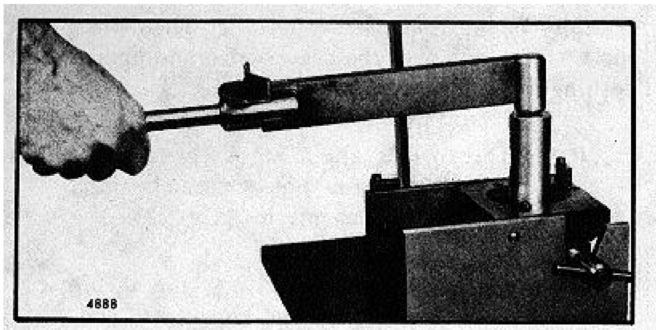


Fig. 41.· Tightening Injector Nut With Torque Wrench

move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.

8. Wash all of the lapped parts in clean fuel oil and dry them with compressed air.

ASSEMBLE INJECTOR

Use an extremely clean bench to work on and to place the parts when assembling an injector. Also be sure all of the injector parts, both new and used, are clean.

Study Figs. 34 through 37 for the proper relative position of the injector parts, then proceed as follows:

Assemble Injector Filters

Always use new filters and gaskets when reassembling an injector.

1. Insert a new filter, dimple end down, slotted end up, in each of the fuel cavities in the top of the injector body (Fig. 35).

NOTE:
Install a new filter in the inlet side (located over the injector rack) in a fuel injector with an offset body. No filter is required in the outlet side of the offset body injector (Fig. 34).

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 (Fig. 23).

3. Purge the filters after installation by directing compressed air or fuel through the filter caps.

4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

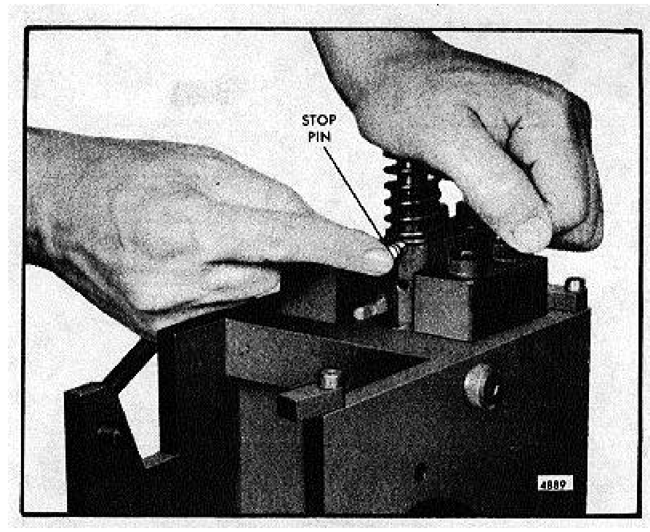


Fig. 42. Installing Injector Follower Stop Pin

Assemble Rack and Gears

Refer to Fig. 36 and note the drill spot marks on the control rack and gear. Then proceed as follows:

1. Hold the injector body, bottom end up, and slide the rack through the hole in the body. Look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

2. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 36).

3. Place the gear retainer on top of the gear.

4. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

Assemble Spray Tip, Spring Cage and Check Valve Assemblies

Refer to Fig. 36 and assemble the parts as follows:

1. Support the injector body, bottom end up, in injector holding fixture J 22396.

2. Place a new seal ring on the shoulder of the body.

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 becoming shredded.

A new injector nut seal ring protector (J 29197) is now available to install the seal ring. Use the following

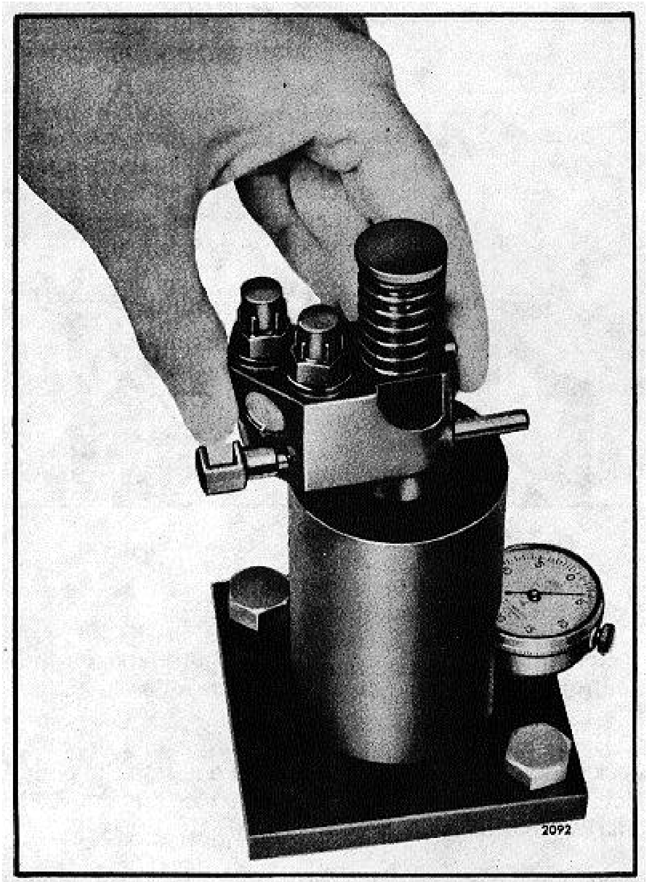


Fig. 43. Checking Injector Spray Tip Concentricity using Tool J 29584

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 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.

4. Place the check valve (without the .010" hole) centrally on the top of the bushing. Then place the check valve cage over the check valve and against the bushing.

NOTE:
The former and new check valve and check valve cage are not separately interchangeable in a former injector (Fig. 38).

5. Insert the spring seat in the valve spring, then insert the assembly into the spring cage, spring seat first.

NOTE:
Install a new spring seat (Fig. 38) in a former injector if a new design spray tip assembly is used.

6. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

NOTE:
When installing a new spray tip assembly in a former injector, a new valve spring seat must also be installed. The current needle valve has a shorter quill.

7. Insert the needle valve, tapered end down, inside of the spray tip (Fig. 2). Then place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

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 (Fig. 40). 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.

9. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 75-85 lb-ft (102-115 Nm) torque (Fig. 41).

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.

Assemble Plunger and Follower

1. Refer to Fig. 37 and slide the head of the plunger into the follower.

2. Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way in. Then place the follower spring on the injector body.

3. Refer to Fig. 42 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. Then align the slot in the follower with the stop pin hole in the injector body. Next align the flat side of the plunger with the slot in the follower. Then insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

Check Spray Tip Concentricity

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in the concentricity gage J 29584 as shown in Fig. 43 and adjust the dial indicator to zero.

2. Rotate the injector 360 ° and note the total runout as indicated on the dial.

3. If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 75-85 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) previously outlined under *Test Injector*.

The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble and test the injector again.

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, Page 10-3-27. to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to Fig. 6 and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.

2. Slide the injector rack control lever over so that it registers with the injector rack.

3. Install the injector clamp, special washer (with 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.

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 brackets to the cylinder head by tightening the bolts to the torque specified on Page 10-3-62.

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 10-3-56.

NOTE:
An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover. A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal

conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectors. Reinstall the rocker cover. Then drain the lubricating oil and change the oil filter elements. Refer to Page 10-9-9 and refill the crankcase to the proper level with the recommended grade of oil.

6. Perform a complete engine tune-up as outlined in Chapter 10. 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

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Fig. 1. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at the top with a neoprene ring and upset into a flare on the lower side of the cylinder head to create water-tight and gas-tight joints at the top and bottom.

Effective with engine serial number 4A-222102 a new Fluoroelastomer (Viton) seal ring is being used.

NOTE: Do not use methoxy propanol based antifreeze in the cooling system of any Detroit Diesel engine built after the above engine serial numbers, or engines where the new (Viton) seal ring has been installed.

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 tube seal ring leak. Then with the fuel injector removed, insert the swaging tool into the fuel injector hole tube. The tool is tapered and flanged to prevent damage to the cylinder head or injector tube. Hit the top of the tool moderately with a one pound hammer two or three blows seating the tool. This will cause the top edge of the injector hole tube to expand, thus increasing the crush on the injector tube seal ring and seal the leak. Install the fuel injector and again pressurize the cooling system to verify the leak has been stopped.

This tool was designed mainly for use on engines built between July, 1973 and August, 1977 with fuel injector hole tube seal rings that may be pressure sensitive and, if so, could take a heat set. The result being a coolant leak at the seal ring. The use of the swaging tool, as stated above, will restore tension to the seal ring.

Remove Injector Tube

When removal of an injector tube is required, use; injector tube service tool set J 22525 as follows:

1. Remove, disassemble and clean the cylinder head as outlined on Page 10-2-20.

2. Place the injector tube installer J 5286-4 in the injector tube. Insert the pilot J 5286-5 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer (Fig. I).

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: I. Place a new injector tube seal ring in the counterbore in the cylinder head.

2. Place the installer J 5286-4 in the injector tube. Then insert the pilot J 5286-5 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig. 2).

3. Slip the injector tube into the injector bore and drive it in place as shown in Fig. 2. Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.

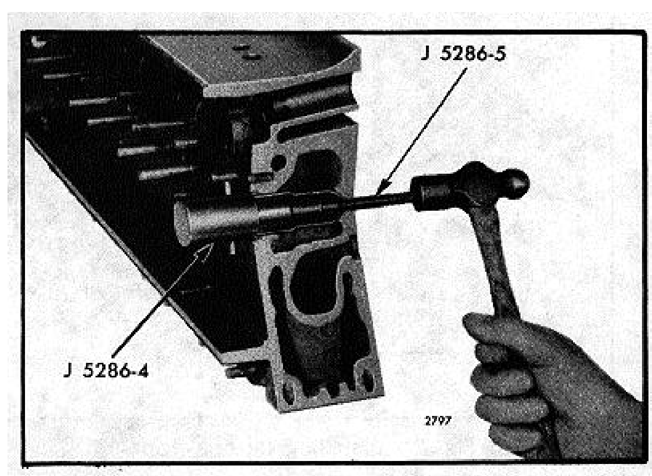


Fig. 1 - Removing Injector Tube

4. With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:
a. Turn the cylinder head bottom side up, remove the pilot J 5286-5 and thread the upsetting die J 5286-6 into the tapped end of the installer J 5286-4 (Fig. 3).

b. Then, using a socket and torque wrench, apply approximately 30 Ib-ft (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 Fig. 4, to receive the injector body nut and spray tip; second, *spot-faced* to remove excess stock at the lower end of the injector tube; and third, *hand reamed*, as shown in Fig. 5, to provide a good seating surface for the bevel or the lower end of the injector nut. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

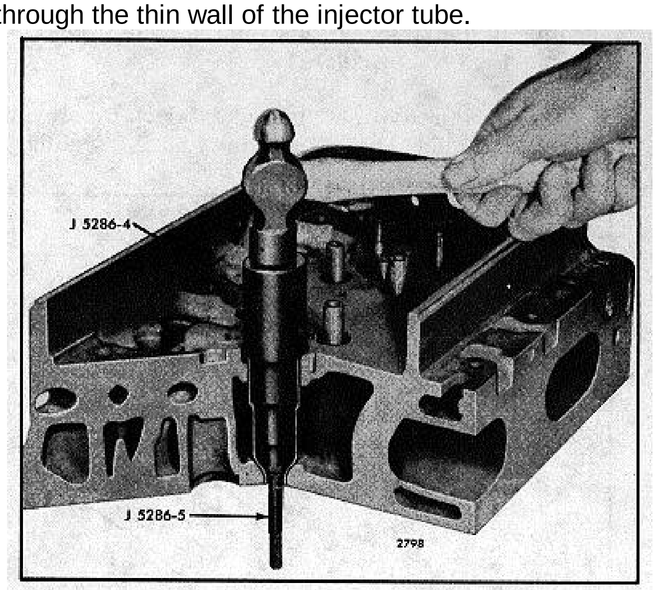


Fig. 2 - Installing Injector Tube

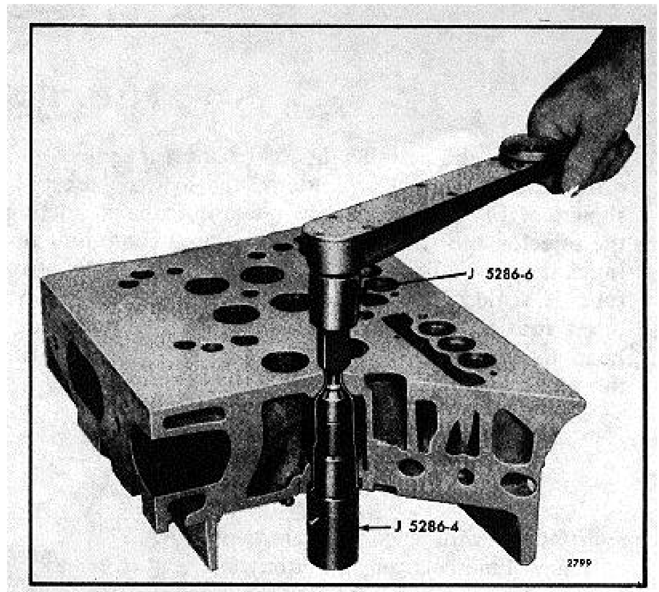


Fig. 3 - Upsetting Injector Tube

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 edges of the flutes.

1. Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:

a. Place a few drops of light cutting oil on the reamer flutes, then carefully position the reamer J 22525-1 in the injector tube.

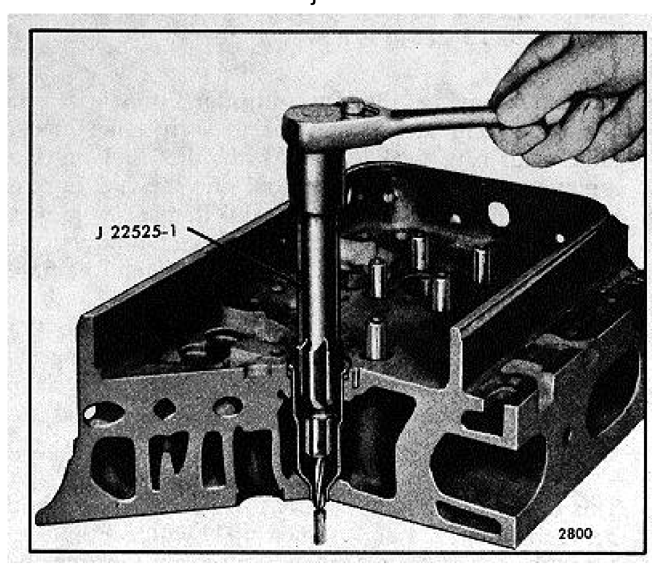


Fig. 4 - Reaming Injector Tube for Injector Body Nut and Spray Tip

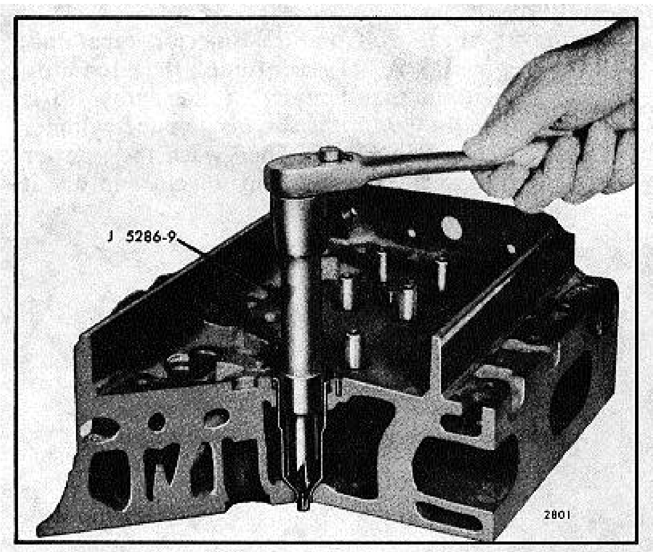


Fig. 5 - Reaming Injector Tube for Injector Nut

b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 4). Clean out all of the chips.

2. Remove excess stock:

a. With the cylinder head bottom side up, insert the pilot of cutting tool J 5286-8 into the small hole of the injector tube.

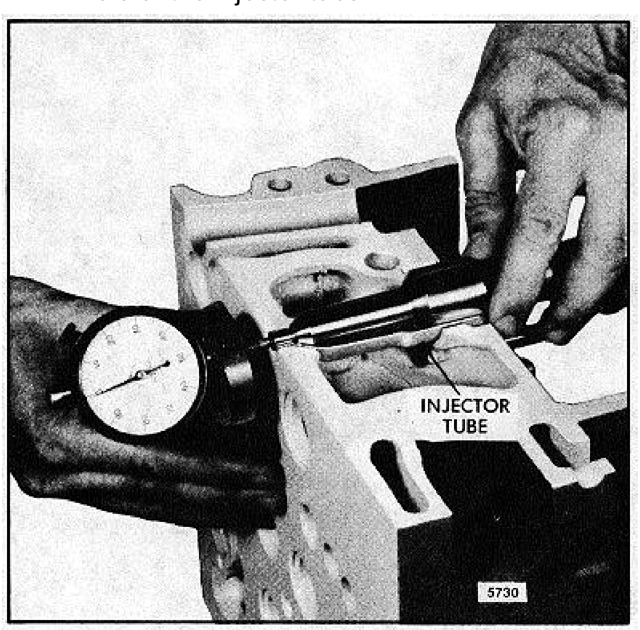


Fig. 6 Measuring Relationship of Bevel Seat of Injector Tube to Fire Deck of Cylinder Head

b. Place a few drops of cutting oil on the tool. Then, using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to .005 " below the finished surface of the cylinder head.

3. Ream the bevel seat in the injector tube:

The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip in the combustion chamber. Therefore, to determine the amount of stock that must be reamed from the bevel seat of the tube, refer to Fig. 6.

Install gage J 25521 in the injector tube. Zero the sled gage dial indicator J 22273 to the fire deck. Gage J 25521 should be flush to ±.014 " with the fire deck of the cylinder head (Fig. 7).

NOTE: Any fire deck resurfacing work must be done prior to final injector tube seat gaging. Refer to Page 10-2-22 for resurfacing instructions.

With the first reaming operation completed and the injector tube spot-faced, wash the interior of the injector tube with clean solvent and dry it with compressed air. Then perform the second reaming operation as follows:

a. Place a few drops of cutting oil on the bevel seat of the tube. Carefully lower the reamer J 5286-9 into the injector tube until it contacts the bevel seat.

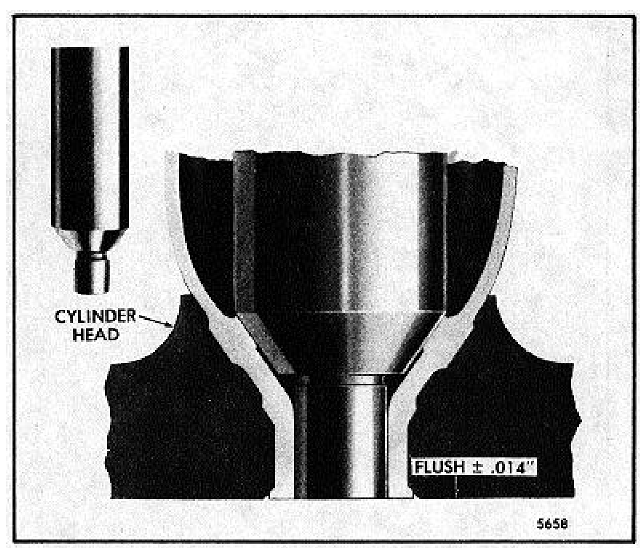


Fig. 7 - Measuring Relationship of Gage to Fire Deck of Cylinder Head

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 gage J 25521, continue the reaming operation until the shoulder of the spray tip is flush to ± .014 " with the fire deck of the cylinder head as shown in Fig. 7. Then wash the interior of the injector tube with clean solvent and dry it with compressed air.

FUEL PUMP

The positive displacement gear-type fuel pump (Fig. 1) transfers fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return manifold and fuel return line.

The fuel pump is attached to the rear end plate cover of the blower assembly with three nylon patch bolts which prevents the oil in the blower cover from seeping out around the bolt threads. The pump is driven off the end of the blower lower rotor by means of a drive coupling fork attached to the end of the pump drive shaft and mating with a drive disc attached to the blower rotor as shown in Fig. 2.

Fuel pumps are furnished in left-hand or right-hand rotation. Since the engine is right-hand rotation, a right-hand pump is used' and is stamped "RH IN". These pumps are not interchangeable, nor can a pump made for one rotation be rebuilt for the other rotation since the relief valve can be installed in only one position in the pump body.

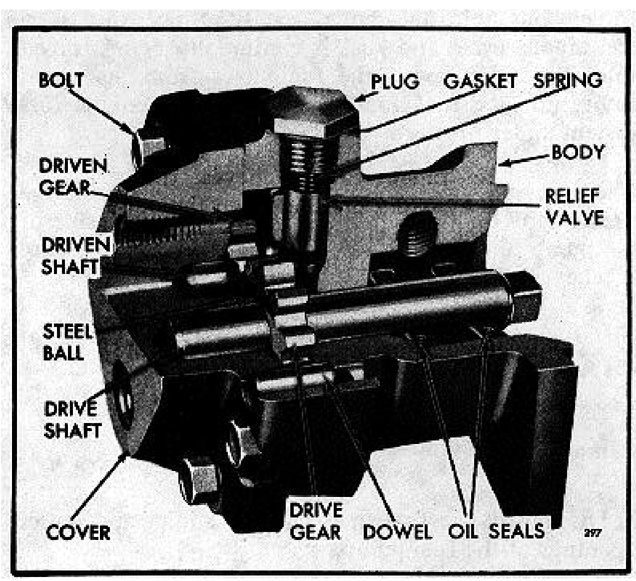


Fig. 1 - Typical Fuel Pump Assembly

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal-to-metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

The fuel pump body is recessed to provide running space for the pump gears (Fig. 3). Recesses are also provided at the inlet and outlet positions of the gears. The small hole "A" permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole "B" and provides for relief of excess discharge pressures. Fuel reenters the inlet side of the pump through hole "C" when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole "C". The cavity "D" provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the blower timing gear compartment (Fig. 4). The oil seals are installed with the lips of the seals facing toward the flanged end of the pump body. A small hole "E" (Fig. 3) serves as a vent passageway in the body, between the inner oil seal and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the inner seal.

However, in this application, where the fuel supply tank is mounted at a level higher than the fuel pump on the engine, the inner seal is installed with the lip of the seal facing the gear pocket (Fig. 4). In this case, the inner seal will prevent seepage of fuel oil along the pump shaft and out the drain hole in the pump body, especially when the engine is shut down. Fuel pumps with this seal arrangement are identified by a "star" stamped on the ground face of the pump cover.

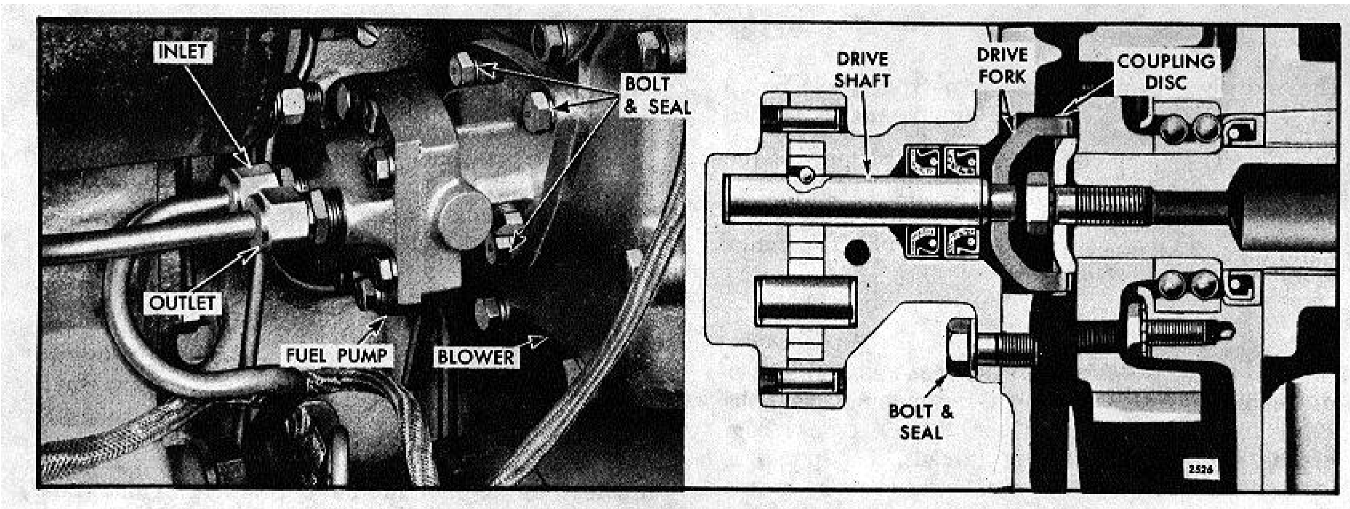


Fig. 2 - Typical Fuel Pump Mounting and Drive

However, a standard pump may be reworked for use in such applications by removing the two oil seals and installing new seals with the lips facing away from each other.

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seepage. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

Effective with engines built November, 1979; a higher temperature material lip type seal is now being used in the fuel pumps. The new fuel pump seal is made of a polyacrylate material, whereas the former seal is made of nitrile. The new fuel pumps (with the polyacrylate seals) will have the seals installed the same as the high lift fuel pumps, with the lips of the seals facing in the opposite direction of each other (Fig. 4). The former fuel pumps have the nitrile seals installed with both seal lips facing the mounting flange end of the pump. Both the polyacrylate and nitrile seals are interchangeable in a fuel pump. Only the polyacrylate seals and fuel pumps with polyacrylate seals will be serviced.

The drive and driven gears are a line-to-line to .001" press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft (Fig. 2).

A spring-loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to the fuel filter) reaches approximately 65 psi (448 kPa).

Operation

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by by-passing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 65 to 75 psi (448 to 517 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold as shown on Page 10-9-6.

Remove Fuel Pump

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.

2. Disconnect the drain tube from the fuel pump.

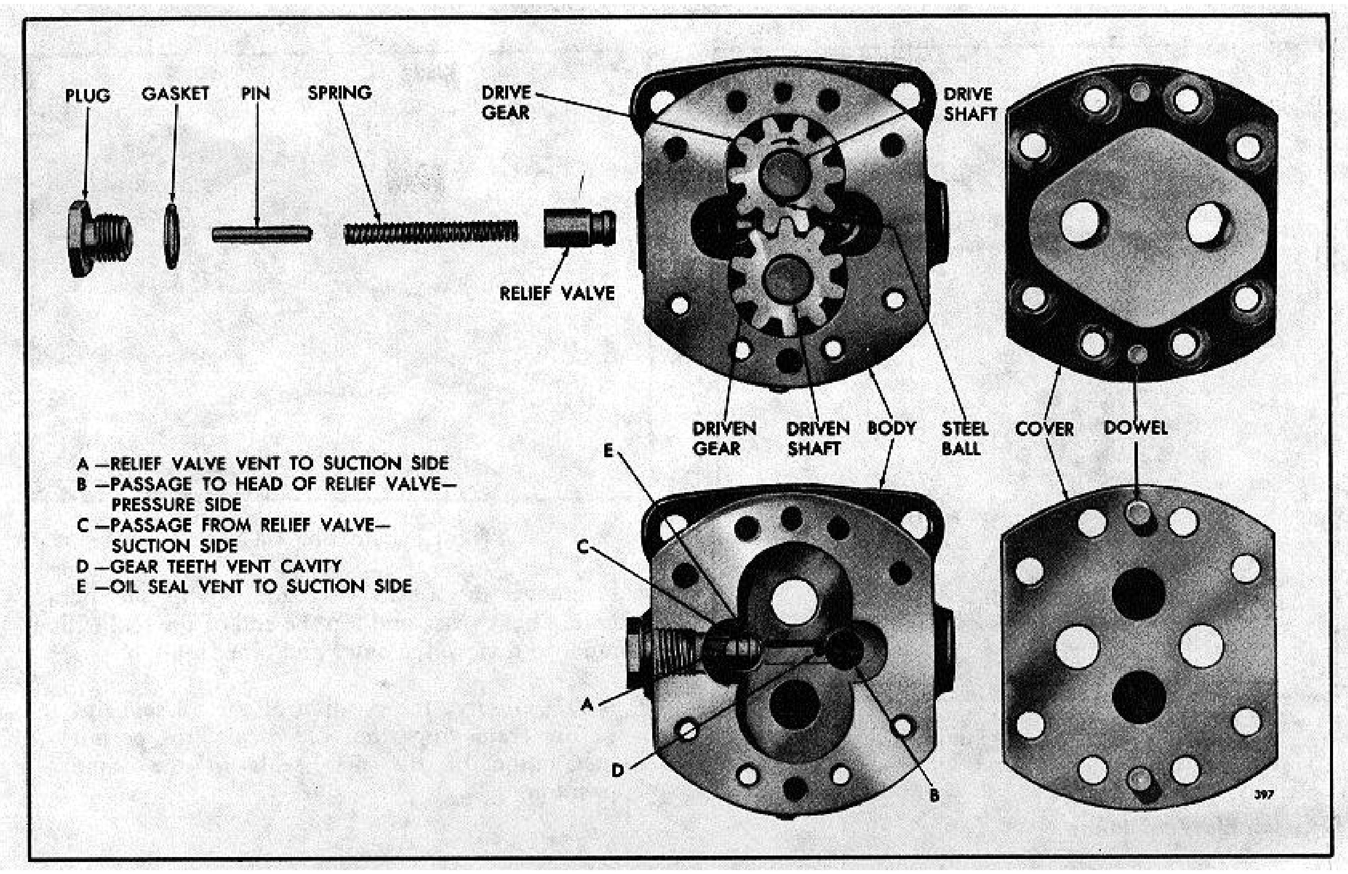


Fig. 3 - Fuel Pump Valving and Rotation (Right-Hand Pump)

3. Remove the three pump attaching bolts, using wrench J 4242, and withdraw the pump from the blower.

4. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

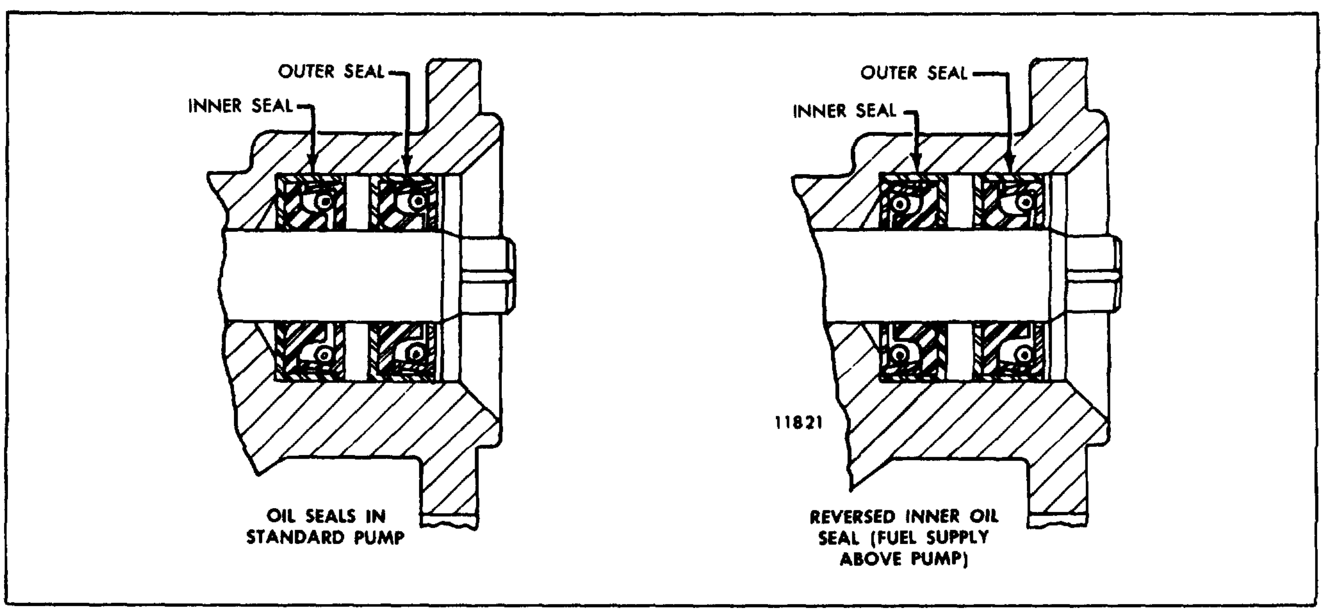


Fig. 4 - Fuel Pump Oil Seal Arrangements

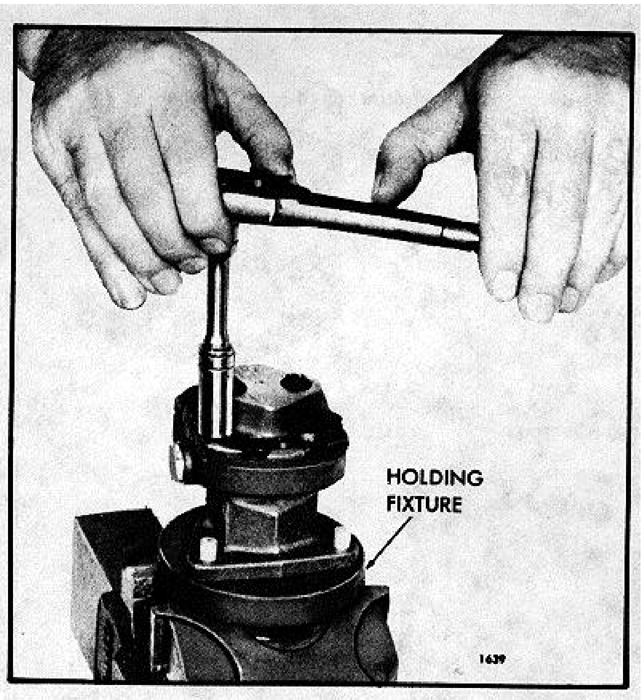


Fig. 5 - Removing Pump Cover

Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508-10 as shown in Fig. 5, refer to Figs. 1 and 7 and disassemble the pump as follows:

1. Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.

2. Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.

3. Press the drive shaft just far enough to remove the steel locking ball. Then invert the shaft and gear assembly and press the shaft from the gear. Do not misplace the steel ball. Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.

4. Remove the driven shaft and gear as an assembly from the pump body. Do not remove the gear from the shaft. The driven gear and shaft are serviced only as an assembly.

5. Remove the relief valve plug and copper gasket.

6. Remove the valve spring, pin and relief valve from the valve cavity in the pump body.

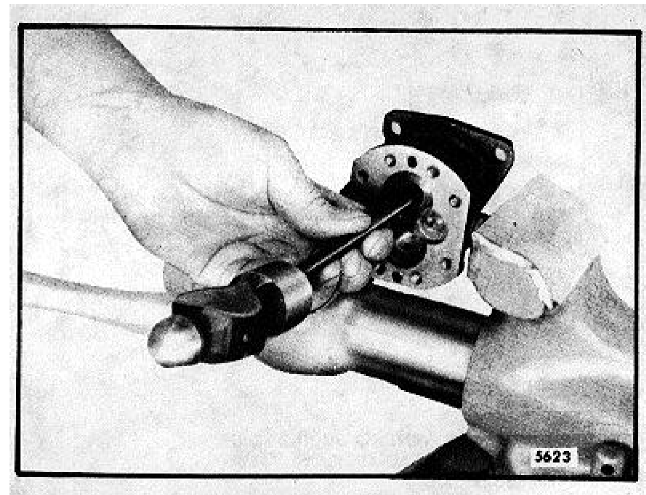


Fig. 6 - Removing Oil Seals

7. If the oil seals need replacing, remove them with oil Fig. 6 Removing Oil Seals seal remover J 1508-13 (Fig. 6). Clamp the pump body in a bench vise and tap the end of the tool with a hammer to remove the outer and inner seals.

NOTE: Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position.

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.

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.

Current standard fuel pumps (with 1/4" wide gears) incorporate a 1/8" shorter pump body with three drain holes, a 1/8" shorter drive shaft and a cover with a 3/8" inlet opening.

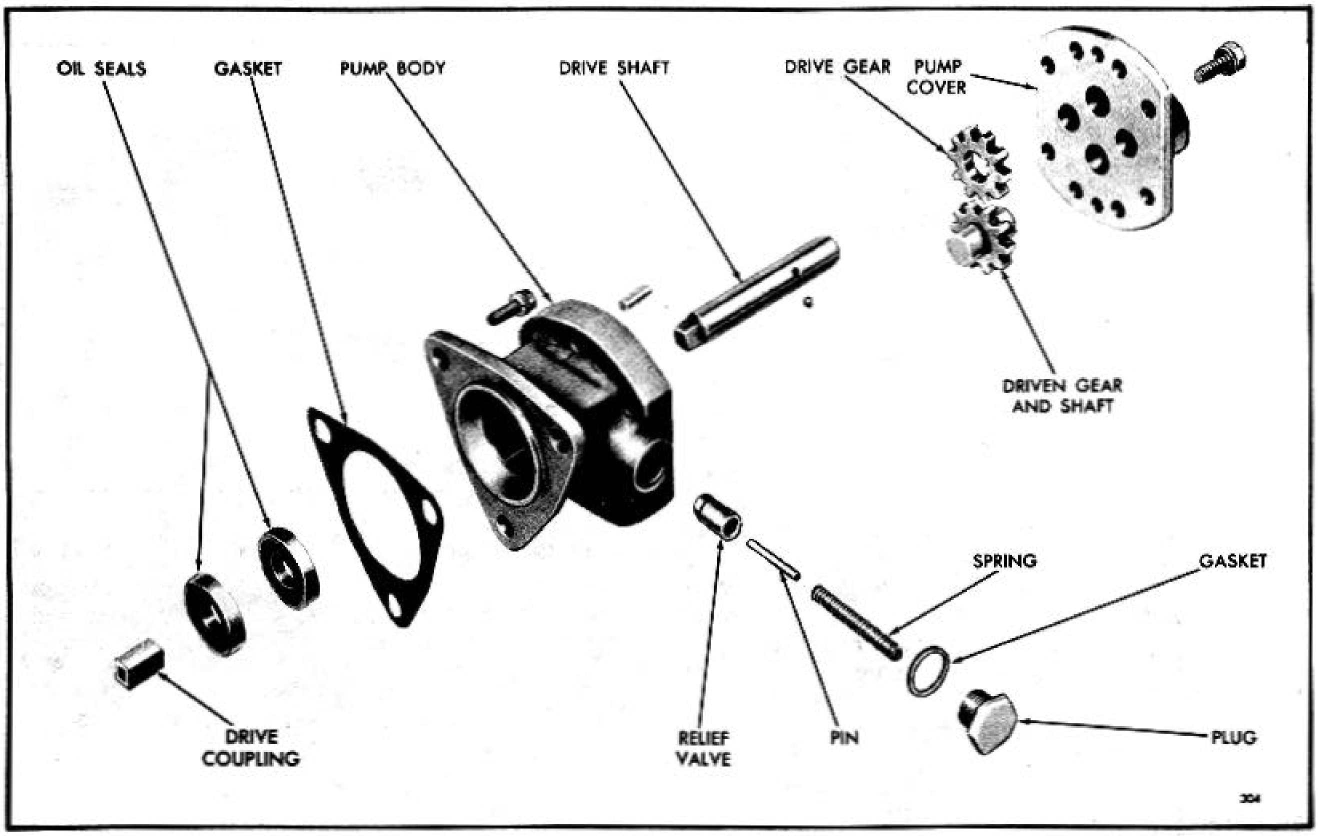


Fig. 7 - Fuel Pump Details and Relative Location of Parts

Assemble Fuel Pump

Refer to Figs. 1, 3 and 7 and assemble the pump as follows: 1. Lubricate the lips of the oil seals with a light coat of vegetable shortening, then install the oil seals in the pump body as follows:

CAUTION: The inboard seal facing "IN" requires greater care at assembly or service to prevent seal lip damage.

a. Place the inner oil seal on the pilot of the installer handle J 1508-8 so that the lip of the seal will face in the same direction as the original seal which was removed, or according to the application as previously described.

b. With the pump body supported on wood blocks (Fig. 8), insert the pilot of the installer handle in

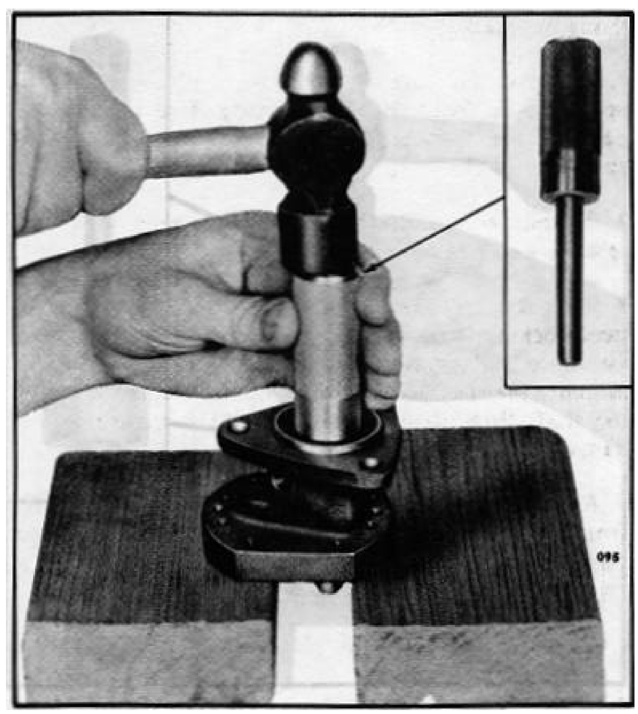


Fig. 8 - Installing Inner Oil Seal

the pump body so the seal starts straight into the pump flange. Then drive the seal in until it bottoms.

c. Place the shorter end of the adaptor J 1508-9 over the pilot and against the shoulder of the installer handle. Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing the adaptor. Then insert the pilot of the installer handle into the pump body and drive the seal in (Fig. 9) until the shoulder of the adaptor contacts the pump body. Thus the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

2. Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring inside of the valve and the pin inside of the spring. With a new gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the 1/2"-20 plug to 18-22 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 ball in the detent and press the gear back until the end of the slot contacts the ball.

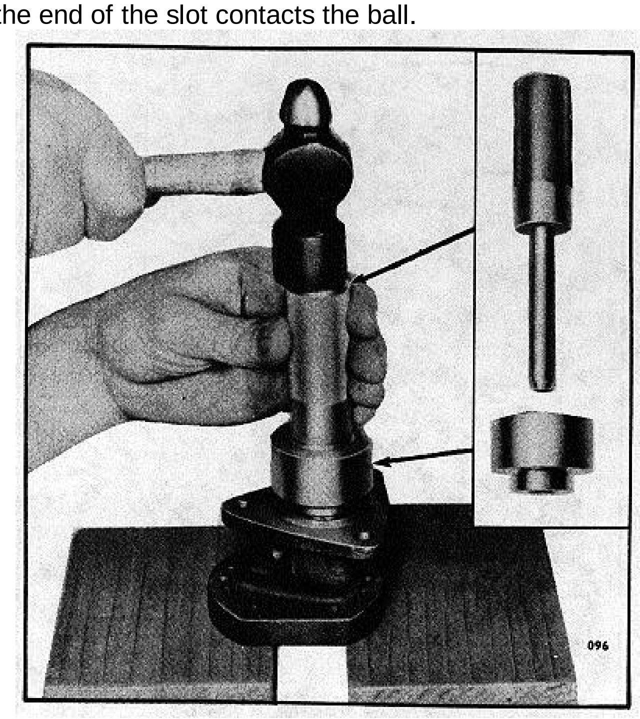


Fig. 9 - Installing Outer Oil Seal

4. Lubricate the pump shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals as shown in Fig. 10.

5. Place the driven shaft and gear assembly in the pump body.

NOTE: 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.

NOTE: The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too much sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result.

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 Fig. 2 that the

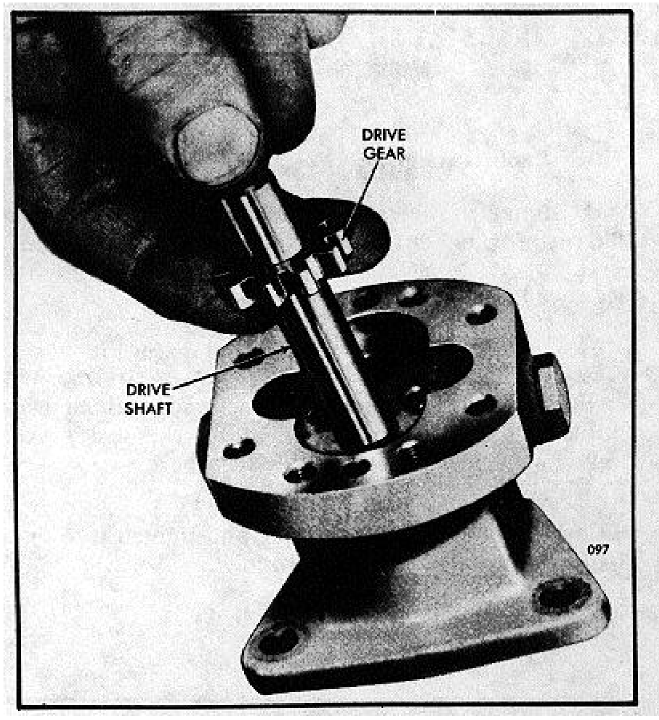


Fig. 10 Installing Drive Shaft and Gear Assembly

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.

NOTE: To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

4. If removed, install the fuel inlet and outlet fittings in the pump cover.

5. Connect the inlet and outlet fuel lines to the fuel pump.

6. Connect the fuel pump drain tube, if used, to the pump body.

7. If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine using tool J 5956. This will prevent the possibility of pump seizure upon initial starting.

FUEL STRAINER AND FUEL FILTER
(Spin-On Type)

A spin-on type fuel strainer and fuel filter (Fig. I) is used on this engine. The spin-on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly (Fig. 2). No separate springs or seats are required to support the filters.

The filter covers incorporate a threaded sleeve to accept the spin-on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

No drain cocks are provided on the spin-on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before reinstalling it.

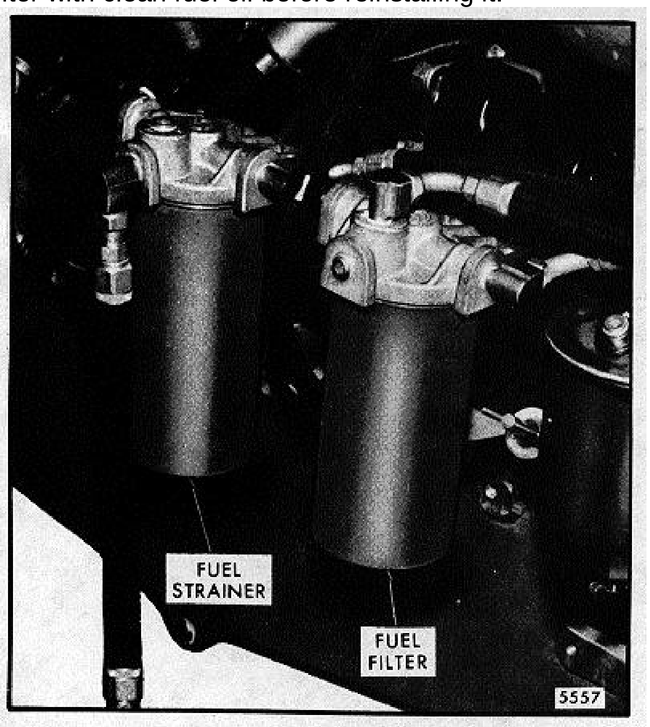


Fig. 1 - Typical Spin-On Filter Mounting

Filter Replacement

A 1" diameter twelve-point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

1. Unscrew the filter (or strainer) and discard it.

2. Fill a new filter replacement cartridge about two-thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

3. Install the new filter assembly and tighten it to one-half of a turn beyond gasket contact.

4. Start the engine and check for leaks.

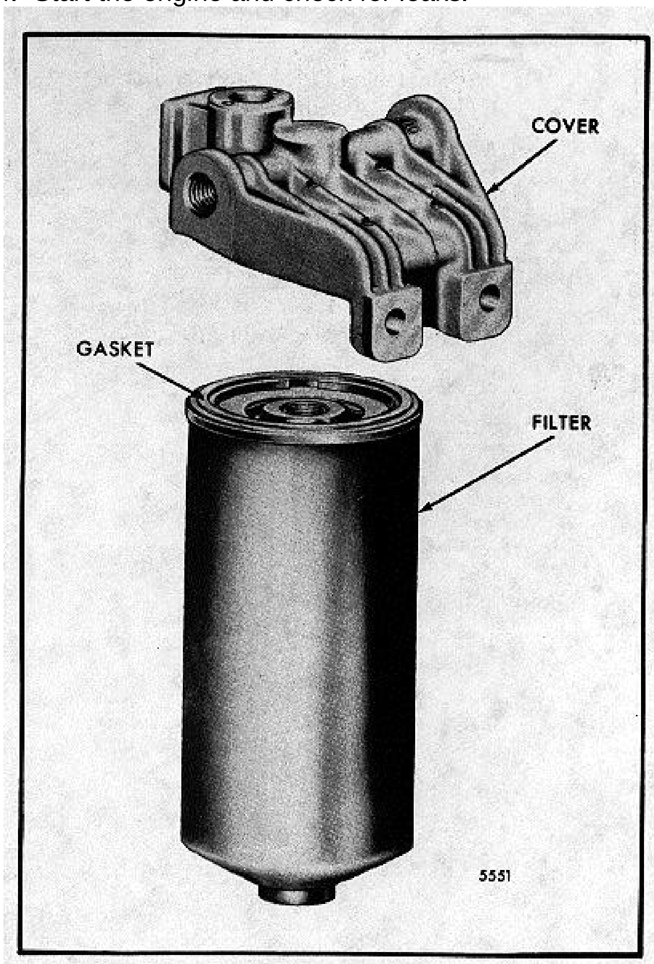


Fig. 2 - Spin-On Filter Details

FUEL MANIFOLD

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 heads (Fig. 1). Since there are inlet and outlet passages provided opposite each injector position in the side of the head as well as at each end, greater flexibility is permitted in the installation of the fuel lines to the fuel manifolds. The fuel passages are identified by the words "IN" (top manifold) and "OUT" (bottom manifold) cast in several places in the side of the cylinder head.

The fuel manifold connectors are assembled to the integral fuel manifold cylinder head, using special steel sealing washers, and tightened to 40-45 Ib-ft (5461 Nm) torque.

A special fitting with a restricted opening is used in the fuel outlet manifold to maintain the proper pressure within the fuel system. Refer to Page 10-9-1 for the size of restriction used.

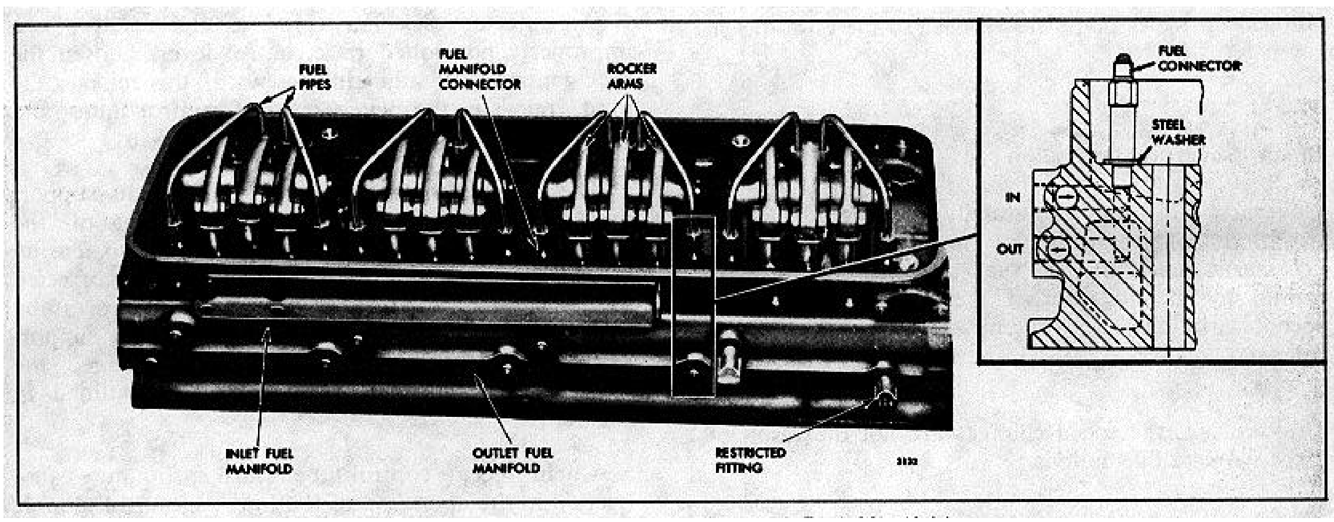


Fig. 1 - Cylinder Head with Integral Fuel Manifolds

MECHANICAL GOVERNOR

Horsepower requirements on an engine may vary due to fluctuating loads; therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the throttle control and the fuel injectors. The governor is mounted on the front end of the blower and is driven by the upper blower rotor. A variable speed governor is used since the engine is subjected to varying load conditions that requires automatic fuel compensation to maintain a near constant speed which may be changed manually by the operator.

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 (refer to Page 10-9-11). If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined on Page 10-3-16.

3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

1. If an injector rack sticks or moves too hard, it may be due to the injector hold-down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolt to 20-25 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 on Page 3-16.

3. An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in Chapter 10.

4. The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their no-fuel position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in Chapter 10.

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

The variable speed mechanical governor performs three functions (Fig. 1):

1. Controls the engine idle speed.

2. Limits the maximum no-load speed.

3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The single weight governor is mounted on the front of the blower and is driven by the upper blower rotor (Fig. 2).

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 for starting and stopping, and a speed control lever (Fig. 1). For starting, the stop lever is moved to the run position, which holds the injector control racks near the full-fuel position.

Upon starting, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion, which is transmitted through the riser and operating shaft to the operating shaft lever. One end of the operating lever bears against the variable speed spring plunger, while the other end provides a changing fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving governor weights and tension on the variable speed spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

A fuel rod connected to the differential lever and injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

Adjustment of the engine idle speed is accomplished by changing the tension on the variable speed spring by means of the idle speed adjusting screw. Refer to Page 10-10-7 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 Page 10-10-6 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 on current engines. 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 on Page 10-3-38 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 Fig. 2 and disconnect the throttle control rod and booster spring from the speed control lever.

2. Remove the four cover screws and lift the governor cover, with the stop lever and retraction spring and cover gasket from the governor housing.

3. Refer to Figs. 1 and 2 and disconnect the fuel rod from the differential lever and injector control tube lever.

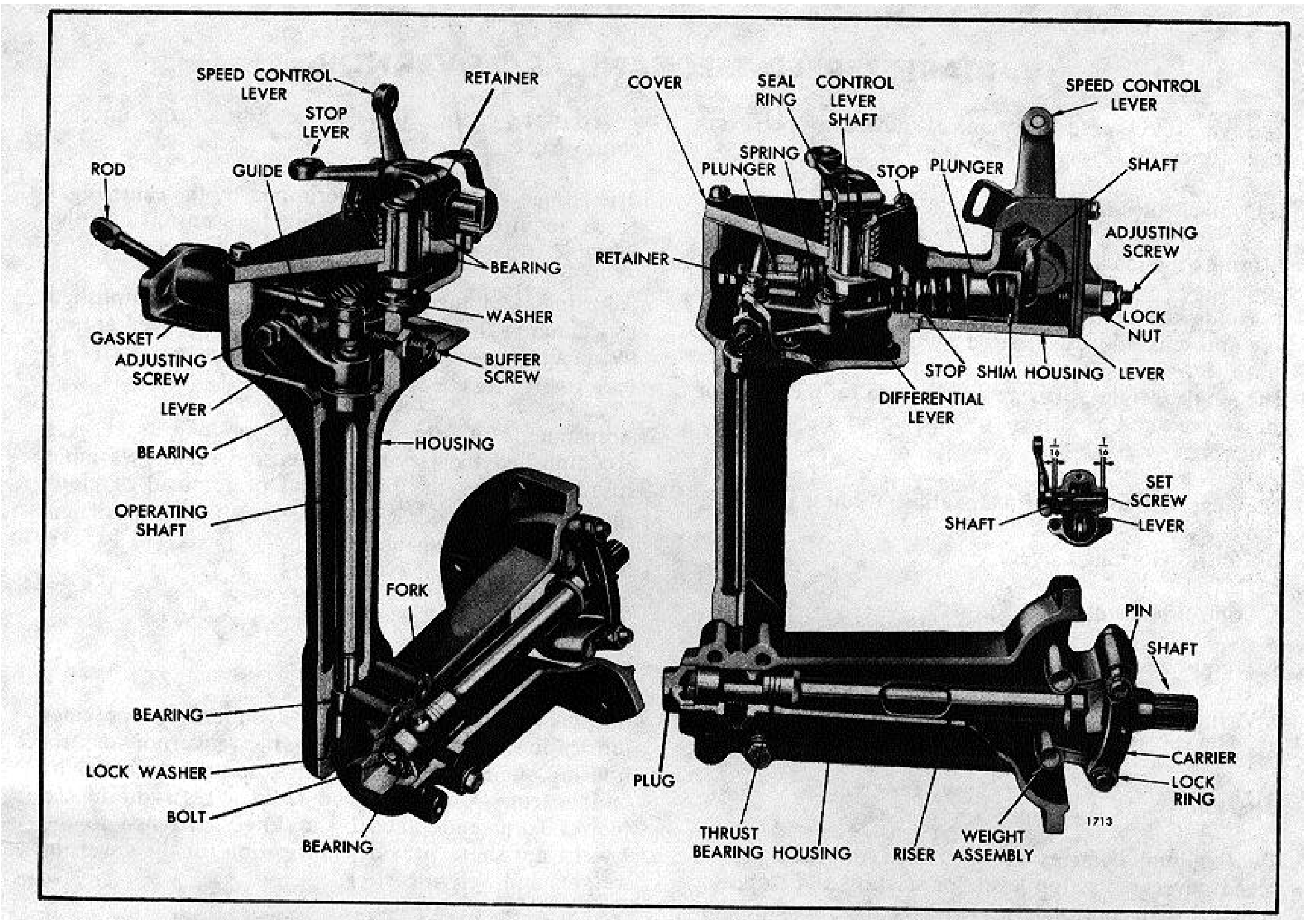


Fig. 1 - Variable Speed Mechanical Governor

4. Disconnect the oil tube at the governor weight housing, or cover.

5. Remove the two governor-to-cylinder head bolts.

6. Remove the control housing from the cylinder head and weight housing.

7. 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 (Fig. 3).

a. Loosen the clamping bolt and remove the stop lever from the shaft. Remove the lever torsion retraction spring.

b. Remove the control shaft lock ring and seal retainer. Withdraw the control shaft from the cover.

c. Remove the seal ring from the governor cover.

d. Wash the cover assembly (on former engines the cover assembly contained two needle bearings, however on current engines, 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 bushing 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 (Fig. 4). Place remover J 21967-01 on top of the bearing or bushing and

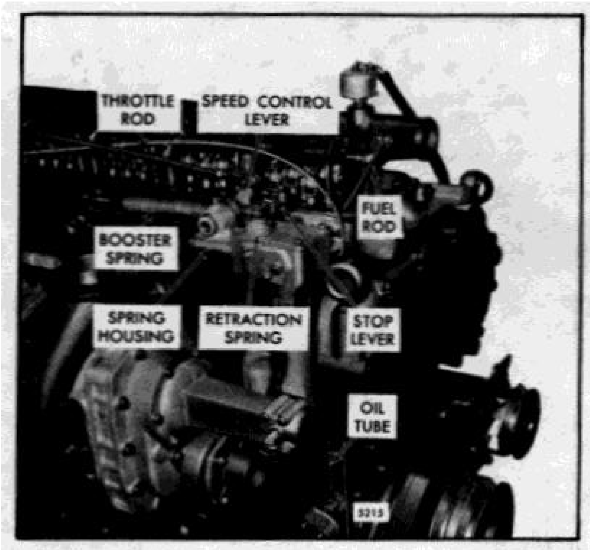


Fig. 2 - Variable Speed Governor Mounting

under the ram of the press, then press both bearings or bushing out of the cover.

2. Disassemble the governor control housing.

   a. Place the control housing in the soft jaws of a vise (Fig. 5).
   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 Fig. 6 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. Support the control housing bottom side up on the bed of the press. Use a brass rod and press the operating shaft from the operating fork (Fig. 7). Withdraw the operating shaft, operating lever and bearing as an assembly from the control housing (Fig. 5).
   g. Support the operating shaft and lever on the bed of the press as shown in Fig. 8. Use a brass rod and press the shaft from the operating lever and bearing.

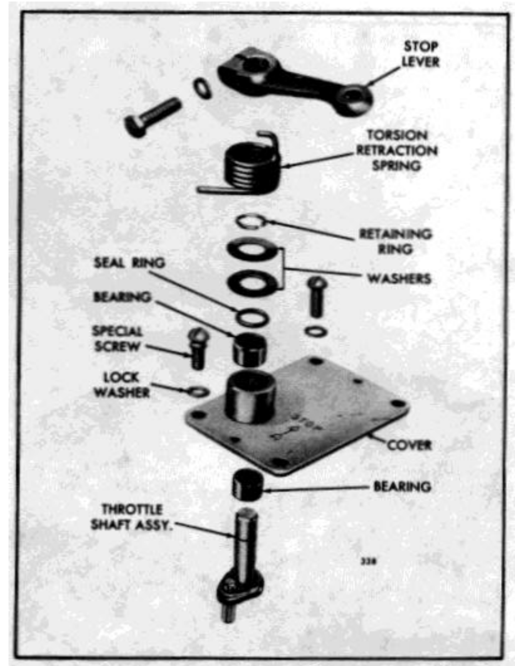


Fig. 3 Governor Cover Details and Relative Location of Parts

3. Disassemble the governor weight housing.

   a. Place the weight housing in the soft jaws of a vise (Fig. 9). Remove the end plug and gasket.
   b. Straighten the tang of the lock washer and remove the bearing retaining bolt.
   c. Thread a 5/16"-24 x 3" bolt into the tapped end of the weight shaft. Support the weight housing on the bed of the press as shown in Fig.10, then press the shaft from the bearing.
   d. Slide the riser thrust bearing and governor riser from the shaft.

      This bearing is specially designed to absorb thrust load; therefore, looseness between the mating parts does not indicate excessive wear.

   e. Remove the bearing from the weight housing.

NOTE: The weight shaft end bearing should be

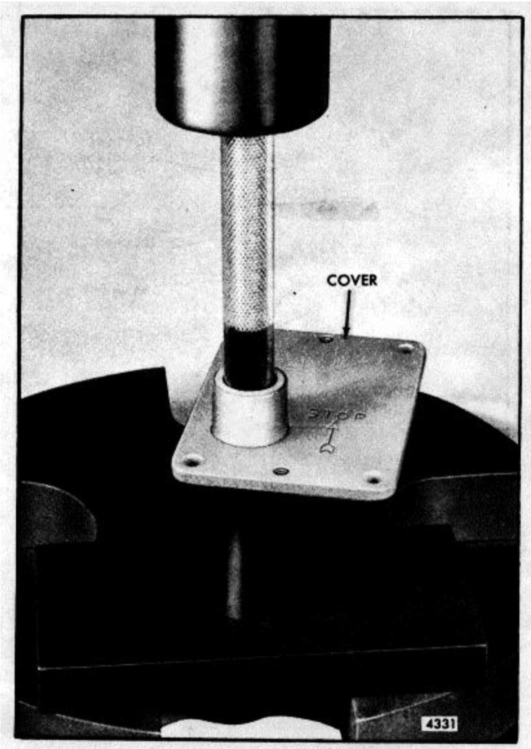


Fig. 4 - Removing Bearings from Cover using Tool J 21967-01

discarded on removal as it becomes brinnelled during the disassembly process.

f. Use tool J 4880 and remove one lock ring from each weight pin. Withdraw the pins, flat washers and governor weights.

g. If required, the weight carrier may be pressed from the governor weight shaft and a new carrier installed (Fig. 9).

4. Disassemble the governor variable speed spring housing.

a. Refer to Fig. I 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 (Fig. 1). Remove the Woodruff key from the shaft (Fig. 13).

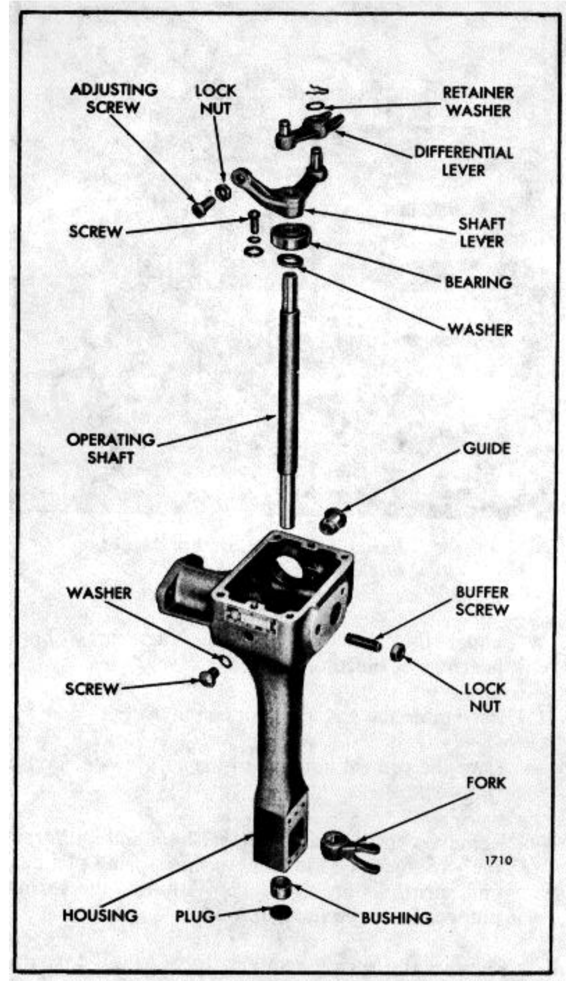


Fig. 5 Governor Control Housing Details and Relative Location of Parts

c. Remove the plain washer and seal from the shaft.

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.

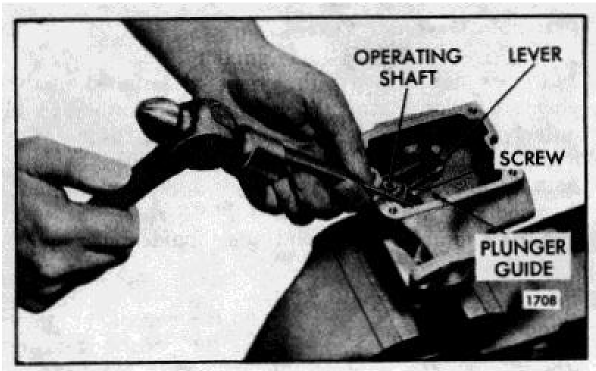


Fig. 6 - Removing Variable Speed Spring Plunger Guide

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, flat 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 current cover assemblies is not serviced. When replacement is necessary, use needle bearings.

Inspect the spring lever shaft and bearings for excessive wear or flat spots at the bearing surface. If one or both conditions exist, a new shaft and bearings must be installed.

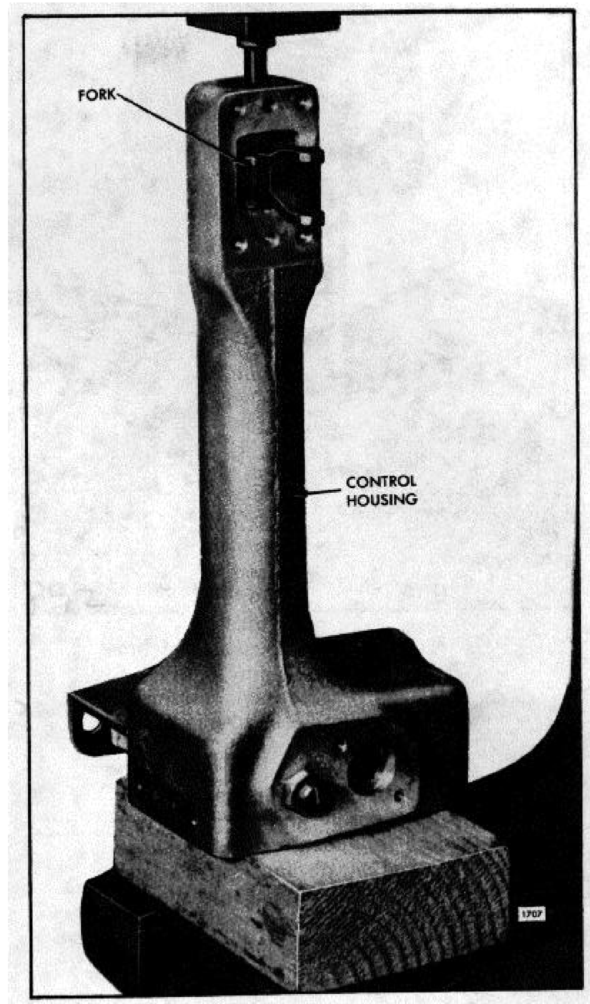


Fig. 7. Removing Operating Shaft from Operating Fork

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 current 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 weights should be installed.

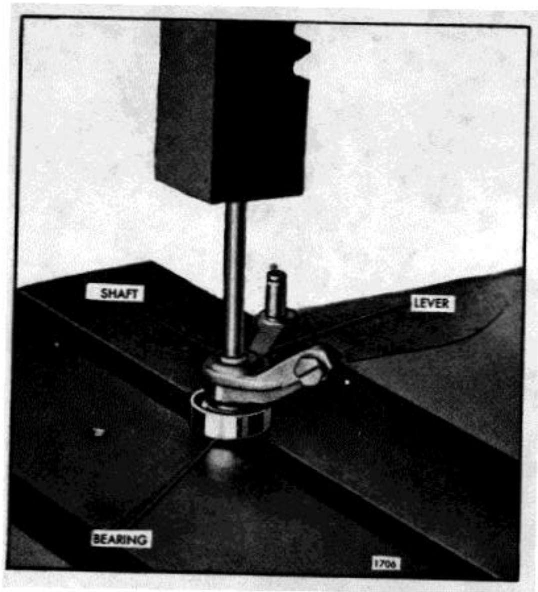


Fig. 8. Removing Operating Shaft from Operating Lever

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 in the bearing and press the bearing in until the shoulder on the tool contacts the cover (Fig. 11).

2. Reverse the governor cover on the bed of the press (inner face of cover up). Start the second bearing straight into the bore of the cover with the bearing number up. Press the bearing in flush with the cover with tool J 21068.

NOTE: Do not use impact tools to install needle bearings.

3. Pack the needle bearings with grease. If the cover contained a bushing which was not removed, lubricate it with clean engine oil. Insert the throttle shaft through the bearing or bushing.

4. Insert a seal ring over the throttle shaft and into the counterbore against the upper bearing. Place the retainer over the shaft and against the seal ring.

5. Locate the lock ring in the groove of the throttle shaft.

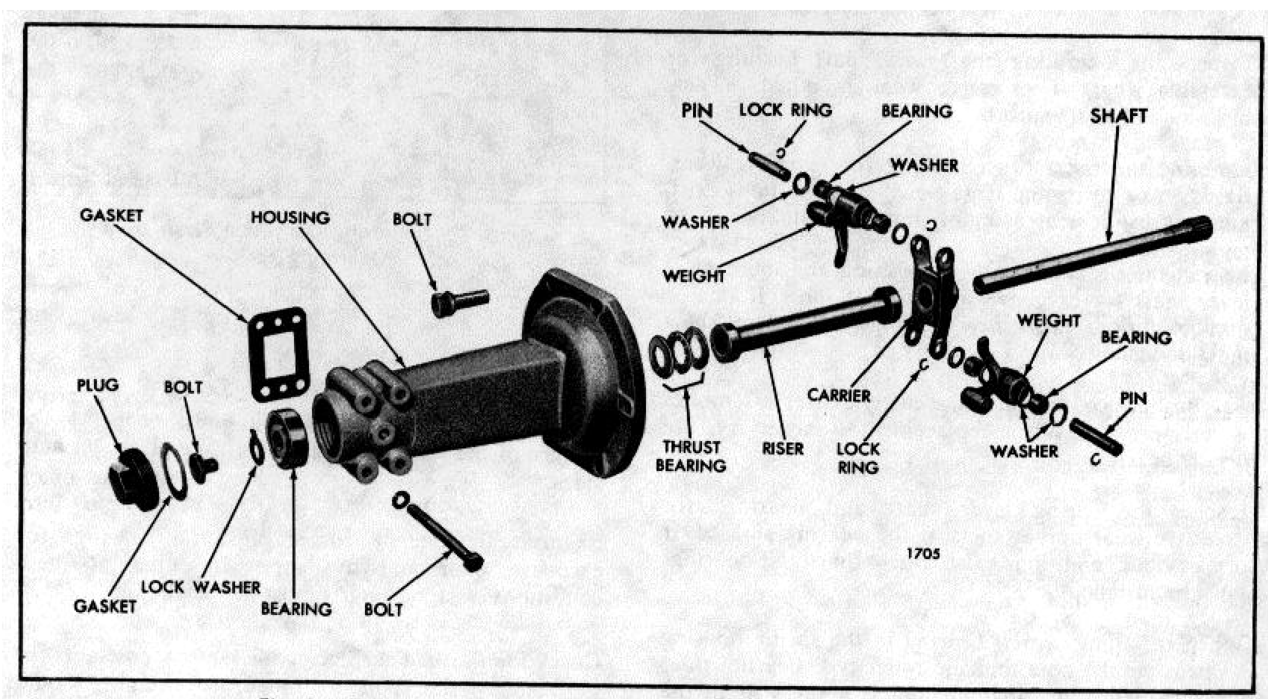


Fig. 9. Governor Weight Housing Details and Relative Location of Parts

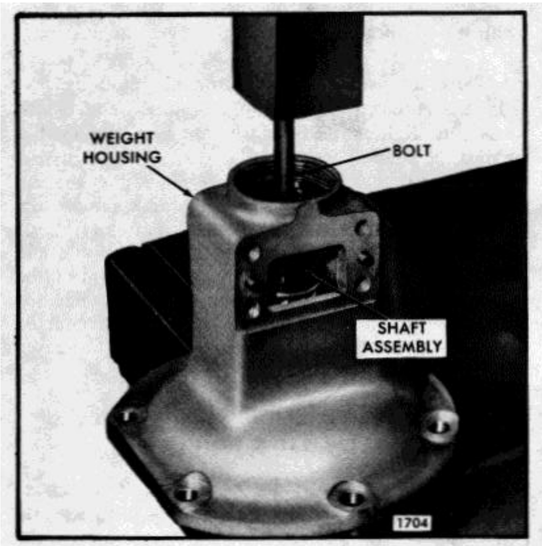


Fig. 10. Removing Governor Weight and Shaft Assembly

6. Place the torsion retraction spring over the cover hub with the hooked end up (Fig. 3). 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 (Fig. 5). 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 Fig. 1.

5. Support the operating shaft and control housing on the bed of an arbor press with the upper end of the

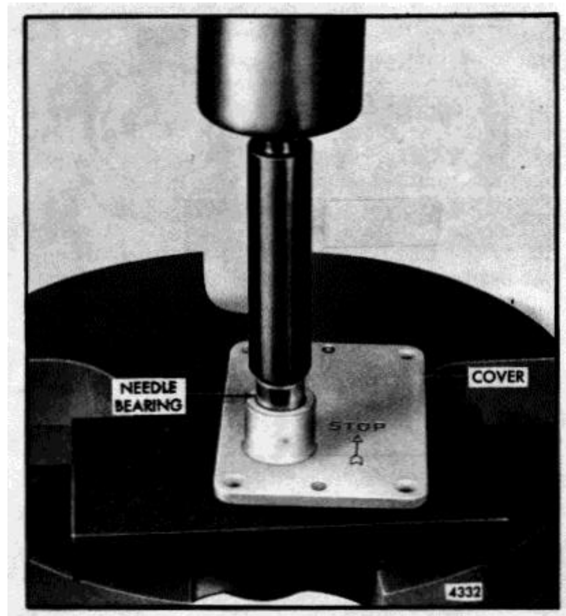


Fig. 11 Installing Needle Bearing in Governor Cover using Tool J 21068

shaft resting on a steel block. Align the flat in the operating fork with the flat on the shaft, then place the sleeve over the end of the shaft and rest it on the fork. Press the fork straight down tight against the shoulder on the shaft.

6. Place the differential lever over the pivot pin of the operating lever. Install the plain washer and spring retainer.

7. Place the lock washer and the flat washer over the bearing retaining screw. Refer to Fig. I and thread the screw in the control housing tight to secure the bearing.

8. Refer to Fig. 6 and insert the variable speed spring plunger guide in the control housing.

9. Apply a good quality sealant around the outer periphery of the expansion plug and tap the plug into the lower end of the control housing.

Assemble Governor Weight Housing

1. Install the lock ring in the groove of the weight pin (Fig. 9). Place the flat washer over the pin and against the lock ring.

2. Start the pin through the opening in the weight carrier. Place the second washer over the pin and against the projecting arm of the weight carrier.

3. Position the governor weight between the projecting arms of the weight carrier. Push the pin through the governor weight. Place the third flat washer over the pin and against the weight.

4. Then push the pin completely through the weight carrier and place the fourth flat washer over the pin and against the projecting arm of the weight carrier. Install the second lock ring in the groove of the weight carrier pin.

5. Install the second governor weight as outlined in Steps 1 through 4.

6. Slide the riser over the shaft and against the finished surfaces of the governor weights as shown in Fig. 1.

7. Assemble the riser thrust bearing on the weight shaft with the bearing race having the smaller inside diameter against the thrust riser. Incorrect installation of the bearing will result in erratic operation of the governor.

8. Insert the weight carrier and shaft assembly in the weight housing.

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 new bearing in place using a 1 3/8" diameter metal bar flat on the ends which will bear against both the inner and outer races of the bearing.

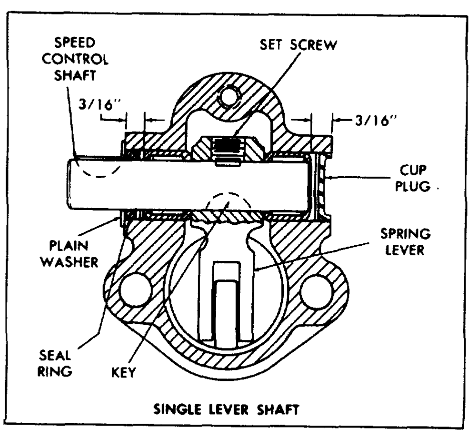


Fig. 12. Cross Section of Governor Variable Speed Spring Housing

10. Place a washer over the bearing retaining bolt (Fig. 9). 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 Figs. 12 and 13. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then start one of the bearings, numbered end up, straight in the bearing bore in the right-hand side of the spring housing.

2. Install the needle bearing pilot rod J 9196-2 in the installer body J 9196-1 and secure it in place with the retaining screw.

3. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press as shown in Fig. 14, then press the bearing in the housing until the shoulder on the installer contacts the housing.

NOTE: When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

4. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

5. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.

6. Insert the correct end of the single lever type, speed control lever shaft through the bearing bore in the side of the spring housing, opposite the bearing previously installed (Fig. 12). Align the key in the shaft with the keyway in the spring lever, and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the set screw hole in the lever.

7. Thread the set screw into the spring lever, making sure the point of the screw is seated in the flat on the shaft.

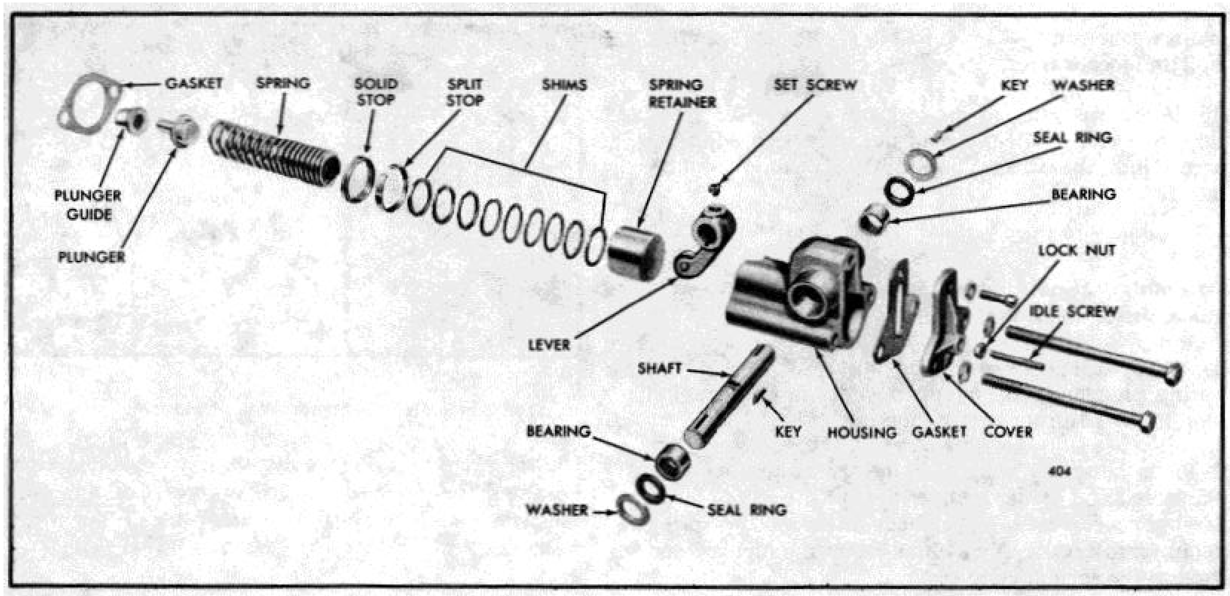


Fig. 13. Variable Speed Spring Housing and Shaft Details and Relative Location of Parts

8. Place the second speed control lever shaft needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

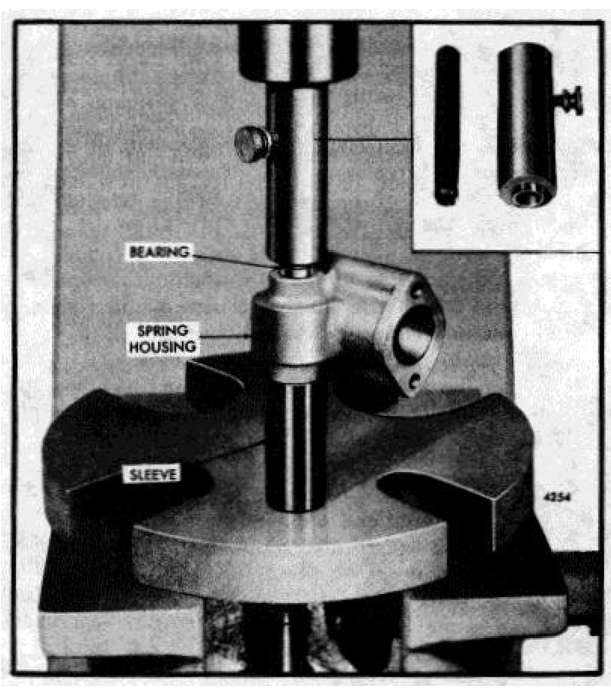


Fig. 14. Installing Speed Control Shaft Bearings in Spring Housing using Tool J 9196.

9. Remove the bearing pilot rod J 9196-2 from the installer body J 9196-1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press as shown in Fig. 14, then press the bearing in the housing until the shoulder on the installer contacts the housing.

10. Apply a thin coat of sealing compound to the outside diameter of the cup plug. Start the cup plug straight in the bearing bore in the housing, then support the spring housing, bearings and shaft assembly on a sleeve on the bed of an arbor press, and press the cup plug in flush with the outside face of the housing (Fig. 12).

11. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to 5-7 lb-ft (7-10 Nm) torque.

12. Stake the edge of the spring lever set screw hole with a small center punch and hammer to retain the set screw in the lever. Then, install the plug in the former spring housing.

13. Place a seal ring over the end of the shaft and push it into the bearing bore and against the bearing. Place the plain washer over the shaft and against the housing, then install the Woodruff key in the keyway in the shaft.

14. Place the speed control lever 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.

15. 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 1.00".

Assemble Variable Speed Spring Housing to the Control Housing

1. Refer to Fig. 12 and insert the small end of the spring plunger in the plunger guide. Insert the solid stop in the governor control housing.

2. Place the spring retainer in the spring housing, with the closed end of the retainer against the spring lever. If shims were used, place them inside of the spring retainer. Insert the split stop in the spring housing and against the spring retainer.

NOTE: Be sure to use shims with an .344" inside diameter. Either spring retainer may be used with shims which have a .750" I.D. However, do not use the .344" I.D. shims with a spring retainer which has only one air bleed 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 Fig. 2 and start the splined end of the weight shaft into the upper blower rotor and position the housing against the blower end plate.

2. Place a new copper gasket on each weight housing-to-blower bolt and thread the bolts into the blower end plate, finger tight only.

3. Place a new gasket over the dowels and against the side of the weight housing facing the engine (Fig. 9).

4. Move the thrust bearing assembly and riser toward the weight end of the shaft.

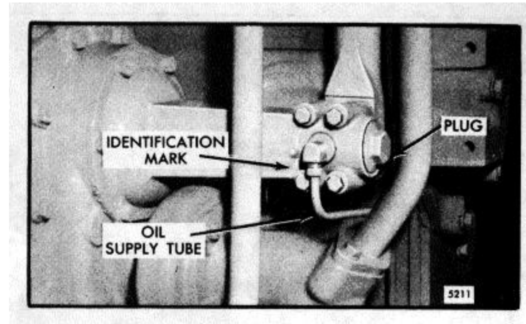


Fig. 15. Governor Weight Housing

5. Refer to Fig. 2 and position the lower end of the Fig. 15 Governor Weight Housing control housing over the dowel pins of the weight housing. The finished surface of the operating fork must be placed against the outer side of the thrust bearing.

NOTE: For ease in assembling the governor control housing to the interim weight housing (no identification mark, Fig. 15), install a special bolt (3/8"-24 x 3/4" or 7/8"), from which the outer 1/2" of thread down to a diameter of 5/16" to 1/4" has been removed, as a tool in the 1/8" NPTF oil hole to prevent the thrust bearing from moving too far forward in the weight housing. Current weight housing has two ribs cast on the inner surface of the housing to prevent any part of the riser thrust bearing from sliding forward to where the operating fork could be inserted on the wrong side of one or more parts of the bearing.

6. Use a new gasket and attach the governor control housing to the cylinder head with two bolts (Fig. 2). Tighten the bolts.

7. Tighten the governor-to-blower bolts with tool J 4242.

8. Connect the oil tube to the restricted fitting on the weight housing, or cover if used.

9. Refer to Fig. I and position the fuel rod over the differential lever pin. Place a flat washer over the pin and secure it with a retainer.

10. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.

11. Place a new gasket on the governor control housing and mount the governor cover on the housing with the pin on the lever shaft registering with the machined slot in the differential lever as shown in Fig. 1.

12. Secure the cover to the governor housing with three regular screws, one special screw and lock washers.

13. Hook the torsion retraction spring to the special cover screw and the stop lever (Fig. 2).

14. Perform an engine tune-up as outlined on Page 10-10-1.

FUEL INJECTOR CONTROL TUBE

The fuel injector control tube assembly (Fig. 1) is mounted on the cylinder head and consists of a control tube, injector rack control levers, a return spring and injector control tube lever mounted in two bracket and bearing assemblies attached to the cylinder head.

The injector rack control levers connect with the fuel injector control racks and are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no-fuel position. The injector control tube lever is pinned to the end of the control tube and connects with the fuel rod which connects with the engine governor. Refer to Chapter 10 for positioning of the injector rack control levers.

Remove Injector Control Tube

1. Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube control lever.

2. Remove the two attaching bolts and lock washers at each bracket. Disengage the rack levers from the injector control racks and lift the control tube assembly from the cylinder head.

Disassemble Injector Control Tube

The injector control tube, one mounting bracket, a spacer and injector control tube lever are available as a service assembly. When any part of this assembly needs replacing, it is recommended the complete service assembly be replaced. Therefore, the disassembly and assembly procedure for these items is not included in the following:

1. Remove the bracket from the injector control tube.

2. Loosen the adjusting screws at each injector rack control lever.

3. Disconnect the return spring from the bracket and front or rear rack lever.

4. Then remove the return spring and rack levers from the control tube.

Inspection

Wash all of the injector control tube parts in clean fuel oil and dry them with compressed air.

Examine the control tube, control lever, control tube rack control levers and brackets for excessive wear, cracks or damage and replace them if necessary. The bearing in the bracket is not serviced separately. Examine the return spring and replace it if worn or fractured.

Assemble Injector Control Tube

With all of the parts cleaned and inspected and the necessary new parts on hand, refer to Fig. 1 and assemble as follows:

1. Install the rack control levers on the control tube, with the levers facing the front bracket position. Turn the adjusting screws into the slots in the control tube far enough to position the levers.

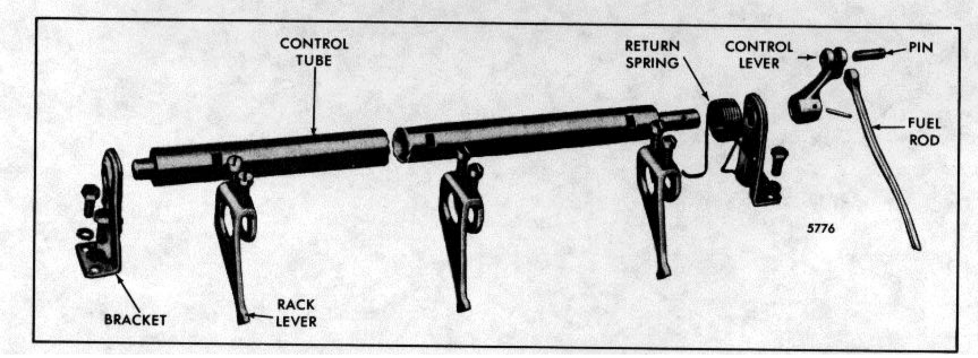


Fig. 1. Injector Control Tube Assembly (Non-Spring Loaded)

2. Install the control tube return spring and front bracket on the control tube. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the front bracket.

Install Injector Control Tube

1. Engage the injector rack control levers with the injector control racks and place the brackets over the mounting holes on the cylinder head.

2. Install the two 1/4 "-20 x 5/8 " bolts and lock washers at each bracket to attach the injector control tube assembly to the cylinder head. Tighten the bolts to 10-12 lb-ft (14-16 Nm) torque.

3. Check the control tube to be sure it is free in the brackets. Tap the control tube lightly to align the bearings in the bracket, if necessary.

4. Connect the fuel rod to the injector tube control lever with a clevis pin and a new cotter pin.

5. Refer to Chapter 10 and position the injector rack control levers.

NOTE: Be sure the injector rack control levers can be placed in a no-fuel position before restarting the engine.

WARNING

Loss of shut down control could result in a runaway engine which could cause personal injury.

SHOP NOTES - TROUBLE SHOOTING - SPECIFICATIONS - SERVICE TOOLS
SHOP NOTES

INJECTOR CALIBRATOR READINGS

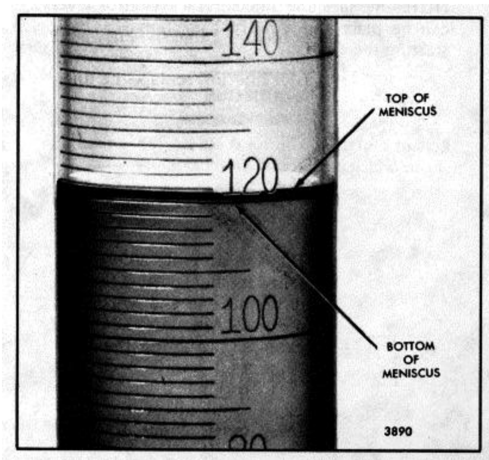


Fig. 1. Checking Fuel Output

Several factors affect the injector calibrator output readings. The four major items are: 1. Operator Errors: If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of I or 2 points will result. Refer to Fig. 1.

2. **Air In Lines:** This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.

3. **Counter Improperly Set**: The counter should be set to divert the injector output at 1,000 strokes.

This should not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 1,000 strokes (if properly set) although the counter may overrun several digits.

4. **Test Oil**: A special test oil is supplied with the calibrator and should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts.

The fuel oil introduced into the test oil when the fuel injector is placed in the calibrator for a calibration check contaminates the test oil. Therefore, it is important that the test oil and test oil filter be changed every six months, or sooner if required.

In addition, other malfunctions such as a slipping drive belt, low level of test oil, a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell-tale conditions.

CHECKING INJECTOR TESTER J 9787 or J 23010

The injector tester (J 9787 or J 23010) should be checked monthly to be sure that it is operating properly. The following check can be made very quickly using test block J 9787-49.

Fill the supply tank in the injector tester with clean injector test oil J 26400. Open the valve in the fuel supply line. Place the test block on the injector locating plate and secure the block in place with the fuel inlet connector clamp. Operate the pump handle until all of the air is out of the test block, then clamp the fuel outlet connector onto the test block. Break the connection at the gage and operate the pump handle until all of the air bubbles in the fuel system disappear. Tighten the connection at the gage. Operate the pump handle to pressurize the tester fuel system to 2400-2500 psi. (16 536-17 225 kPa). Close the valve on the fuel supply line. After a slight initial drop, the pressure should remain steady. This indicates that the injector tester is operating properly. Open the fuel valve and remove the test block.

If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected and the tester rechecked before checking an injector.

Occasionally dirt will get into the pump check valve in the tester, resulting in internal pump valve leakage and the inability to build up pressure in the tester fuel system. Pump valve leakage must be corrected before an injector can be properly tested.

When the above occurs, loosen the fuel inlet connector clamp and operate the tester pump handle in an attempt to purge the dirt from the pump check valve. A few quick strokes of the pump handle will usually correct a dirt condition. 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 gage line is damaged or broken, install a new replacement line (available from the tester manufacturer). Do not shorten the old lines or the volume of test oil will be altered sufficiently to give an inaccurate valve holding pressure test.

If it is suspected that the lines have been altered, i.e. by shortening or replacing with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

REFINISH LAPPING BLOCKS

Fig. 2 Refinishing Lapping Blocks

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time.

It is good practice, where considerable lapping work is done, to devote some time each day to refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the blocks.

To refinish the blocks, spread some 600 grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together as shown in Fig. 2. Alternate the blocks from time to time. For example, assuming the blocks are numbered 1, 2 and 3, work I and 2 together, then I and 3, and finish by working 2 and 3 together. Continue this procedure until all of the blocks are perfectly flat and free of imperfections.

Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory when the entire surface is a solid dark gray. Bright or exceptionally dark spots indicate defects and additional lapping is required.

After the surfaces have been finished, remove the powder by rinsing the lapping blocks in trichloroethylene and scrubbing with a bristle brush.

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 masters, the calibrator can be considered accurate.

Injector testing can be carried out now without any adjustment of figures. However, when testing new injectors for output, any difference between the calibrator and the masters should be used to compute new injector calibration. If more than a 2% variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

INJECTOR TIMING

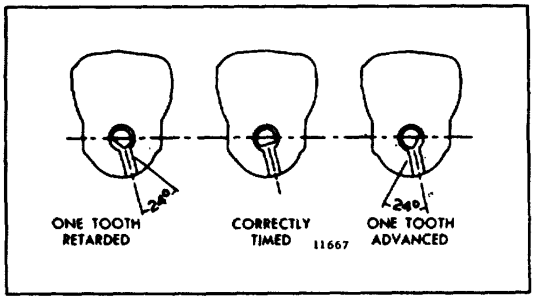


Fig. 3 Injector Rack-to-Gear Timing

If it is suspected that a fuel injector is "out of time", the injector rack-to-gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector rack and gear are correctly timed. When the rack is all the way in (full-fuel position), the flat side of the plunger will be visible in the hole, indicating that the injector is "in time". If the flat side of the plunger does not come into full view (Fig. 3) and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack-to-gear timing.

INJECTOR SPRAY TIPS

Due to a slight variation in the size of the small orifices in the end of each spray tip, the fuel output of an injector may be varied by replacing the spray tip.

Flow gage J 25600 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

EFFECT OF PRE-IGNITION ON FUEL INJECTOR

Pre-ignition is due to ignition of fuel or lubricating oil in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures and may eventually cause burning of the injector spray tip and lead to failure of the injectors in other cylinders.

When pre-ignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of pre-ignition to avoid recurrence of the problem. Check for oil pull-over from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

INJECTOR PLUNGERS

The fuel output and the operating characteristics of an injector are, to a great extent, determined by the type of plunger used. Three types of plungers are illustrated in Fig. 4. The beginning of the injection period is controlled by the upper helix angle. The lower helix angle retards or advances the end of the injection period. Therefore, it is imperative that the correct plunger is installed whenever an injector is overhauled.

If injectors with different type plungers (and spray tips) are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Injector plungers cannot be reworked to change the output or operating characteristics. Grinding will destroy the hardened case and result in chipping at the helices and seizure or scoring of the plunger.

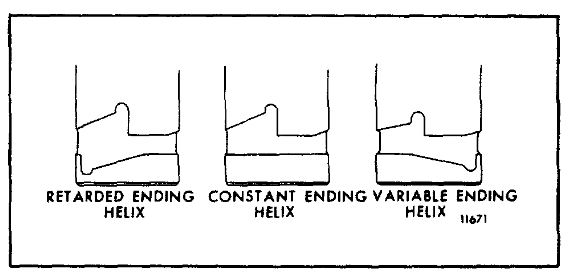


Fig. 4 Types of Injector Plungers

REFINISHING INJECTOR FOLLOWER FACE

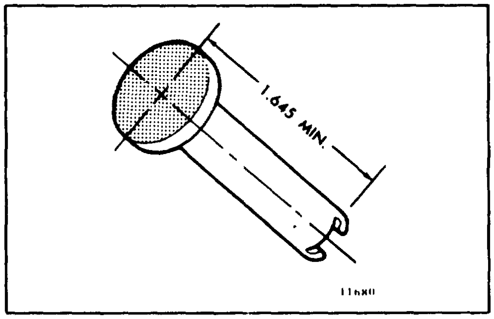


Fig. 5 Injector Follower

When refinishing the face of an injector follower, it is extremely important that the distance between the follower face and the plunger slot is not less than 1.645" minimum as shown in Fig. 5. If this distance is less than specified, the height of the injector follower in relation to the injector body will be altered and proper injector timing cannot be realized.

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 too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return line in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observing the fuel filter contents after the filter is bled and the engine is operated for 15 to 20 minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

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 Purge

Prime and/or purge the engine fuel system before starting the fuel leak check. Prime the system by blocking or disconnecting the line from the fuel pump, then apply fuel under pressure (60-80 psi or 413552 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.

Check for Leaks

Use one of the following methods to check for leaks.

Method I. 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 connectors join the cylinder head and where the fuel pipes join the fuel pipe nuts.

If there is any leakage at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking. Disassemble, inspect and correct or replace the suspect part (connector washer, connector, injector or jumper line). Test and reinspect.

Method 2. Use when the engine is not operating such as during or after repairs.

Remove the rocker covers. Pour lube oil over all fuel pipes and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as mentioned in Method 1.

Block off the fuel return line and disconnect the fuel pump supply line at the secondary filter. Install a pressure gage in the filter adaptor, then apply 6080 psi (413-552 kPa) fuel to the outlet side of the secondary filter with the inlets plugged. Severe leaks will show up immediately. Minor leaks caused by nicks or burrs on sealing surfaces will take longer to appear.

After maintaining 40-80 psi (276-552 kPa) for 20 to 30 minutes, a careful puddle inspection should reveal any suspect connectors. Inspect and repair or replace connectors as necessary. Test and reinspect (see note).

Method 3. Use while the engine is operating at 400600 rpm.

Apply an outside fuel source capable of 60-80 psi (413-552 kPa) to the outlet side of the secondary filter. Pour lube oil over jumper lines and connectors so that oil puddles form where lines and connectors meet. Install a valve and a pressure gage in the fuel return line. With the engine idling, close the valve enough to raise the engine fuel pressure to 70 psi (483 kPa). After 10 to 20 minutes inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on. Repair and retest.

NOTE: With the engine at rest, as in Method 2 all injectors will leak to some extent when pressurized. The leakage occurs because there is no place else for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off.

Slightly worn plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exists.

If injectors are suspected of leaking and contributing to dilution of the lube oil, they should not be tested by pressurizing the fuel system as in Method 2. Injectors should be removed from the engine and tested for pressure-holding capability (see Fuel Injector Section).

Points to Remember

Lube oil puddle inspection is the key to pressure testing the fuel system for internal leaks. This test can be performed any time the rocker covers are removed, after the fuel pipes and connectors have been splashed with oil and there is normal fuel pressure in the system. The weak or missing puddles show where the leaks are.

All leakage or spillage of fuel during leak detection testing further dilutes the lube oil, so the final step in maintenance of this type should include lube oil and lube oil filter changes.

TROUBLE SHOOTING

FUEL PUMP

The fuel pump is so constructed as to be inherently trouble free. By using clean, water-free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

However, if the fuel pump fails to function satisfactorily, first check the fuel level in the fuel tank, then make sure the fuel supply valve is open. Also check for external fuel leaks at the fuel line connections and filter gaskets. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through the pump flange drain hole, then crank the engine momentarily and note whether the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the valve and its bore or seat. This permits the fuel to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. Reinstall the valve.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

CHECKING FUEL FLOW

1. Disconnect the fuel return hose from the fitting at the fuel tank and hold the open end in a convenient receptacle (Fig. 6).

2. Start and run the engine at 1200 rpm and measure the fuel flow. Refer to Page 10-9-1 for the specified quantity per minute.

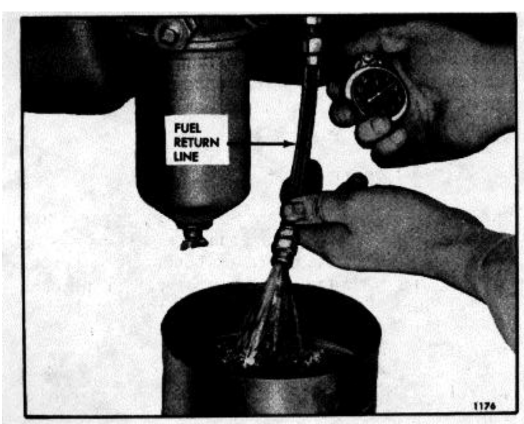


Fig. 6 Measuring Fuel Flow

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 fuel strainer cartridge. Then start the engine and run it at 1200 rpm to check the fuel flow. If the flow is still unsatisfactory, perform Step "b" below:

b. Replace the fuel filter cartridge. If the flow is still unsatisfactory, do as instructed in Step "c".

c. Substitute another fuel pump that is known to be in good condition and again check the fuel flow. When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault and may be checked as follows:

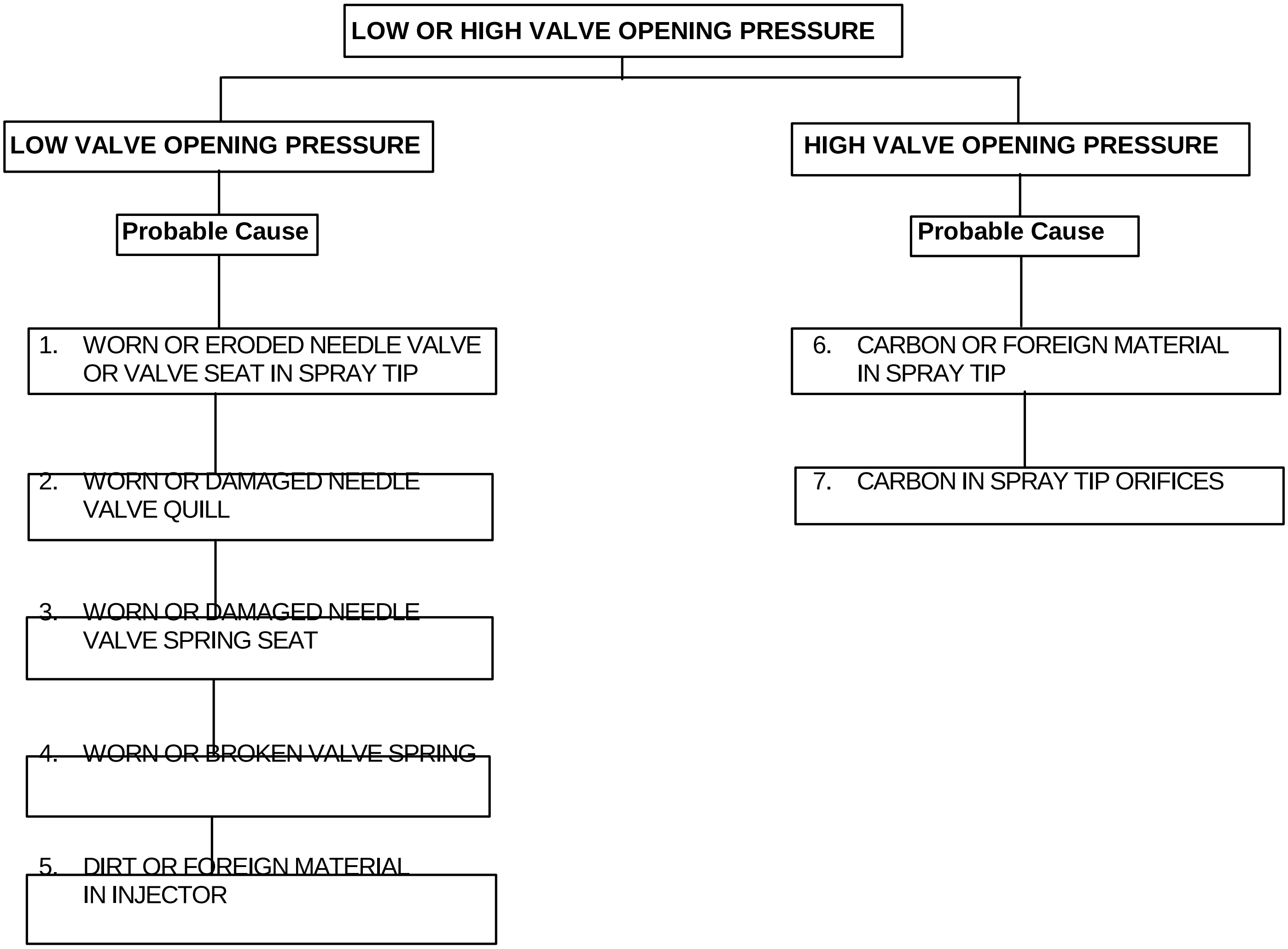
1. Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screw driver. If a cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out.

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.

TROUBLE SHOOTING CHARTS (Needle Valve Injectors)

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.

TROUBLE SHOOTING CHARTS (Needle Valve Injectors)

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.

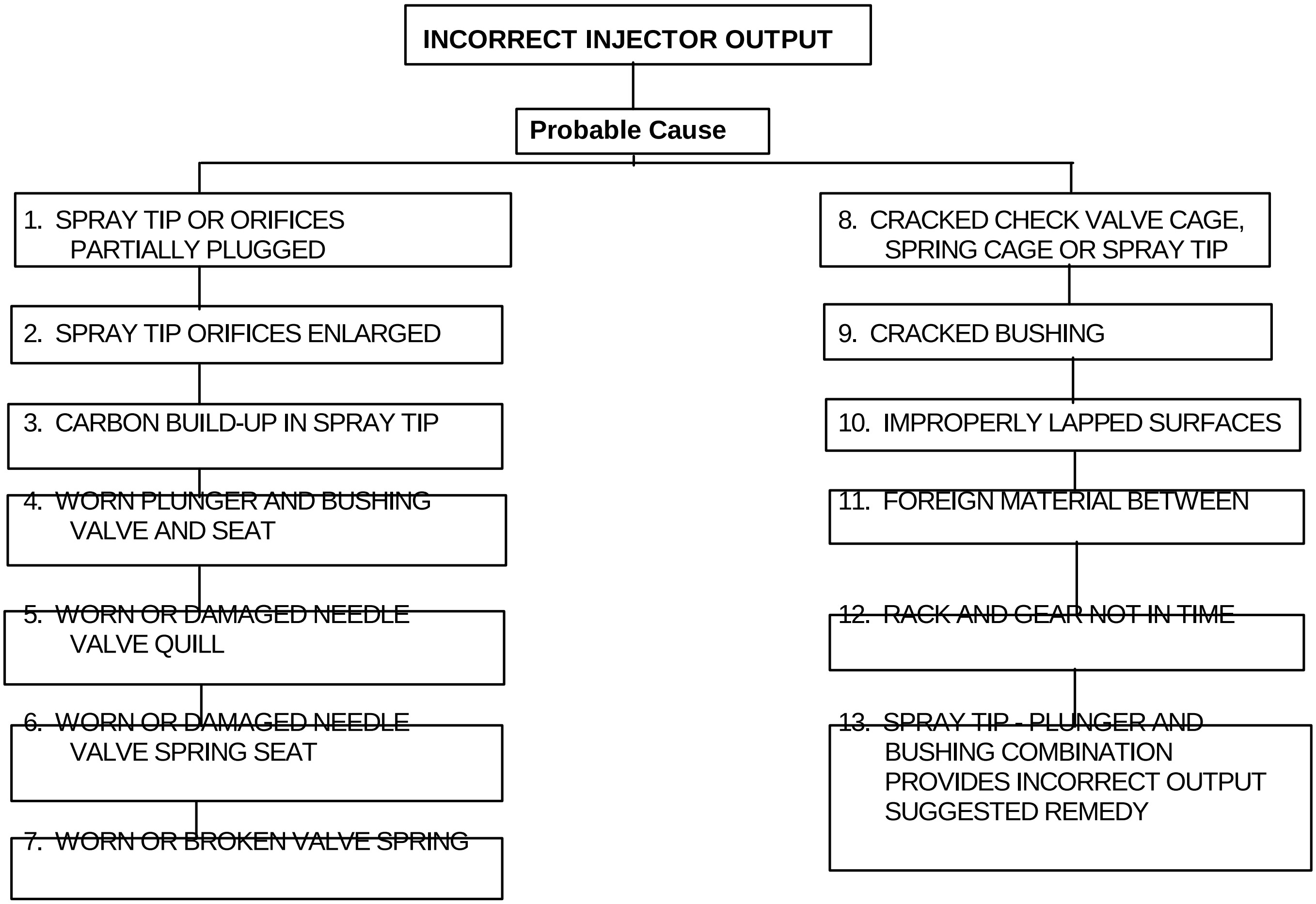
11. Install new body plugs.

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.

TROUBLE SHOOTING CHARTS (Noodle Valve Injectors)



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.

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		GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None		GM 255-M	1	No. 6 thru 1 1/2	60,000
None		GM 260-M	2	No. 6 thru 3/4	74,000
				over 3/4 to 1 1/2	60,000
	Bolts and Screws	GM 280-M	5	No. 6 thru 1	120,000
				over 1 to 1 1/2	105,000
	Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
	Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
	Bolts and Screws	GM 300-M	8	1/4 thru I 1/2	150,000
	Bolts and Screws	GM 455-M	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	CI TORQUE (lb-ft)	ENGINE TORQUE (Nm)
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.

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR	
Auxiliary injector tester ("N" injectors)	J 22640
Fuel pipe socket	J 8932-01
Fuel system primer	J 5956
Injector body reamer	J 21089
Injector body thread reconditioning set	J 22690
Injector calibrator	J 22410
Injector nut seal ring installer	J 29197
Injector service set (includes *tools)	J 1241-07
Injector service set ("N" injectors - 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
*Spray tip 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 9787
Injector tester	J 23010
Injector tester modification package (J 23010 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
Injector vise jaws (standard body)	J 1261
Lapping Block set	J 22090
Polishing compound ("N" injectors)	J 23038
Polishing stick set ("N" injectors)	J 22964
Spray tip flow gage	J 25600
Spray tip gage ("N" injectors)	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 bearing remover/installer	J 21967-01
High-speed spring retainer nut wrench	J 1652-01
Variable speed spring housing bearing installer set	J 9196

10-3-66

AIR INTAKE SYSTEM **CHAPTER 4**

CONTENTS

PAGE

AIR INTAKE SYSTEM

In the scavenging process employed in the 71 In-Line engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, therefore, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air, entering the blower from the air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows in Fig. 1.

The continuous discharge of fresh air from the blower creates an air pressure of approximately 7 psi (48 kPa) in the air chamber of the cylinder block at maximum engine speed. This air sweeps through the intake ports, which start to open as the piston approaches the end of its downward travel and close after the compression stroke begins.

The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

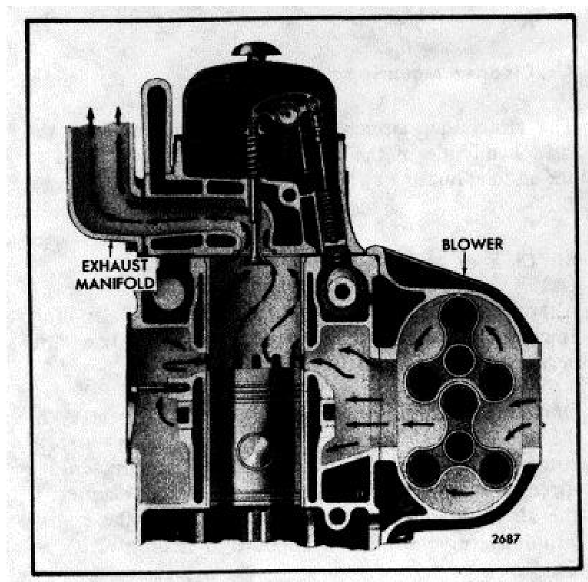


Fig. 1 - Air Flow Through Blower and Engine

AIR CLEANER

The air cleaner is designed to remove foreign matter from the air, pass the required volume of air for proper combustion and scavenging, and maintain their efficiency for a reasonable period of time before requiring service.

The importance of keeping dust and grit-laden air out of an engine cannot be over-emphasized since clean air is so essential to satisfactory engine operation and long engine life. The air cleaner must be able to remove fine materials such as dust and blown sand as well as coarse materials such as chaff, sawdust, or lint from the air. It must also have a reservoir capacity large enough to retain the material separated from the air to permit operation for a reasonable period before cleaning and servicing are required.

Dust and dirt entering an engine will cause rapid wear of piston rings, cylinder liners, pistons and the exhaust valve mechanism resulting in a loss of power and high lubricating oil consumption. Also, dust and dirt which is allowed to build-up in the air cleaner passages will eventually restrict the air supply to the engine and result in heavy carbon deposits on pistons and valves due to incomplete combustion.

Air Cleaner Mounting
The air cleaner assembly is remotely mounted on the right hand side of the engine hood and is connected to the air inlet housing by air tight ducts.

Air Cleaner Maintenance
Although the air cleaner is highly efficient, this efficiency depends upon proper maintenance and periodic servicing.

Damaged gaskets, loose hose connections or leaks in the duct work, which permit dust-laden air to completely bypass the cleaner and enter the engine directly, will lower the efficiency of the air cleaner. If the air cleaner is not serviced periodically, the engine will not receive a sufficient amount of clean air.

No set rule for servicing an air cleaner can be given since it depends upon the type of air cleaner, the condition of the air supply, and the type of application. An air cleaner operating in severe dust will require more frequent service than an air cleaner operating in comparatively clean air. The most satisfactory service period should be determined by frequently inspecting the air cleaner under normal operating conditions, then setting the service period to best suit the requirements of the particular engine application, The following maintenance procedure will assure efficient air cleaner operation.

1. Keep the air cleaner tight on the air intake pipe to the engine.

2. Keep the air cleaner properly assembled so the joints are strictly air tight.

3. Repair any damage to the air cleaner or related parts immediately.

4. Inspect and clean or replace the air cleaner element as operating conditions warrant. In the dry type cleaner, it is possible to clean and reuse the element several times as long as the paper is not ruptured in the process.

5. After servicing the air cleaner, remove the air inlet housing and clean accumulated dirt deposits from the blower screen and the inlet housing. Keep all air intake passages and the air box clean.

6. Where a rubber hose is employed, cement it in place. Use a new hose and hose clamps, if necessary, to obtain an air tight connection.

7. Carefully inspect the entire air system periodically. Enough dust-laden air will pass through an almost invisible crack or opening to eventually cause damage to an engine.

Dry Type Air Cleaner
The Donaldson dry type air cleaner shown in Fig. 1. is designed to provide highly efficient air filtration under all operating conditions. The cleaner has a replaceable impregnated paper filter element that can be cleaned.

The fins on the element give high speed rotation to the intake air, which separates a large portion of the dust from the air by centrifugal action. The plastic fins, the element and the gasket make up a single replaceable element assembly.

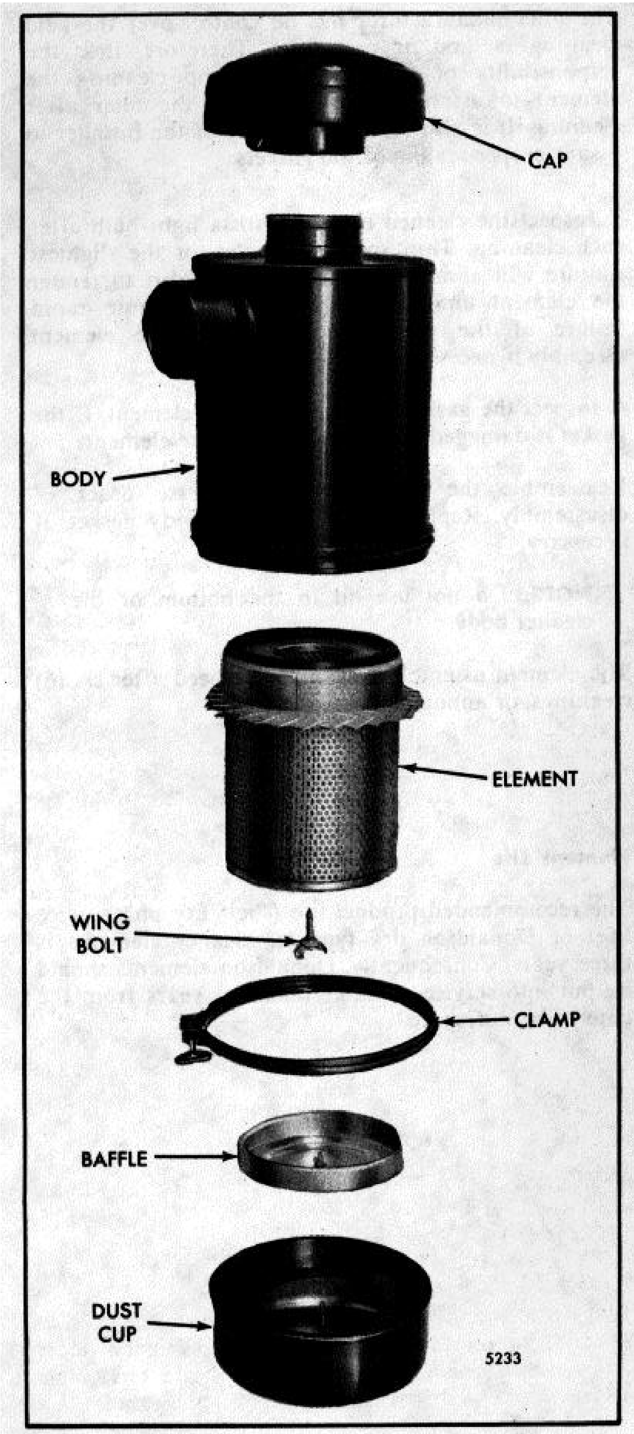


Fig. 1 - Dry Type Air Cleaner (Heavy Duty)

The dust is swept through a space in the side of the baffle and collects in the lower portion of the body or dust cup. The dust remaining in the precleaned air is removed by the element.

Service

The air cleaner should be serviced as operating conditions warrant. See Page 10-11-3 for element change intervals.

Under no engine operating conditions should the maximum allowable air intake restriction listed on Page 10-11-4 of the service manual be exceeded. Check restriction with a water manometer using the procedure outlined under "final RUN-IN" on Page 10-9-5. In addition, inlet restriction should be adjusted for high altitude conditions (see TABLE 1). A clogged air cleaner element will cause excessive intake restriction, reduce air supply to the engine, poor performance and higher valve and cylinder temperatures.

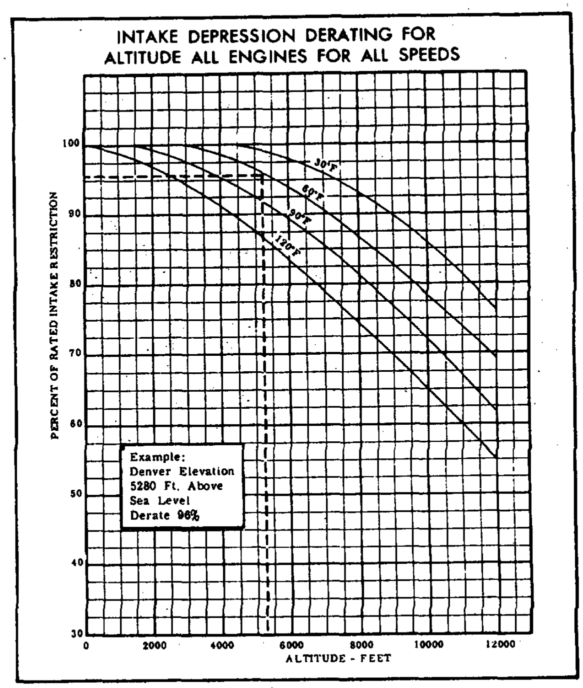


TABLE 1

Disassemble the cleaner in Fig. 1 as follows:

1. Loosen the dust cup clamp and remove the dust cup.

2. Loosen the wing bolt in the dust cup and remove the baffle from the dust cup.

3. Remove the wing bolt from the cleaner body and remove the element assembly.

4. Remove the dust and thoroughly clean the cleaner body, dust cup and baffle.

The paper pleated element assembly can be cleaned as follows:

NOTE: The pre-cleaning fins are not removable.

1. The element can be dry cleaned by directing clean air up and down the pleats on the clean air side of the element.

NOTE: Air pressure at the nozzle of the air hose must not exceed 30 psi (207 kPa). Maintain a reasonable distance between the nozzle and the element.

2. To wash the element, use the Donaldson Filter Cleaner or a non-sudsing equivalent. Proportions are 2 ounces of cleaner to I gallon of water. For best mixing results, use a small amount of cool tap water then add it to warm (100°F or 38°C) water to give the proper proportion. Soak the element for 15 minutes, then rinse it thoroughly with clean water from a hose (maximum pressure 40 psi or 276 kPa). Air dry the element completely before reusing (a fan or air draft may be used, but do not heat the element to hasten drying).

The filter manufacturer has no control over the field cleaning method or procedure. Therefore, it is the responsibility of the person or shop cleaning the element to assure the reliability of the filter after cleaning. It is also the responsibility of the installer to assure proper sealing of the gaskets.

3. Inspect the cleaned element with a light bulb after each cleaning. Thin spots, pin holes, or the slightest rupture will admit sufficient air borne dirt to render the element unfit for further use and cause rapid failure of the piston rings. Replace the element assembly if necessary.

4. Inspect the gasket on the end of the element. If the gasket is damaged or missing, replace the element.

Reassemble the air cleaner in reverse order of disassembly. Replace the air cleaner body gasket, if necessary.

NOTE: Do not use oil in the bottom of the cleaner body.

The element assembly should be replaced after six (6) cleanings, or annually.

Element Life
The recommended product life (shelf life plus service life) of Donaldson dry type air cleaner elements is three years. Consequently, Donaldson elements should be put into service no later than two years from the date of manufacture.

AIR SHUTDOWN HOUSING

The air shutdown housing, mounted on the side of the blower, serves as a mounting for the air cleaner or for air cleaner ducting. The air shutdown housing contains an air shutdown valve that shuts off the air supply and stops the engine whenever abnormal operating conditions require an emergency shut down (Page 10-8-12).

Remove Air Shutdown Housing

1. Remove the air cleaner ducts.

2. Disconnect the cable assembly from the air shut-off cam pin handle.

3. Remove the bolts and washers that retain the housing to the blower and remove the housing from the blower. Remove the air shutdown housing gasket from the blower.

Disassemble Air Shutdown Housing

If necessary, the air shut-off valve assembly may be disassembled after the air shutdown housing has been removed from the blower.

Refer to Fig. 1 and disassemble the air shut-off valve assembly as follows:

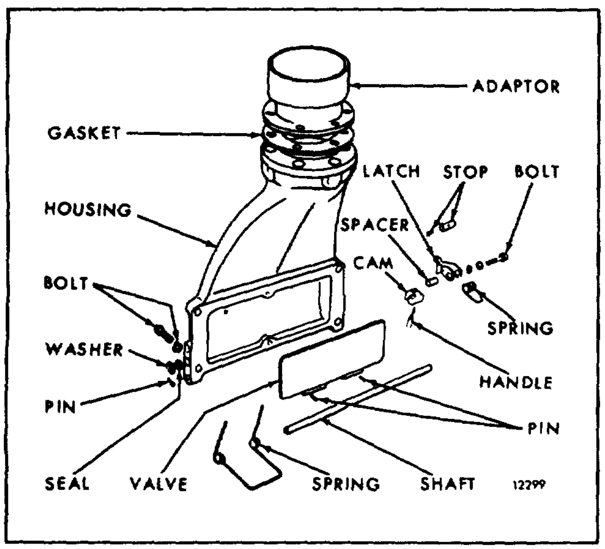


Fig. 1 Typical Current Cam and Latch Type Air Shutdown Housing Details and Relative Location of Parts.

1. Use a small punch to remove the pin from the air shut-off valve shaft. Remove the washer from the shaft. Remove and discard the seal ring from the housing.

2. Remove the pins that secure the air shut-off valve to the shaft.

3. Note the position of the air shut-off valve spring and the valve. Then withdraw the shaft from the housing to release the valve and spring in the housing. Remove and discard the seal ring from the housing.

4. Remove the bolt, lock washer and plain washer from the housing and remove the latch, latch spring and spacer.

Inspection

Clean all of the parts thoroughly, including the blower screen, with fuel oil and dry them with compressed air. Inspect the parts for wear or damage. The face of the air shut-off valve must be perfectly flat to assure a tight seal when it is in the shutdown position.

Assemble Air Shutdown Assembly

The holes for the cam pin handle and the retaining pins must be drilled at the time a new service shaft or air shut-off valve are assembled. Refer to Fig. 1 and proceed as follows:

1. Place the valve and spring in position in the housing and slip the shaft in place. The shaft must extend .760" from the side of the housing where the shutdown latch is assembled. Then install the pins which retain the valve to the shaft.

2. Lubricate with engine oil and install a new seal ring at each end of the shaft.

3. Install the cam and cam pin handle on the shaft.

4. Install a washer and retaining pin at the other end of the shaft.

5. Assemble the spacer and spring on the latch. Then slip the attaching bolt through the lock washer, plain washer, latch and spacer. Attach the latch assembly to the housing and tighten the bolt.

6. After assembly, check for .015 " to .040 " shaft end play.

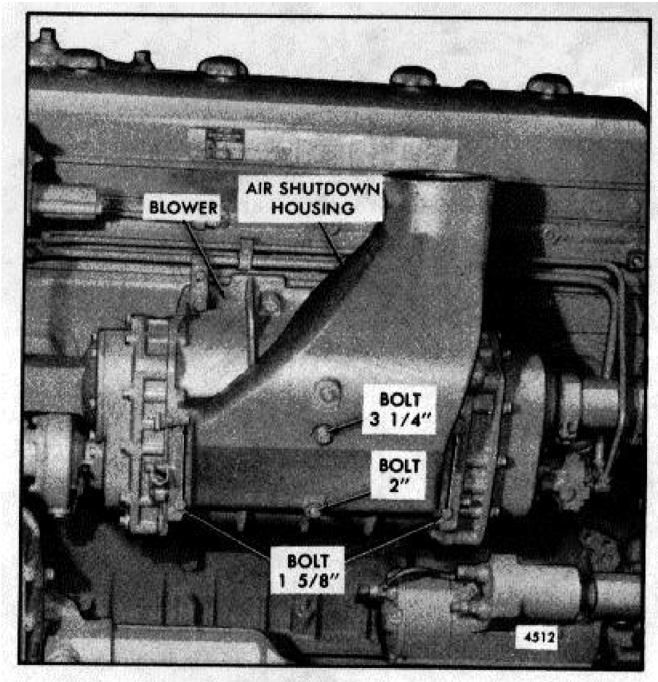


Fig. 2 - Air Shutdown Housing Mounting and Bolt Location

Install Air Shutdown Housing

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

IMPORTANT: The current blower screen gasket consists of wire mesh secured between two sheets of gasket material. The former screen was imbedded in one sheet of gasket material and was installed with the screen side toward the blower.

2. Refer to Fig. 2 and mount the air shutdown housing together with the striker plate gasket and striker plate on the blower with bolts and lock washers and tighten the bolts to 16-20 lb-ft (22-27 Nm) torque.

NOTE: The 3/8 "-16 x 3-1/4" bolt and the 3/8 "-16 x 2 " bolt must be installed as shown in Fig. 2. The four 1-5/8" bolts are installed in the four corner bosses of the housing.

3. Connect the cable assembly to the air shut-off cam handle pin.

4. Start and run the engine at idle speed and no-load. Trip the air shutdown. If the engine does not stop, check it for air leakage between the valve and the striker plate. If necessary, reposition the valve.

5. Install the air cleaner or air cleaner ducts.

BLOWER

The blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow three-lobe rotors revolve with very close clearances in the housing bolted to the cylinder block. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form, (Fig. 1).

Two timing gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance; therefore, as the lobes of the upper and lower rotors do not touch at any time, no lubrication is required.

Oil seals located in the blower end plates prevent air leakage and also keep the oil used for lubricating the timing gears and rotor shaft bearings from entering the rotor compartment.

Lip type oil seals are installed in the blower end plates.

Each rotor is supported in the doweled end plates of the blower housing by a roller bearing at the front end and a double row pre-loaded radial and thrust ball bearing at the gear end.

The blower upper rotor is driven by the blower drive shaft which is coupled to the upper rotor timing gear by means of a flexible drive hub (20 Fig. 1).

A flexible coupling, formed by an elliptical cam driven by two bundles of leaf springs which ride on four semi-cylindrical supports and spring seats is attached to the blower drive gear (42 Fig. 1), and prevents the transfer of torque fluctuations to the blower.

The small diameter rotor blower with a 2.00:1 blower-to-engine speed ratio is employed. This type blower does not use reduction gears. The blower drive gear has 39 teeth.

Since the lower rotor (timing) gear (14) is also splined to the lower rotor shaft, it drives the upper rotor (timing) gear (13).

The blower rotors are timed by the two rotor (timing) gears (13) and (14) at the rear end of the rotor shafts.

This timing must be correct, otherwise the required clearance between the rotor lobes will not be maintained.

Normal gear wear causes a decrease in the rotor-to-rotor clearance between the leading edge of the upper rotor lobes and the trailing edge of the lower rotor lobes of the blower.

While the rotor lobe clearance may be adjusted by the use of shims behind the gears, gear backlash cannot be corrected. When gears have worn to the point where the backlash exceeds .004", replace the gears.

Lubrication

Oil drains from the valve operating mechanism on the cylinder head into the camshaft pocket in the cylinder block. Then, when it reaches a certain level, the oil flows from the pocket into cavities at the upper corners of the blower and through passages in the blower and end plates to lubricate the bearings, governor and water pump drives at the front end, and bearings and gears at the rear end of the blower. A slinger attached to the front end of the lower rotor shaft throws oil onto the front roller bearings and governor weights. A dam in the blower end plates maintains oil at a level adequate to submerge the lower portion of the slinger and the driven gear.

Surplus oil overflows the dams in the end plates and returns through two drilled holes in the cylinder block to the engine crankcase.

Inspection of Blower

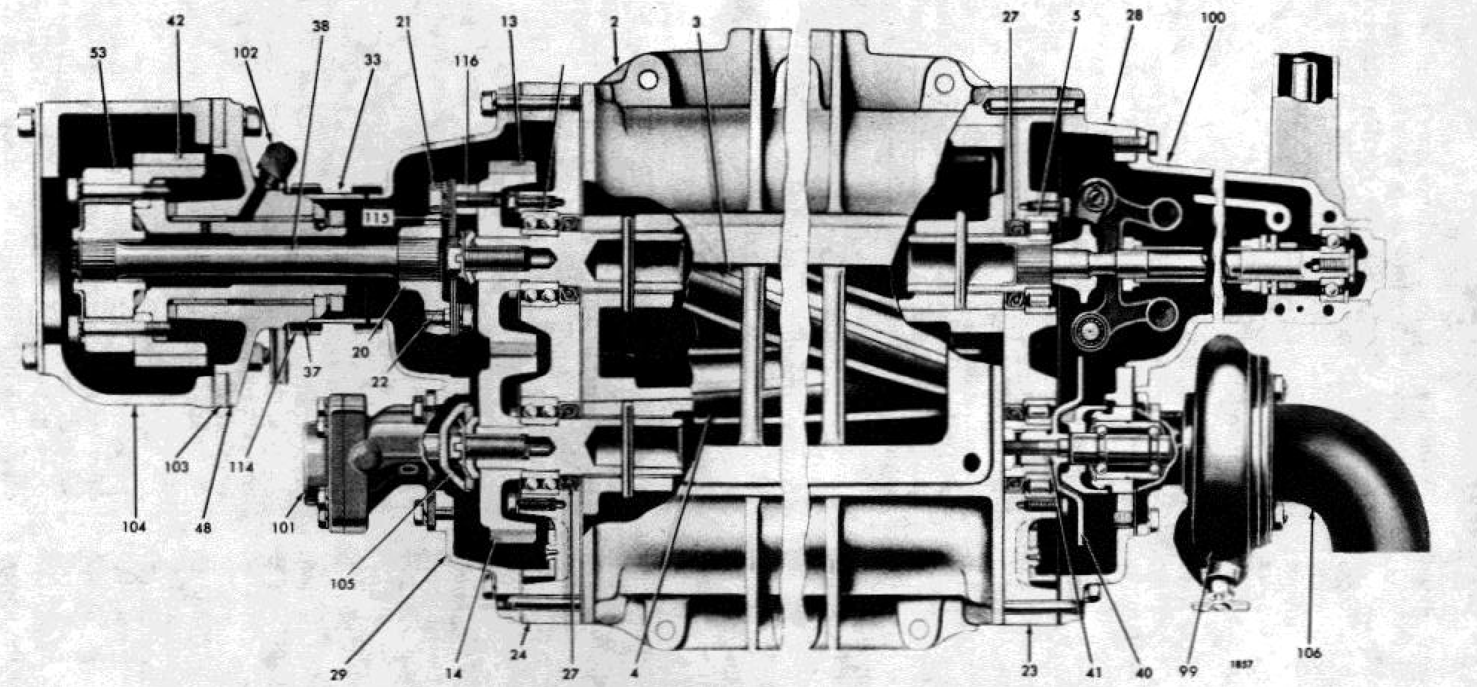
The blower may be inspected for any of the following conditions without being removed from the engine. However, the air shutdown housing must be removed.

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 the housing, remove the blower from the engine and dress the parts down to eliminate the interference, or replace the rotors if they are too badly scored.

Leaky oil seals are usually manifested by the presence of oil on the blower end plates and rotors or the inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals is indicative of an oil leak.



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

Fig. 1 - Blower and Drive Assembly and Accessories including Mechanical Governor Attached to blower

A worn blower drive, resulting in a rattling noise inside the blower, may be detected by grasping the top rotor firmly and attempting to rotate it. Rotors may move from 3/8" to 5/8", measured at the lobe crown, with a springing action. When released, the rotors should move back at least 1/4". If the rotors cannot be moved as directed above, or if the rotors move too freely, inspect the flexible blower drive coupling and replace it if necessary.

If the drive coupling is worn, the blower drive gear assembly may be removed from the cylinder block end plate after the blower has been removed from the engine and the drive gear hub bearing support to cylinder block end plate bolts are removed (refer to Page 10-2-125).

Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates, or between the rotors and the housing. Generally, a combination of these conditions exists. A loose shaft usually causes rubbing between the rotors and the end plates. Worn or damaged bearings will cause rubbing between the mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing. This condition will usually show up at the end where the bearings have failed.

Excessive backlash 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 as noted on Page 10-11-3 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 (refer to Page 10-1 1-7).

Remove Blower In most cases, removal of the blower, together with the governor drive, fresh water pump, fuel oil pump, and the blower drive shaft cover, will be found most advantageous. For removal of this assembly, refer to Fig. 2 and proceed as follows:

1. Drain the cooling system.

2. Remove the governor control housing assembly as outlined under Remove Governor on Page 10-3-39 for a variable speed governor.

3. Disconnect the fuel lines at the fuel pump.

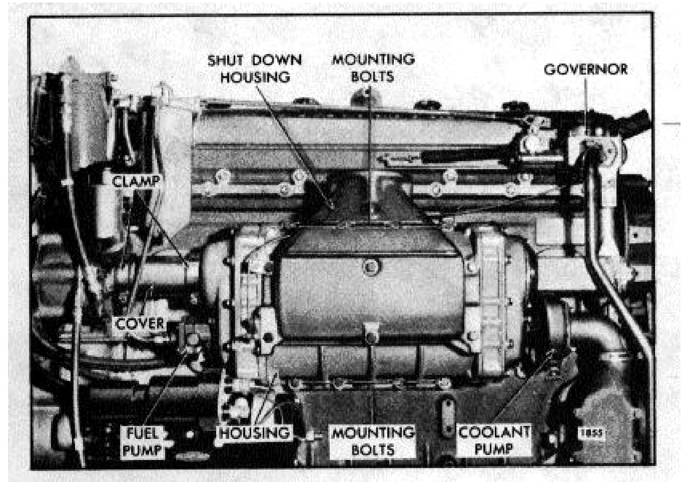


Fig. 2 Typical Blower Mounting (71 Engine)

4. Loosen the water pump connections at the pump cover (inlet) and the cylinder block.

5. Disconnect the control wire from the shutdown valve shaft lever, then remove the bolt securing the control wire clip to the air shutdown housing.

6. Remove the air cleaner air ducts, then remove the air inlet housing, gasket, striker plate and air inlet screen and gasket from the blower.

7. Remove the blower drive shaft as outlined on Page 10-2-124.

8. Loosen the blower drive shaft cover seal clamp (114 Fig. I) at the blower drive gear hub support.

9. Remove the bolts and plain washers securing the blower to the cylinder block. Slide the blower slightly forward, withdraw the blower drive shaft cover from the seal, then lift the blower away from the cylinder block.

Remove Accessories from Blower

1. Remove the three bolts and seal washer assembly 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 assembly securing the fresh water pump to the blower front end plate cover, then remove the water pump and gasket. If necessary, tap the pump with a plastic hammer to loosen it.

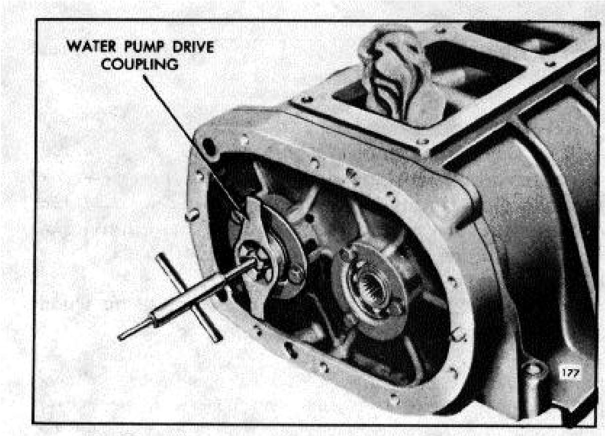


Fig. 3 - Removing Water Pump Drive Coupling Bolt from Blower Rotor Shaft

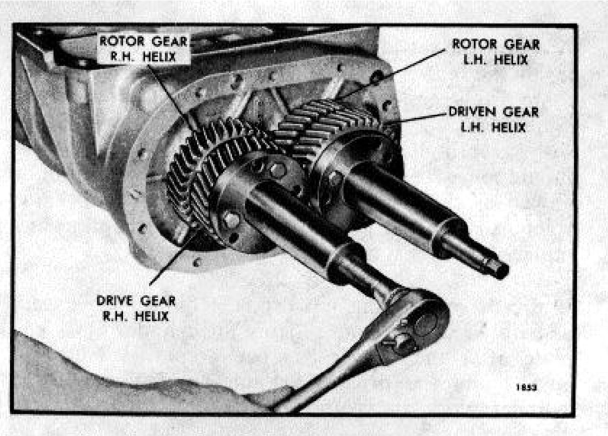


Fig. 4 Removing Blower Rotor Gears from Blower Rotor Shafts with Tool Set J 6270-F

4. Remove the six bolts and seal washer assembly securing the governor weight housing to the blower front end plate cover, then remove the weight housing and gasket.

Disassemble Blower

Refer to Figs. 1 and 7 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 cloth between the rotors to prevent the rotors from turning. Then, remove the bolt securing the water pump drive coupling to the blower rotor shaft as shown in Fig. 3.

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 6471-1 to the adaptor and pull the drive coupling from the blower rotor shaft.

4. Refer to Fig. 7 and remove the bolts (21), lock washers and plain washers securing the blower rotor drive hub (20) and drive hub plates (115) to the blower rotor timing gear (13). Remove the drive hub plates and spacers (116) from the gear. If necessary, remove the 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, lockwasher and fuel pump coupling disc (18) securing the other timing gear to the lefthand helix rotor shaft.

b. Back out the center screw of both pullers J 627031 and secure the pullers to the timing 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 (Fig. 4).

d. Remove the shims from the rotor shafts or the inner face of the gears and note the number and thickness of the shims used with each gear.

6. Remove the bolts and lock washers securing the rotor shaft bearing retainers (6) to both the front and rear end plates. Remove the retainers.

7. Remove the blower rear end plate and bearing assembly from the blower housing and rotors with the two pullers J 6270-31 as follows:

a. Remove the two fillister head screws (26) securing the rear end plate (24) to the blower housing, and loosen the two fillister head screws securing the front end plate (23) to the housing approximately three turns.

b. Back out the center screws of the pullers far enough to permit the flange of each puller to lay flat on the face of the end plate.

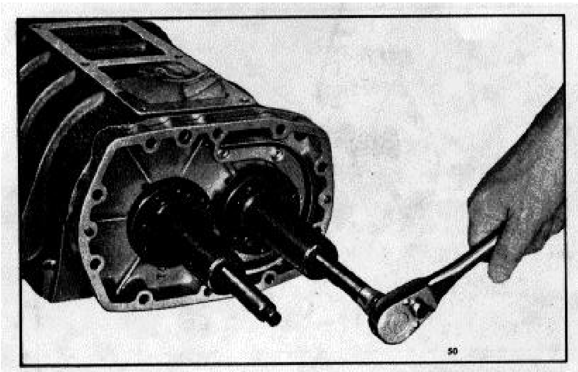


Fig 5 - Removing Blower End Plate using Tool Set J 6270-F

c. Align the hole in each puller flange with the tapped holes in the end plate and secure the pullers to the end plate with six 1/4"-20 x 1-1/4" bolts.

CAUTION: Be sure that the 1/4"-20 bolts are threaded all the way into the tapped holes in the end plate to provide maximum anchorage for the pullers and to eliminate possible damage to the end plate.

d. Turn the two pullers screws uniformly clockwise and withdraw the end plate and bearings from the blower housing and rotors as shown in Fig. 5.

8. Remove the blower front end plate in the same manner as described in Step 7 above.

9. Withdraw the blower rotors from the housing.

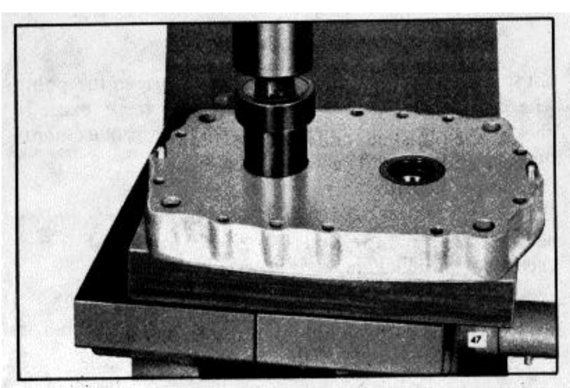


Fig. 6 Removing Oil Seal and Bearing from End Plate with Tool J 6270-3

10. Remove the bearings and the lip type oil seals from the blower end plates as follows:

a. When performing a major overhaul, discard the oil seals, otherwise inspect the oil seals. If the seals are scored, or hard, new seals must be installed. If necessary, remove the seals from the end plates at the same time the individual bearings are removed.

b. Support the outer face of the end plate on wood blocks on the bed of an arbor press.

c. Place the long end of the oil seal remover and installer J 6270-3 down through the oil seal and into the bearing, with the opposite end of the remover under the ram of the press (Fig. 6). Then, press the bearing and oil seal out of the end plate. Discard the oil seal.

d. Remove the remaining bearings and oil seals 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 holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots. .

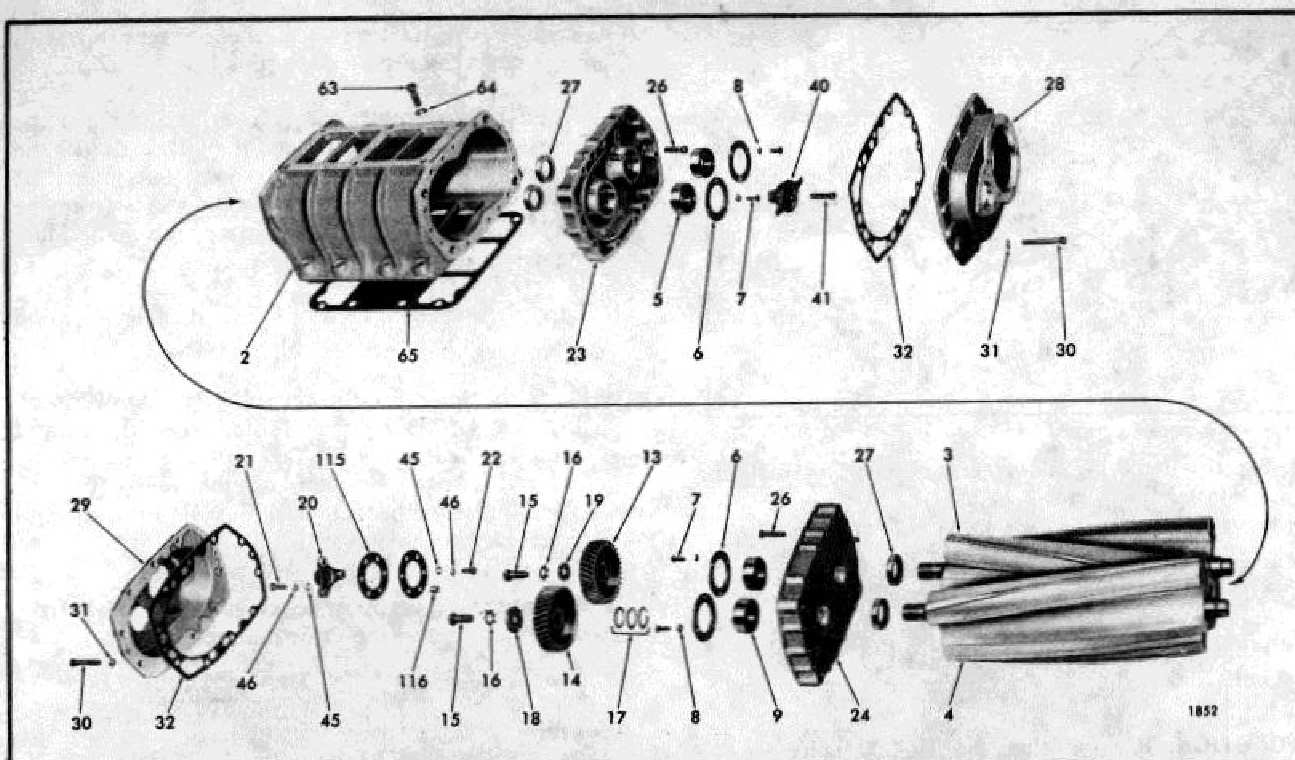
The double-row ball bearings are pre-loaded and have no end play. A new double-row bearing will seem to have considerable resistance to motion when revolved by hand.

NOTE: When a blower with lip type oil seals is being reconditioned oversize oil seals and oil seal spacers are available in the blower kit to replace the standard oil seals where the blower rotor shafts are grooved.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring. Rotors must be smooth for efficient operation of the blower. If the rotors are slightly scored or burred, they may be cleaned up with emery cloth.

Examine the rotor shaft serrations for wear, burrs or peening. Also, inspect the bearing and oil seal contact surfaces of the shafts for wear and scoring.

Inspect the inside surface of the blower housing for burrs and scoring. The inside surface must be smooth for efficient operation of the blower. If the inside surface of the housing is slightly scored or burred, it may be cleaned up with emery cloth.



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
45. Plain Washer
46. Lock Washer
63. Bolt--Blower Mounting
64. Plain Washer--Blower Mounting
115. Plate--Blower Rotor Drive Hub
116. Spacer--Place to Gear

Fig. 7 - Typical Details and Relative Location of Parts

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.

NOTE: Be careful not to remove metal at the joint face between the end plates and the housing. Air or oil leaks could develop after assembly.

Examine the serrations in the blower timing gears for wear and peening; also check the teeth for wear, chipping or damage. If the gears are worn to the point where the backlash between the gear teeth exceeds .004", or damaged sufficiently to require replacement, both gears must be replaced as a set.

Check the blower drive shaft serrations for wear or peening. Replace the shaft if it is bent, cracked or has excessive spline wear.

Inspect the serrations inside the rotor drive hub for wear and peening.

Inspect the blower drive coupling springs (pack) and the cam for wear.

Replace all worn or excessively damaged blower parts.

Assemble Blower

Several precautions are given below to assure proper assembly of the rotors and gears for correct blower timing.

The lobes on the upper blower rotor and the teeth on its gear form a right-hand helix while the lobes and teeth of the lower rotor and gear form a left-hand helix. Therefore, a rotor with right-hand helix lobes must be used with a gear having right-hand helix teeth and vice versa.

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.

With this precaution in mind, proceed with blower assembly, referring to Figs. 7 through 15 as directed in the text.

1. Install the lip type oil seals as follows (Fig. 9).

   a. Support the blower end plate, finished surface facing up, on wood blocks on the bed of an arbor press (Fig. 8).

   NOTE

   If oversize oil seals are being used in the blower end plates, use installer J 6270-28 to install the oversize oil seal spacers on the rotor shafts.

   b. Start the oil seal straight into the bore in the end plate with the sealing edge facing down (toward the bearing bore).

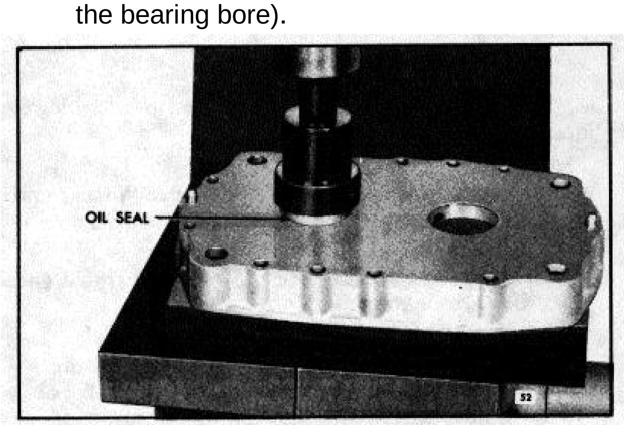


Fig. 8 - Installing Oil Seal in Blower End Plate using Tool J 6270-3.

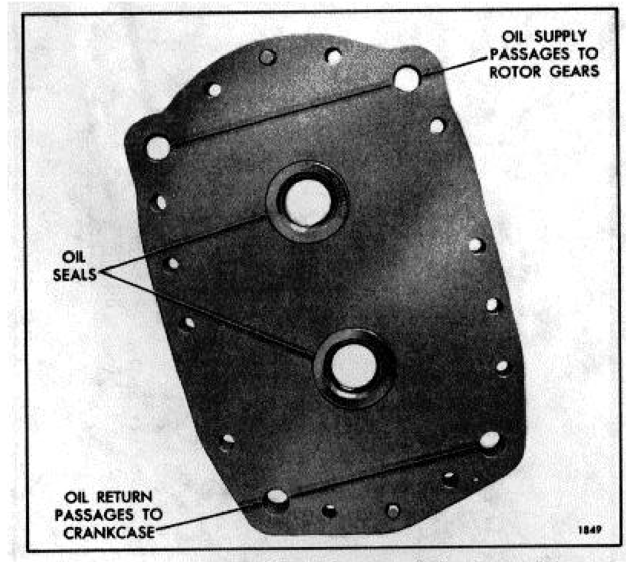


Fig. 9 - Blower End Plate and Lip Type Oil Seal Location.

   c. Place the short end of oil seal remover and installer J 6270-3 in the oil seal and press the oil seal into the end plate until the shoulder on the installer contacts the end plate (Fig. 8).

   NOTE

   A step under the shoulder of the installer will position the oil seal approximately .005" below the finished face of the end plate. This is within the .002" to .008" specified.

   d. Install the remaining oil seals in the end plates in the same manner.

Assemble Rotors and End Plates

No gaskets are used between the end plates and the housing; therefore, the mating surfaces must be perfectly flat and smooth.

Apply a rubber base sealant as required to avoid leakage between the end plates and the blower housing.

NOTE

Be sure no sealant protrudes into the blower housing. Also, the sealant must not prevent the end plates from laying against the housing.

1. Install the blower front end plate. Make sure the mark TOP on the outer ribbed side is at the top of the blower housing, identified by the flange which supports the housing on the top edge of the cylinder block (Fig. 10).

The front and rear end plates of the blower are interchangeable.

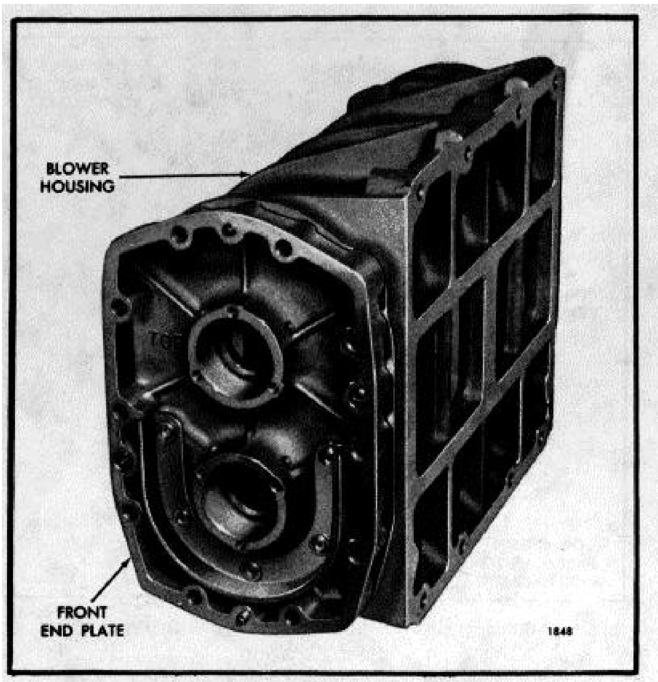


Fig. 10 - Position of Blower Front End Plate on Housing.

One end plate should be assembled to the front end of the blower housing first and the other plate should be assembled to the rear of the blower housing after the rotors are in place. Attach an end plate to the front of the blower housing as follows:

a. Check the dowel pins. The dowel pins must project .380" from the flat inner face, and .270" from the outer face of the front end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.

b. Place the blower housing on a bench with the top of the housing up, and the front end of the housing facing the outside of the bench.

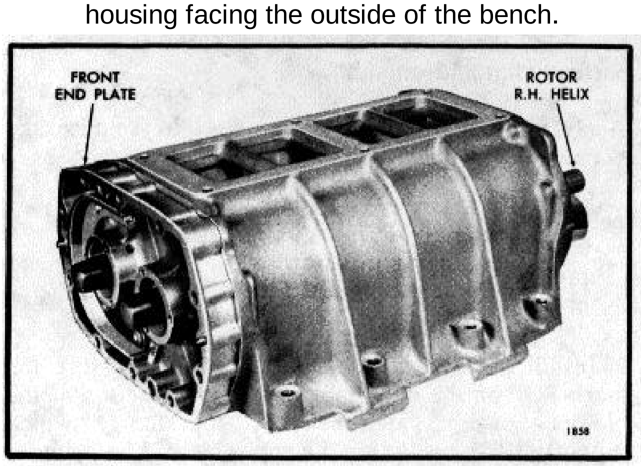


Fig. 11 - Assembling Blower Rotors into Housing and Front End Plate (Lip Type Oil Seals) using Tool J 6270-5.

c. Position the end plate in front of the blower housing with the flat finished face of the end plate facing the housing and the end marked TOP facing the flanged side of the housing. Then, start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing.

d. Insert the two fillister head screws through the 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.

2. Assemble the blower rotors in the blower housing and front end plate as follows:

The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig. 18.

NOTE

The housing used in N Blower assemblies are stamped for identification with the letter "E", near the top of the housing.

a. Place an oil seal pilot J 6270-5 on the short (non-splined) end of each rotor shaft. Then, place the rotors in mesh with the omitted serrations in the shafts in alignment as shown in Fig. 18.

NOTE

When oversize oil seals are used in the blower end plate, use oil seal spacer installers J 6270-28 for the oil seal pilots in place of J 6270-5.

b. Insert the blower rotors with oil seal pilots straight into the blower housing with the right-hand helix rotor at the top, flange, side of the housing. Then, push the rotor shafts and oil seal pilots on through the oil seal in the front end plate as shown in Fig. 11.

c. Remove the oil seal pilots from the rotor shafts.

3. Attach the blower rear end plate to the blower housing as follows:

a. Reverse the blower housing on the bench (rear end of housing facing the outside of the bench).

b. Place an oil seal pilot J 6270-5 on the serrated end of each rotor shaft.

NOTE

When oversize oil seals are used in the blower end plate, use oil seal spacer installers J 6270-28 for the oil seal pilots in place of J 6270-5.

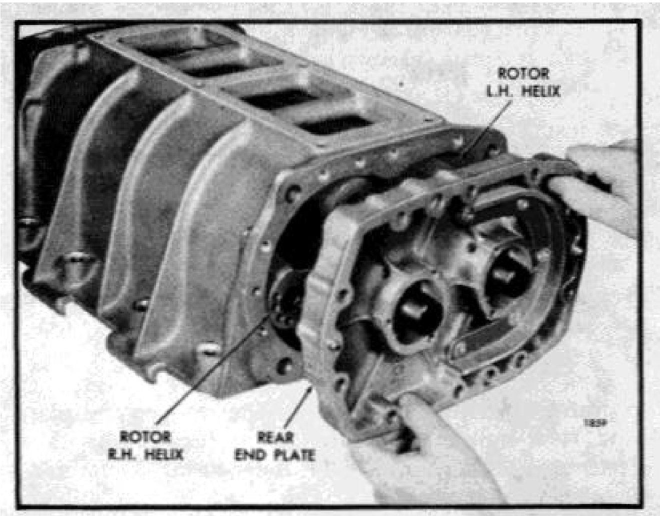


Fig. 12 - Installing Blower Rear End Plate (Lip Type Oil Seals) using Tool J 6270-5.

c. Check the dowel pins. The dowel pins must project .380" from the flat inner face, and .270" from the outer face of the rear end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.

d. Place the rear end plate in position in front of the oil seal pilots with the flat finished face of the end plate facing the blower housing and the mark TOP on the end plate at the top flange side of the housing.

e. Place the rear end plate over the oil seal pilots (Fig. 12) and start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing.

f. Insert the two fillister head screws through the end plate and thread them into the housing. Tighten the screws to 5-10 lb-ft (7-14 Nm) torque. Do not use lock washers on these screws.

g. Remove the oil seal pilots from the rotor shafts.

Install Blower Rotor Shaft Bearings and Gears

1. With the blower housing, rotors and end plates still supported in a vertical position on the two wood blocks, install the 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, numbered end up, straight on one of the rotor shafts.

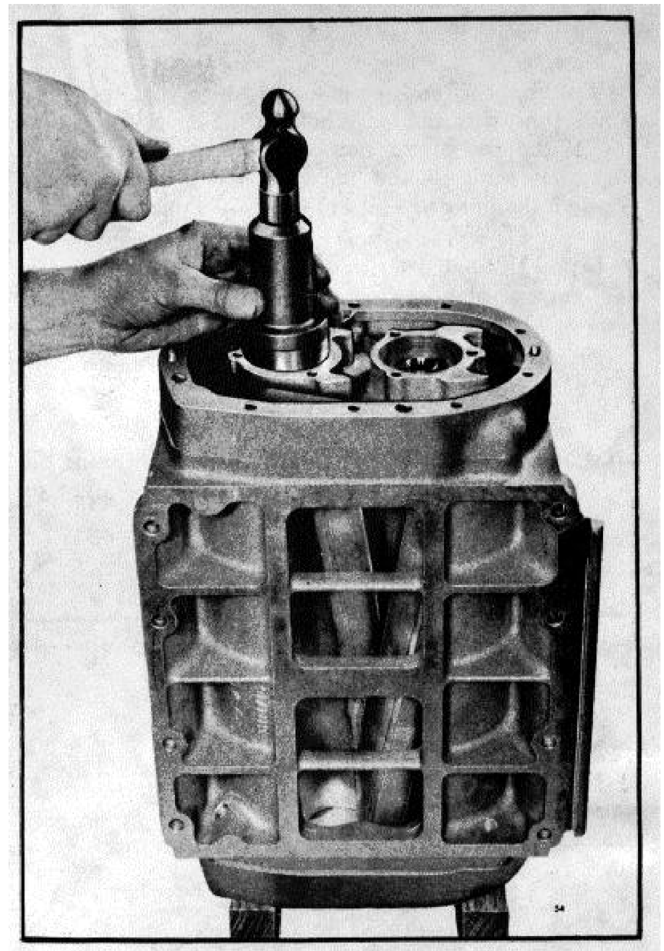


Fig. 13 - Installing Roller Bearing on Rotor Shaft and in Front End Plate using Tool J 6270-4.

b. Place installer J 6270-4 on top of the bearing and tap the bearing on the shaft and into the front end plate as shown in Fig. 13.

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 folded cloth 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. Refer to Fig. 7 and affix a new gasket (32) to the blower front end plate cover (28).

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. (Fig. 14).

b. Lubricate one of the ball bearings with engine oil. Start the bearing numbered end up, straight on one of the rotor shafts.

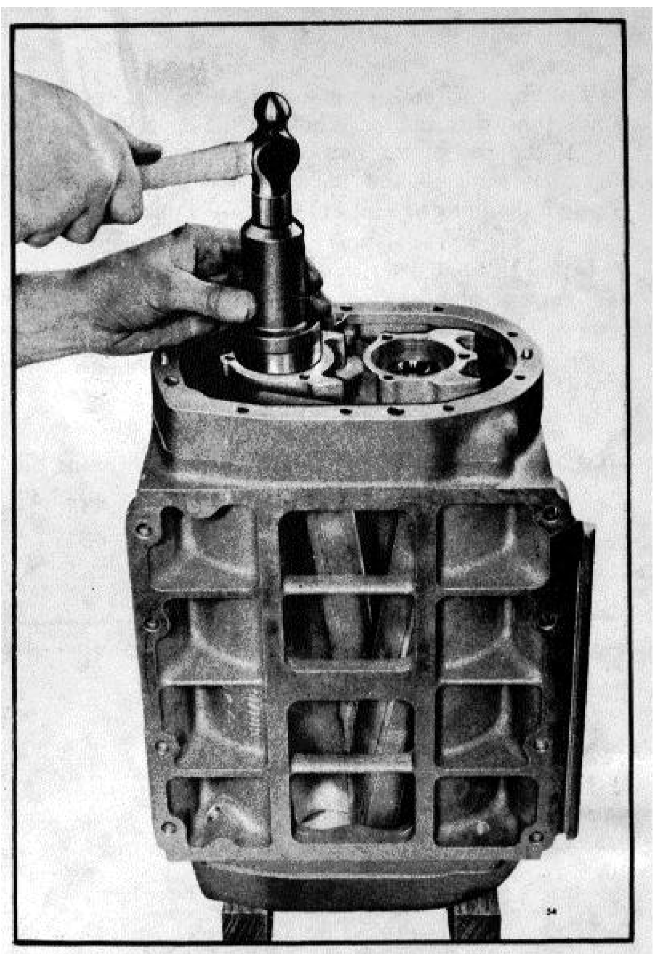


Fig. 14 - Installing Ball Bearing on Rotor Shaft and in Rear End Plate using Tool J 6270-7.

c. 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 Fig. 14.

d. Install the second ball bearing on the remaining rotor shaft in the same manner.

e. 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.

6. Make a preliminary check of the rotor-to-end plate and rotor-to-housing clearances at this time with a feeler gage as shown in Fig. 19. Refer to Fig. 17 for minimum blower clearances.

7. Install the blower rotor timing gears as follows:

One serration is omitted on the drive end of each blower rotor shaft and a corresponding serration is omitted in each gear. Assemble the gears on the rotor shafts with the serrations in alignment.

A center punch mark placed in the end of each rotor shaft at the omitted serrations will assist in aligning the gears on the shafts.

a. Place the blower housing and rotor assembly on the bench with the air inlet side of the housing facing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench.

b. Rotate the rotors to bring the omitted serrations on the shafts in alignment and facing the top of the blower housing (Fig. 18).

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; refer to Fig. 18.

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.

f. Start both rotor gears straight on the rotor shafts with the right-hand helix gear on the right-hand helix rotor and the left-hand helix gear on the left-hand helix rotor, and the omitted serrations in the gears in line with the omitted serrations on the rotor shafts.

g. Thread an installer screw J 6270-8 in the end of each rotor shaft until it bottoms. Place gear installer J 6270-7 over the installer screw and against the right-hand helix gear and gear installer J 6270-6 over the installer screw and against the left-hand helix gear. Then, thread a nut on each installer screw (Fig. 15).

h. Place a clean folded cloth between the lobes of the rotors, to prevent the rotors from turning. Then, turn the nuts on the installer screws clockwise as shown in Fig. 15 and draw the two gears into position at the same time, tight against the shims and bearing inner races.

i. Remove the rotor timing gear installers from the rotor shafts.

j. Place a lock washer (16) and the gear retaining washer (19) on one of the gear retaining bolts (Fig. 7). Thread the bolt into the right-hand helix rotor shaft, and guide the lugs on the retaining washer in the slots in the gear hub.

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 the fuel pump drive coupling disc (18) on the remaining gear retaining bolt (Fig. 7). 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.

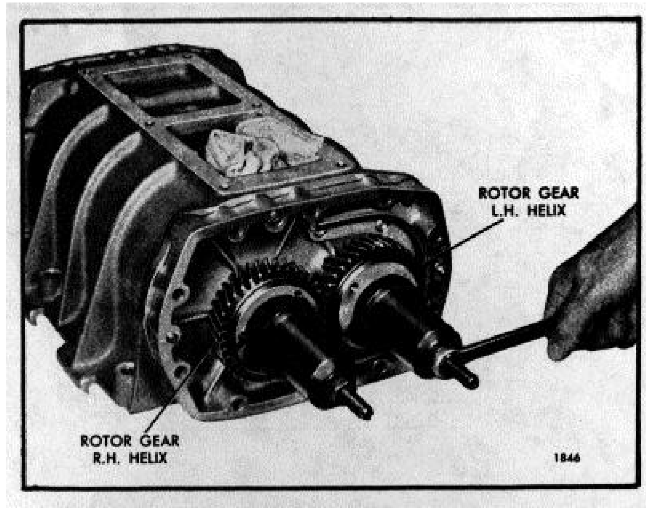


Fig. 15 - Installing Rotor Gears on Rotor Shafts for Preliminary Check of Clearances using Tool J 6270-6, 7 and 8.

l. Bend one of the tangs of each lock washer over against the head of the gear retaining bolt. Remove the cloth from between 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.

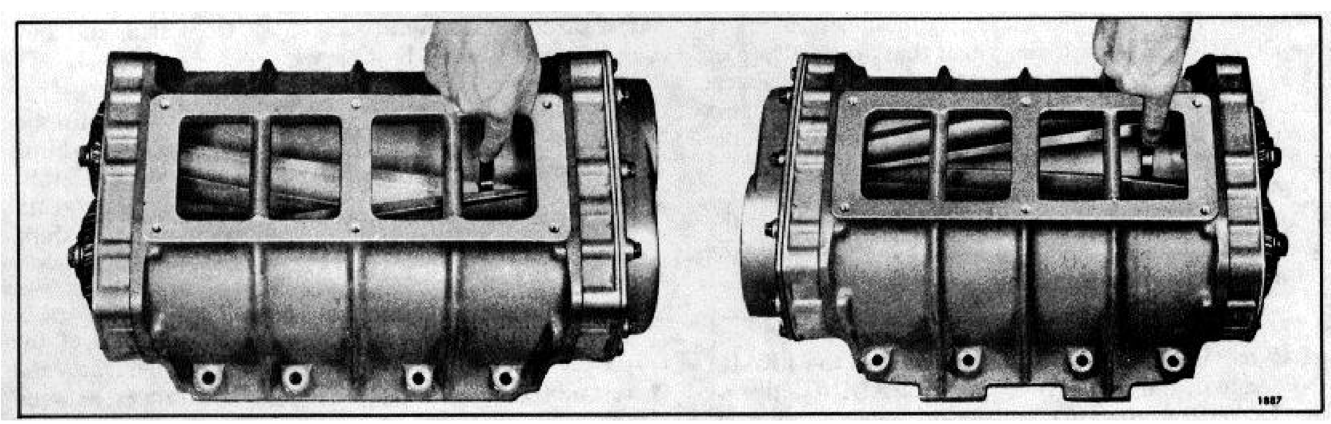
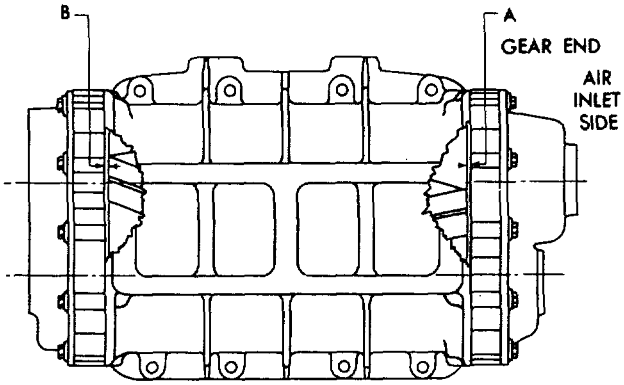
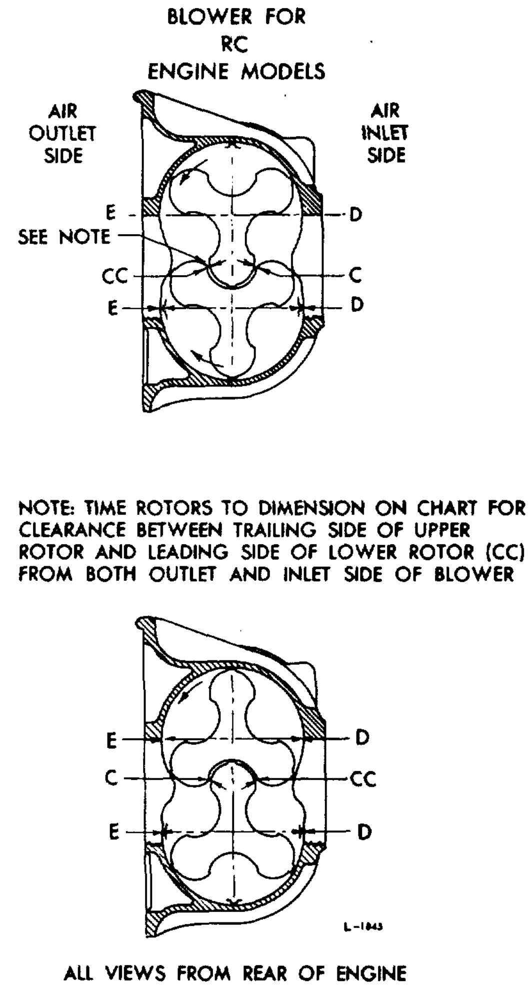


Fig. 16 - Measuring "CC" and "C" Clearances Between Blower Rotor Lobes.





		A	B	C	CC	D	E
3-71	MIN.	.007	.007	.010	.004	.015	.004
	MAX.				.008		
4-71	MIN.	.007	.009	.010	.004	.015	.004
	MAX.				.008		
6-71	MIN.	.007	.014	.010	.004	.015	.004
	MAX.				.008		
6-71P	MIN.	.012	.019	.014	.002	.030	.004
	MAX.				.006		

TIME ROTORS TO DIMENSIONS ABOVE

NOTE: TIME ROTORS TO DIMENSION ON CHART FOR CLEARANCE BETWEEN TRAILING SIDE OF UPPER ROTOR AND LEADING SIDE OF LOWER ROTOR (CC) FROM BOTH OUTLET AND INLET SIDE OF BLOWER

Fig. 17 - Chart of Minimum Clearances for Blowers.

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" wide feeler gages in the manner shown in Fig. 16. When measuring clearances of more than .005", laminated feeler gages that are made up of .002", .003" or .005" feeler stock are more practical and suitable than a single feeler gage. Clearances should be measured from both the inlet and outlet sides of the blower.

A specially designed feeler gage set J 1698-02 for the blower clearance operation is available. Time the rotors as follows:

1. 71 Blower - Timing the rotors to have .002" or .004" to .006" or .008" clearance between the **TRAILING** edge of the **UPPER** rotor and **LEADING** edge of the **LOWER** rotor ("CC" clearance) measured from both the inlet and outlet sides as shown in Figs. 16 and 17. If possible, keep this clearance to the minimum dimension. Then check the clearance between the **LEADING** edge of the **UPPER** and the **TRAILING** edge of the **LOWER** rotors ("C" clearance) for the minimum clearance shown in Fig. 17. Rotor-to-rotor measurements should be taken 1" from each end and at the center of the blower.

2. After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear to produce the desired result. When more or less shims are required, both gears must be removed from the rotors. Placing a .003" shim in back of a rotor gear will revolve the rotor .001 ".

3. Install the required thickness of shims back of the proper gear and next to the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.

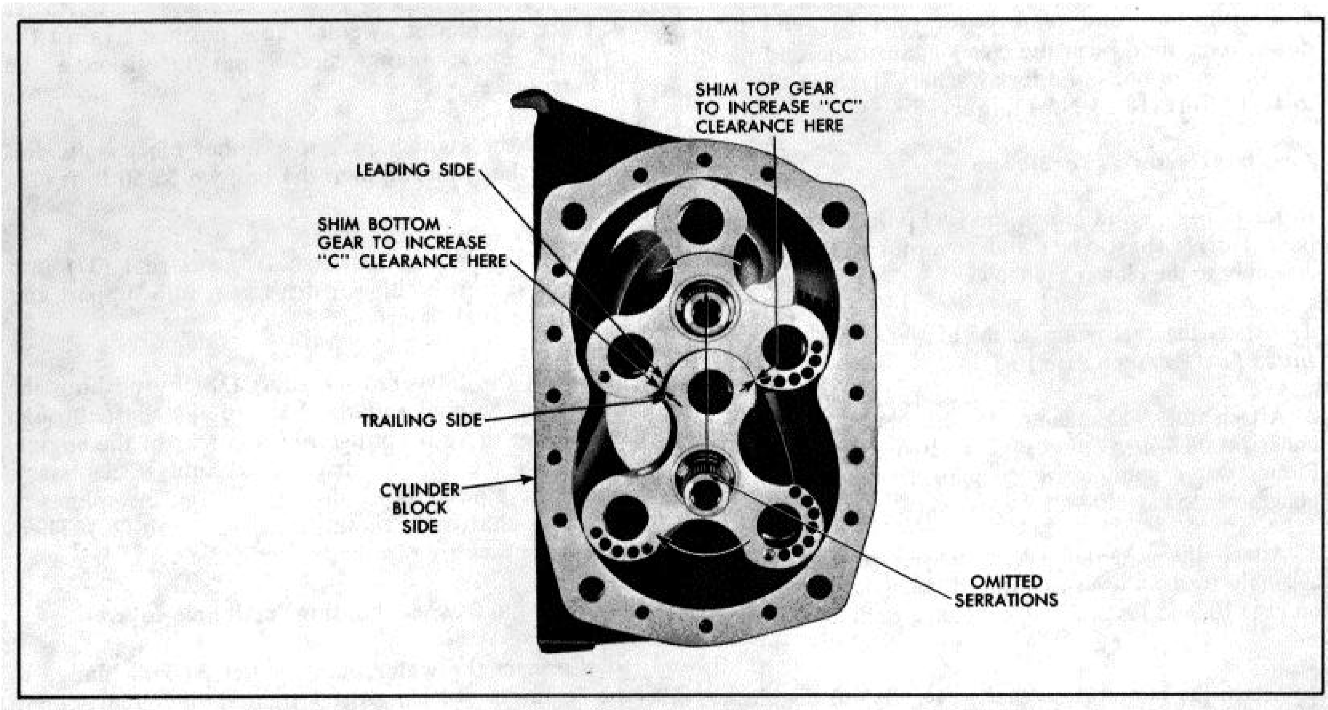


Fig. 18 - Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances.

4. Determine the minimum clearances at points "A" and "B" shown in Fig. 17. Insert the feeler gages, as shown in Fig. 19, 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 Fig. 17 for the minimum clearances.

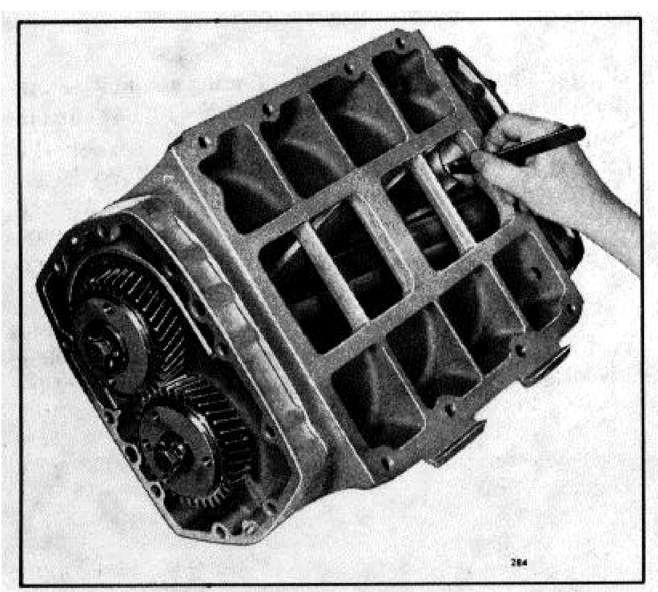


Fig. 19 - Measuring End Clearance Between Blower Rotors and End Plate .

5. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side -twelve measurements in all. See Fig. 17 for the minimum clearances.

After the blower rotors, are timed, complete the assembly of the blower as outlined below.

2. Refer to Fig. 7 and attach the blower rotor drive hub (20) and drive hub plates (115) to the blower gears as follows:

a. If removed, attach the rotor drive hub plates (115) to the 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) 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 .020" total indicator reading.

3. Affix a new gasket (32) to the blower rear end plate cover (29).

4. Position the end plate cover over the end plate dowel pins, then push the cover against the end plate. Install the ten bolts and lock washers. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

Attach Accessories to Blower

Refer to Fig. 1 and attach the fuel pump, water pump, blower drive shaft cover and governor weight housing assembly to the blower as follows:

1. Attach the fuel pump to the blower as outlined under *Install Fuel Pump* on Page 10-3-34.

2. Attach the water pump to the blower as outlined under *Install Water Pump* on Page 10-6-9. To convert the former water pump drive coupling to the current coupling, refer to Page 10-4-21,

3. Attach the governor weight housing to drive housing assembly to the blower as outlined under *Install Governor* on Page 10-3-48 for the variable speed governor.

4. Attach the blower drive shaft cover (33) to the blower rear end plate cover (29) with cover seal (37) and seal clamp (114) as shown in Fig. 1.

Attach Blower to Engine

Refer to Fig. 2 or 7 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. 1300, or equivalent, to prevent the gasket from shifting when placing the blower against the block.

2. Place a new drive shaft cover seal (37) and seal clamp (114) over the end of the drive shaft cover (33).

3. Place the water pump outlet packing flange, flat face toward pump body, and slide a new packing ring over the pump outlet. Then, place a new water pump cover seal and clamp on top of the oil cooler housing outlet opening.

4. Place the blower assembly into position against the cylinder block, being careful not to dislodge the blower gasket.

5. Install the eight blower to cylinder block bolts and plain washers, and tighten the bolts to 55-60 lb-ft (7581 Nm) torque.

6. Slide the blower drive shaft cover seal (37) into position against the blower drive gear hub support and tighten the seal clamp.

7. Install the blower drive shaft (38) by pushing the plain end, without squared hole, of the shaft through the blower drive coupling from the rear of the engine, then into the blower drive gear hub. If necessary, rotate the blower rotors slightly to align the splines of the drive shaft with those in the gear hub (20). Then, install the lock ring in the blower drive cam.

8. Install the flywheel housing small hole cover.

9. Connect the water pump outlet packing flange to the cylinder block. Also, tighten the seal clamp connecting the water pump cover to the oil cooler housing.

10. Place the blower air shutdown housing, together with the striker plate gasket, striker plate (if used) and screen and gasket assembly against the blower (with the screen side of gasket assembly toward the blower). Secure them in place with bolts and lock washers. Tighten the bolts to 16-20 lb-ft (22-27 Nm) torque.

11. Connect the control wire to the air shutdown valve shaft lever and attach the control wire clip under the head of the air inlet housing attaching bolt.

12. Install the governor control housing assembly as outlined under *Install Governor* on Page 10-3-48 for the variable speed governor.

13. Install the air cleaner air ducts.

14. Connect the fuel lines to the fuel pump.

15. Fill the cooling system with clean fresh water plus rust inhibitor (or sufficient quantity of an ethylene glycol base antifreeze) and check the system for leaks.

SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

INSTALLING WATER PUMP DRIVE AND ROTOR SHAFT KIT

The current design water pump intermediate drive coupling is designed to minimize wear, thereby increasing service life.

To convert the former drive coupling to the current coupling, a "Water Pump Drive and Rotor Shaft Kit" must be used.

NOTE:

Before the kit can be installed, refer to Page 104-9 and remove and disassemble the blower.

Remove Rotor Stub Shaft

Refer to Fig. 1 for identification and location of the parts.

1. Use a sharp screw driver or similar tool to punch a hole in the center of the core plug, opposite the visible drilled hole in the rotor, and pry out the plug.

2. Drive the groove pin down through the shaft with a punch until it reaches the position shown by the dotted line.

3. Bend the groove pin with the punch until it is almost "L" shaped as shown by the solid line. This operation is necessary because the length of the pin is

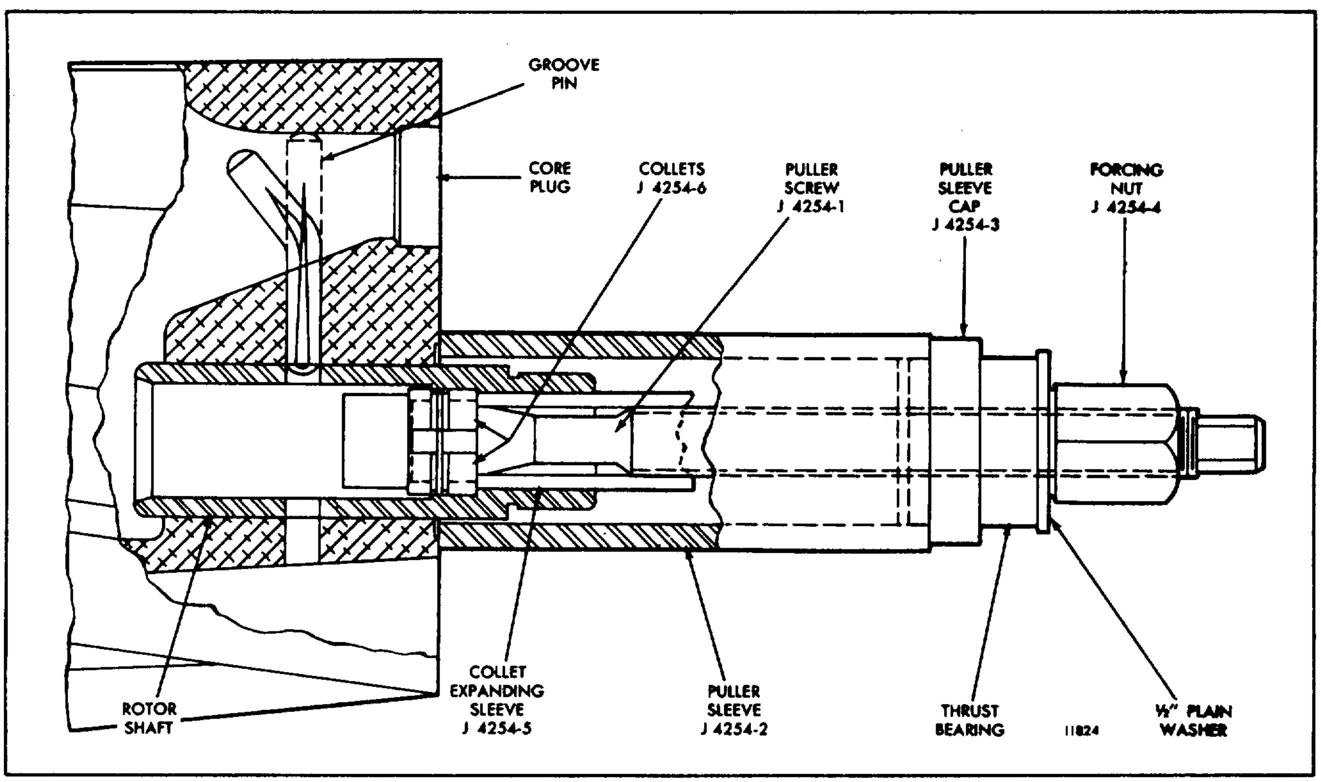


Fig. 1 - Removing Rotor Stub Shaft.

greater than the corresponding width of the rotor cavity.

4. Drive the groove pin in until it drops into the rotor cavity.

5. Remove the plug from the inside of the rotor shaft by driving it out of the shaft and into the rotor body.

6. Clamp the rotor firmly in a vise with soft wood blocks between the rotor and the vise jaws.

7. Insert the puller screw (J 4254-1) with the collets (J 4254-6) in the retracted position into the rotor shaft until the collets are beyond the shoulder on the internal surface of the shaft.

8. Push the collets on to the larger diameter of the puller screw as shown. Remove the collet expanding sleeve (J 4254-5).

9. Coat the threads of the puller screw with an extreme pressure lubricant.

10. Pull the puller screw outward by hand until the collets seat against the internal shoulder of the rotor shaft and maintain tension on the puller screw.

11. While holding the puller screw in this position, place the following tool components, in the order named, over the puller screw: puller sleeve (J 4254-2), puller sleeve cap (J 4254-3), thrust bearing, 1/2" plain washer and forcing nut (J 4254-4).

12. Tighten the forcing nut until it is finger tight.

13. Thread the forcing nut on the puller screw to remove the shaft from the rotor.

14. Remove the rotor from the vise and shake the rotor shaft plug and groove pin from the rotor cavity.

Install Service Rotor Front Stub Shaft

1. Coat the new blower rotor front shaft with lubriplate, or equivalent.

2. Use a suitable press arrangement, align the rotor shaft with its hole in the rotor and press the shaft into the rotor to the height of the spacer (J 4254-8).

3. Drill and ream a new .250 " diameter, 2.500 " deep pin hole in the rotor 120 " from the existing pin hole.

4. Drive the new groove pin into the new hole. The end of the pin must be .0625 " below the rotor surface.

5. Install a new core plug.

6. Stake the pin and the core plug after installation and remove all raised burrs.

After the modified lower blower rotor assembly has been used in the re-assembly of the blower up to the point where the water pump intermediate drive coupling is to be installed, install the new water pump intermediate drive coupling in accordance with the following procedure.

Attach Water Pump Intermediate Drive Coupling to Blower Rotor

1. Install the splined end of the water pump intermediate drive coupling into the lower blower rotor front stub shaft.

2. Insert the 5/16" bolt through the water pump coupling and thread it into the rotor shaft and plug assembly.

3. Tighten the bolt to 15-19 lb-ft (20-26 Nm) torque.

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

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 "		

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		GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None		GM 255-M	1	No. 6 thru 1 1/2	60,000
None		GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
	Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
	Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
	Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
	Bolts and Screws	GM 300-M	8	1/4 thru I 1/2	150,000
	Bolts and Screws	GM 455-M	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
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

LUBRICATION SYSTEM **CHAPTER 5**

CONTENTS PAGE

LUBRICATION SYSTEM

Fig. 1 schematically illustrates the flow of oil through a typical In-line 71 lubricating system including the various components such as the oil pump, oil cooler, bypass and full-flow filters, the pressure regulator valve and bypass valve.

The lubricating oil is circulated by a gear-type pressure pump mounted on the No. I 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, bypasses 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 bypass valve directly into the oil gallery.

Clean engine oil is assured at all times by the use of a replaceable element type full-flow oil filter incorporated in the engine lubrication system. With this type filter, which is installed in the lubricating system between the pump and the cooler, all of the oil is filtered before entering the engine.

Stabilized oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve located between the pump outlet and the inlet to the cylinder block. When the oil pressure at the valve exceeds 50 psi (345 kPa), the regulator valve opens 'and remains open until the pressure is less than the opening pressure.

Oil Distribution

Oil from the cooler is conducted by a vertical passage to a longitudinal main oil gallery on the blower side of the cylinder block. As shown in Fig. I, 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 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, balancer shaft and idler gear.

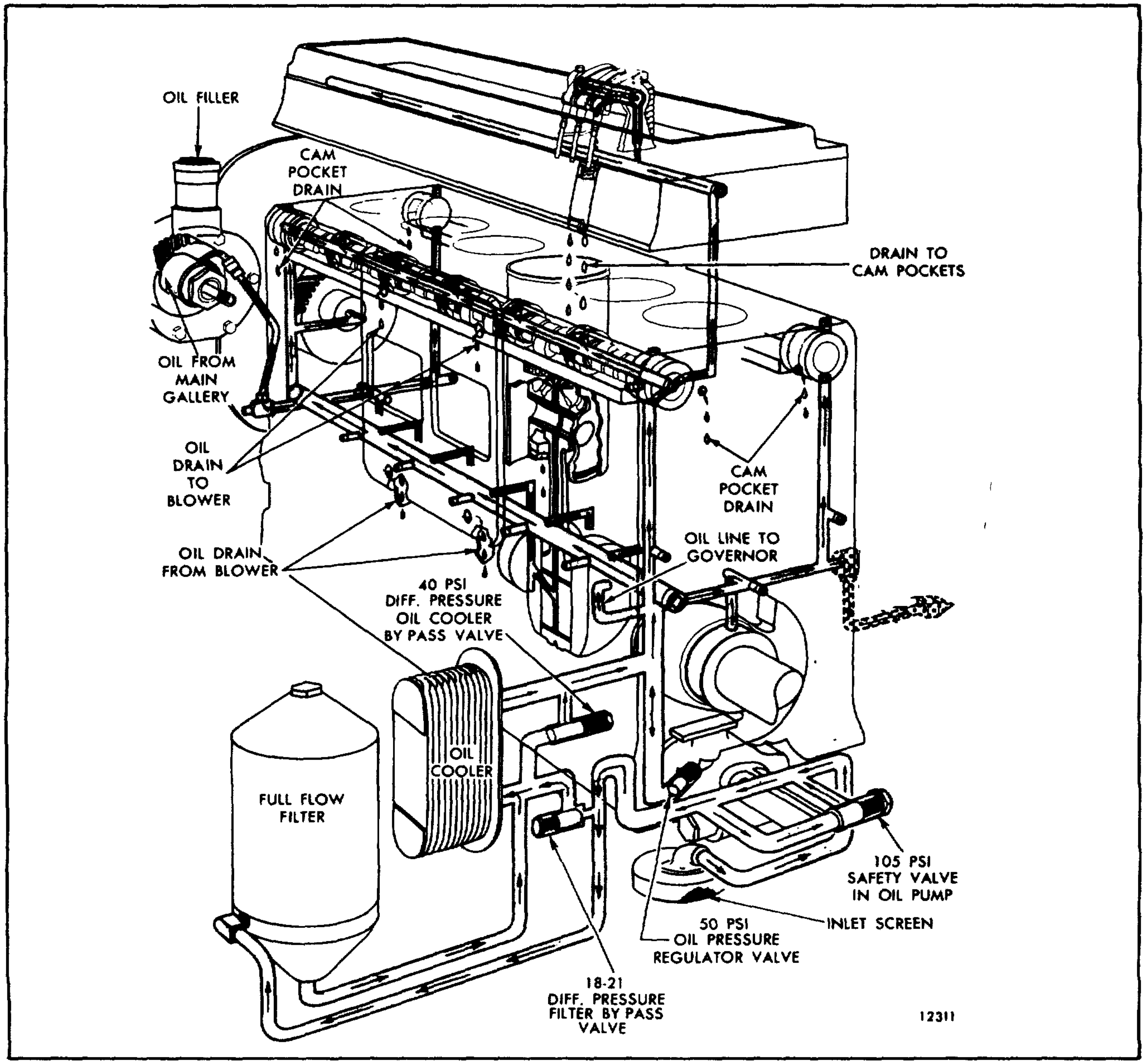


Fig. 1 - Schematic Diagram of Typical Lubrication System.

The blower drive gear bearing is lubricated through an external pipe from the rear horizontal oil passage of the cylinder block.

A longitudinal oil gallery on the camshaft side of the cylinder head is supplied with oil from one of the vertical bores located at each end of the cylinder block. Oil from this gallery enters the drilled rocker arm shafts through the rocker shaft brackets at the lower ends of the drilled bolts and lubricates the rocker arm bearings and push rod clevis bearings.

Excess oil from the rocker arms lubricates the ends of the valve push rods, injector push rods and the cam followers, and then drains to cam pockets in the top of cylinder block from which the cams are lubricated. When these pockets are filled, the oil overflows through two holes, one at each end of the blower housing, as shown in Figs. 1 and 2, and thus provides lubrication for the blower drive gears at the rear end and for the governor mechanism at the front end. A dam in the blower rear end plate cover maintains an oil level in

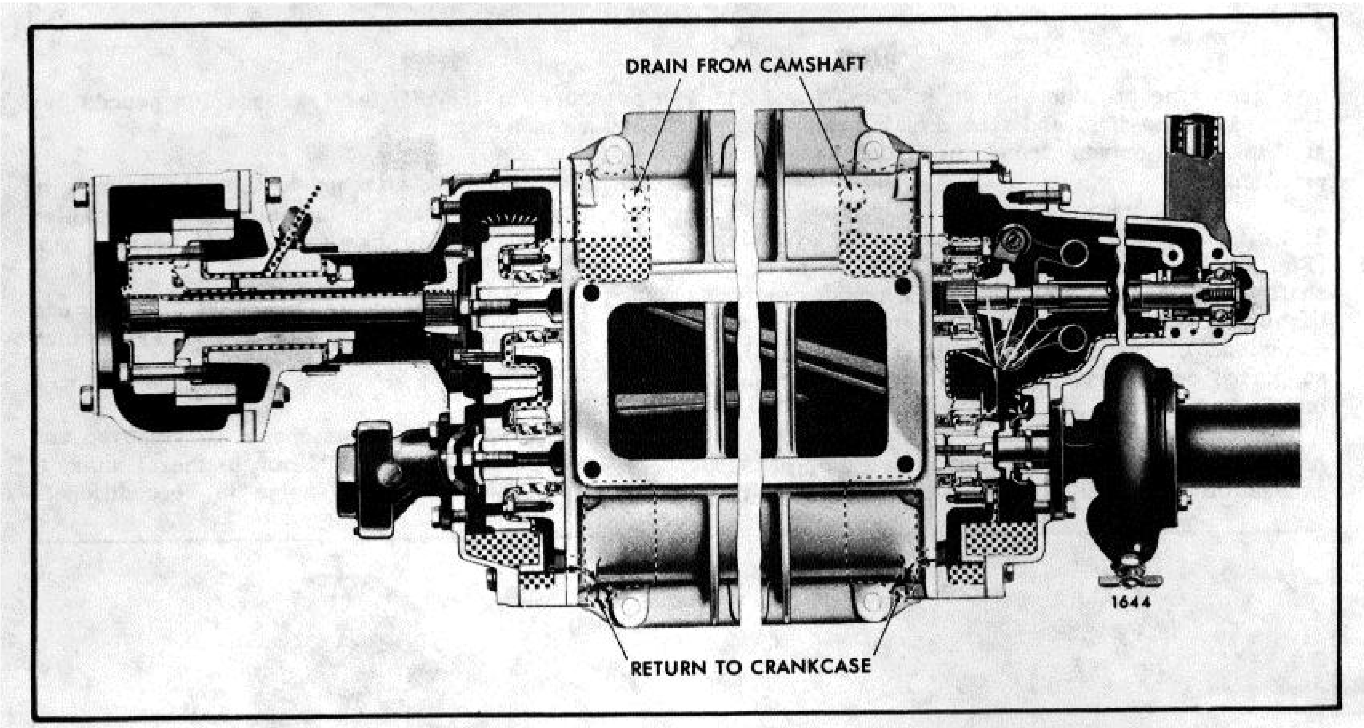


Fig. 2 - Blower Lubrication.

which the teeth of the lower blower rotor timing gear run. A slinger at the forward end of lower rotor throws oil from the dam onto the governor weight assembly. Surplus oil overflows the dam in the two end plate covers and passes through drilled holes in the cylinder block to the oil pan.

Lubrication System Maintenance

Use the proper viscosity grade and type of heavy duty oil as outlined in the Lubrication Specifications on Page 10-9-9. 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 Chapter 6 for the recommended cleaning procedure.

Detection of Lube Oil Leaks

Detroit Diesel Allison uses red dye to detect lube oil system leaks during engine test. Customers receiving new engines may notice some residual dye remaining in their lube oil systems. This dye should be quickly dispersed after the first few hours of engine operation.

OIL PUMP

The gear type oil pump shown in Figs. 1 and 2 is mounted on the first and second main bearing caps and is gear driven from the front end of the crankshaft.

The oil pump helical gears rotate inside a housing (Fig. 1). The drive gear (23) is keyed to the drive shaft which is supported inside the housing on two bushings with a drive-driven gear keyed to the outer end of the shaft. The driven gear (24) is supported on the driven gear shaft which is pressed into the pump body.

An integral plunger-type relief valve (4) by-passes excess oil to the inlet side of the pump when the pressure in the oil lines exceeds 105 pounds per square inch.

An inlet pipe (19), attached to the inlet opening in the pump body, leads to the inlet screen (2) which is mounted with brackets to a main bearing cap.

The inlet screen is located below the oil in the pan and serves to strain out any foreign material which might damage the pump.

The oil pump inlet screen should be removed and cleaned periodically in addition to the cleaning it receives each time the engine is reconditioned.

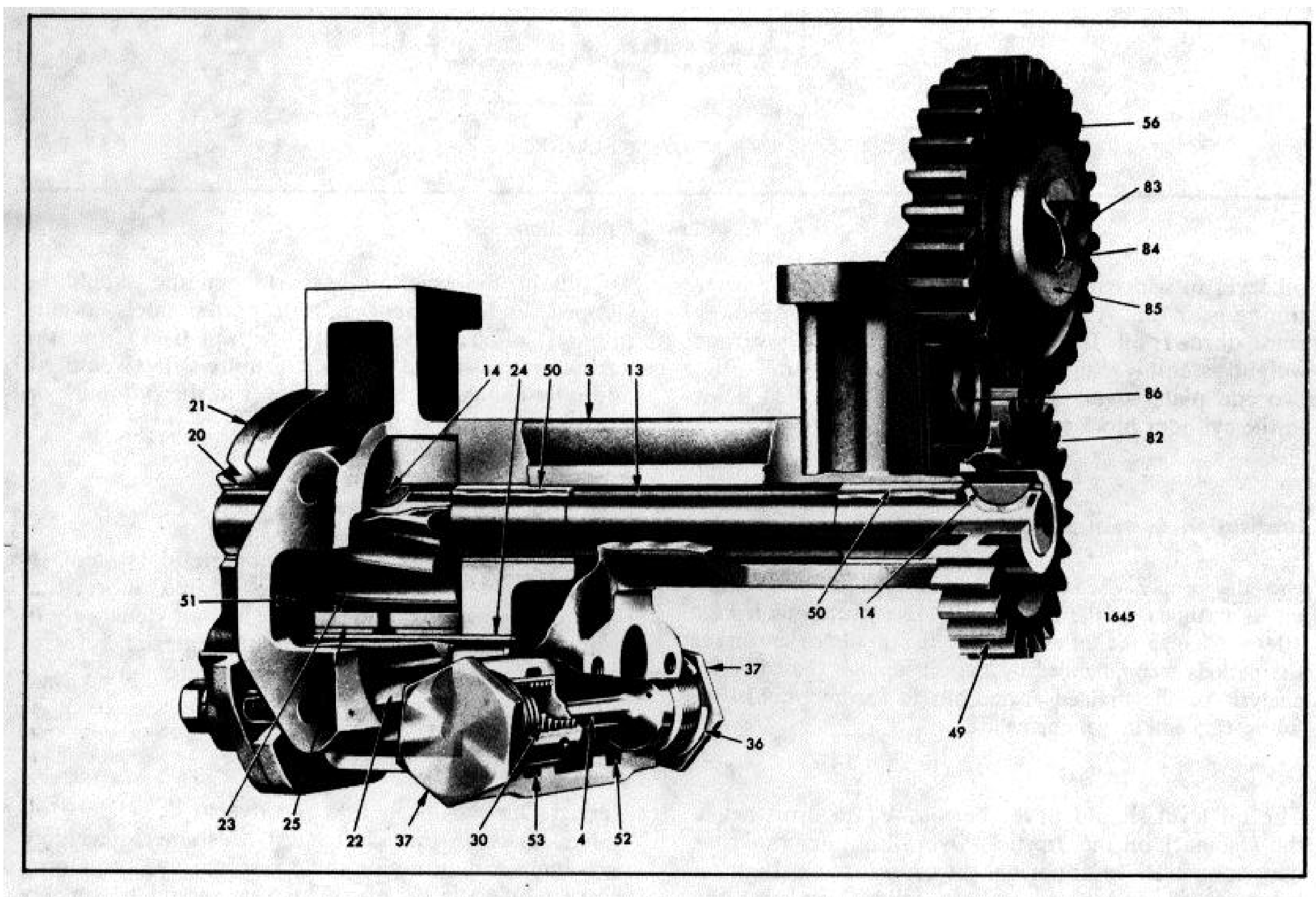


Fig. 1 - Oil Pump Assembly.

3. Body--Oil Pump
4. Valve--Oil Pressure Relief
13. Shaft--Drive
14. Woodruff Key
20. Bushing--Drive Shaft (short)
21. Cover--Pump
22. Gear--Driven
23. Gear--Drive
24. Shaft--Driven Gear
25. Bushing
30. Spring--Relief Valve
36. Gasket--Copper
37. Plug--Relief Valve
49. Gear--Drive-Driven
50. Bushing--Drive Shaft (Long)
51. Gear Cavity (Intake Side)
52. Oil Passage (Gear Cavity to Pump Outlet)
53. Oil Passage (By-Pass to Intake Side of Gear Cavity)
56. Gear--Idler
82. Support--Idler Gear
83. Bolt--Idler Gear-to-Support
84. Lock Washer
85. Thrust Washer--Idler Gear-to-Support Bolt
86. Bolt--Support-to-pump

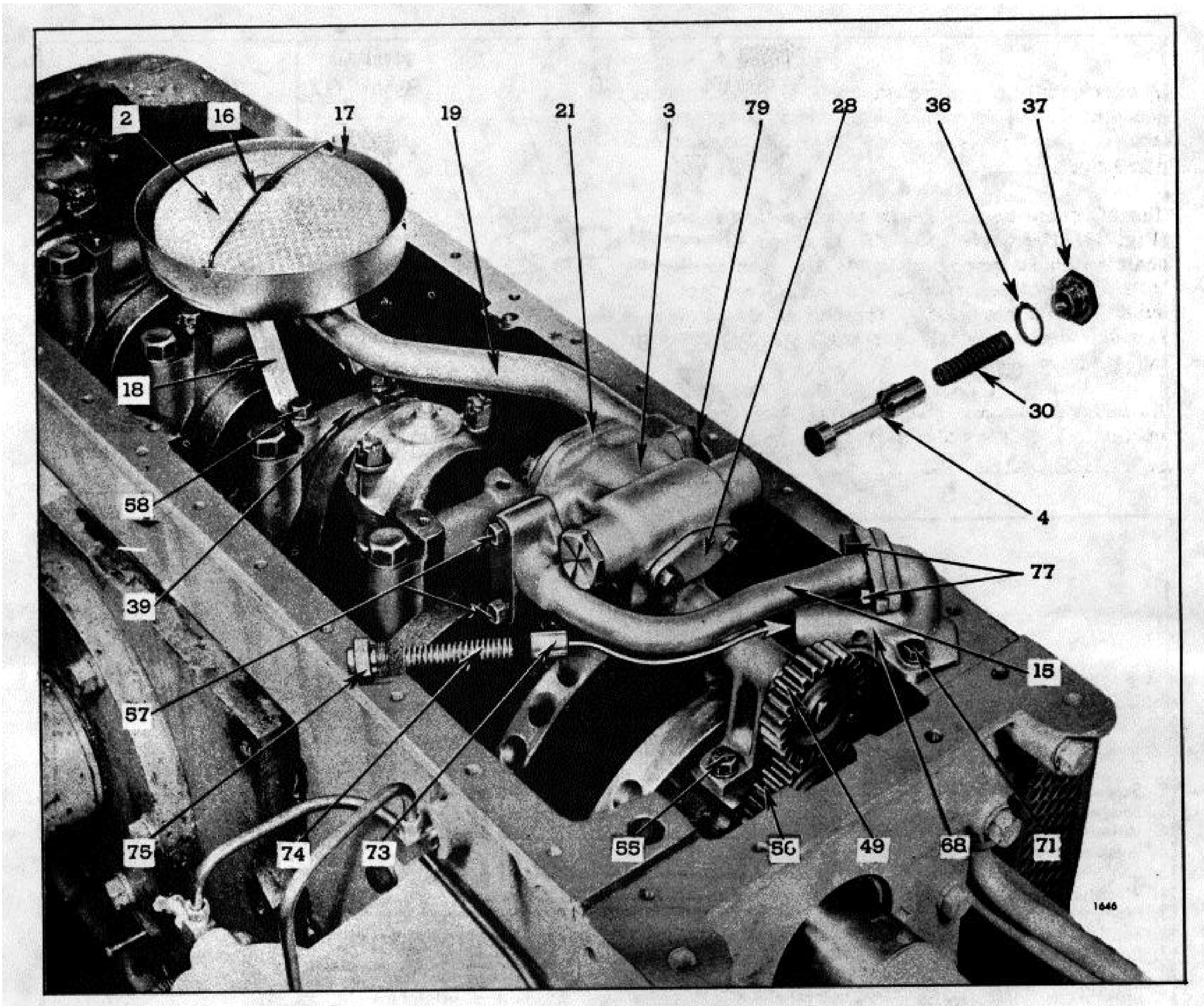


Fig. 2 - Typical Oil Pump Mounting.

An idler gear (56) is mounted on a support bracket which is attached to the pump body (Fig. 1).

Pressure lubrication of the idler gear bushing is provided by means of a drilled passage in the pump

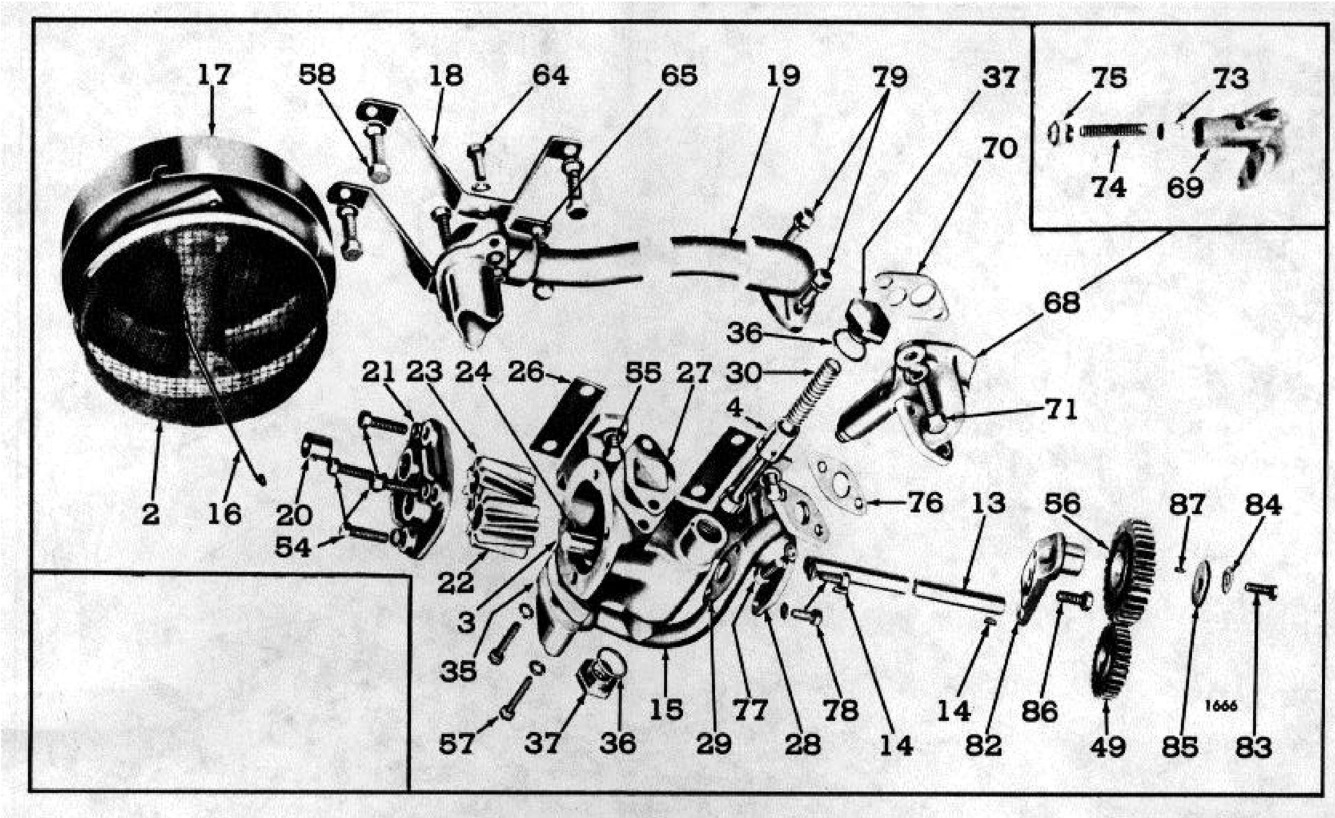


Fig. 3 - Oil Pump Details and Relative Location of Parts.

body and a connecting passage in the idler gear support bracket.

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 (Fig. 2).

NOTE:
Remove and save the shims, if used between the oil pump mounting feet and the bearing caps.

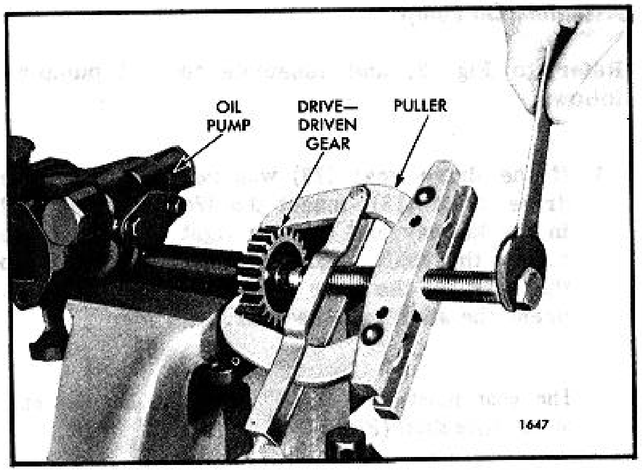


Fig. 4 - Removing Oil Pump Drive-Driven Gear from Shaft.

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 (Fig. 3).

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 drivedriven gear from the outer end of the pump drive shaft as shown in Fig. 4.

8. Remove the Woodruff key (14) from the drive shaft and withdraw the shaft and driven gear (22) from the pump body.

9. Unscrew the bolt (86) and remove the 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 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 Fig. 5. 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 .499" diameter

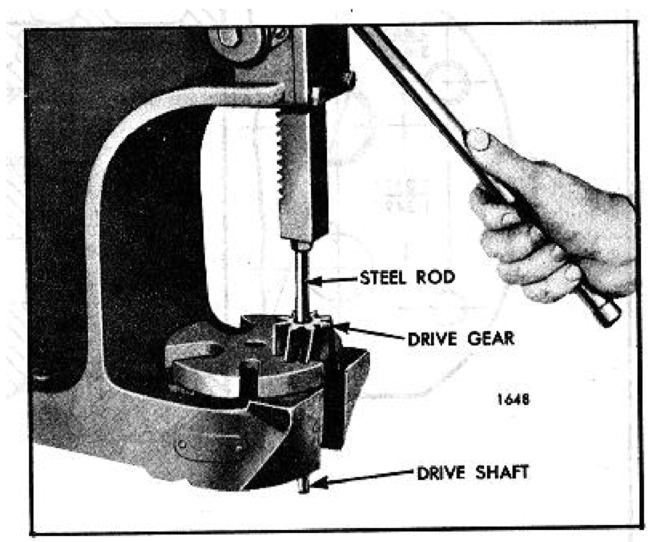


Fig. 5 - Removing Oil Pump Drive Gear form Shaft.

driven gear shaft must be reamed to .500" i .0005" and bushings used with the .623" diameter shaft must be reamed to .625"* .0005".

Inspect the bushings in the pump body and cover. If the bushing are worn excessively, replace the pump body and cover assemblies unless suitable boring equipment is available for finishing the new bushings. When installing new bushings, replace all of the bushings. The bushings must be located and positioned as shown in Fig. 6. Also, the gear bore and the bushing bore in both the pump body and cover must be concentric within .001". The shaft-pump body-bushing clearance with new parts is .0008" to .0025". The shaft-to-pump cover bushing clearance with new parts is .0010" to .0027".

In an efficient oil pump, the gears should have a free-running fit (with no perceptible looseness) in the pump housing. If the gear teeth are scored or worn, install new gears. The use of excessively worn gears will result in low engine oil pressure which in turn, may lead to serious damage throughout the engine.

Inspect the pressure relief valve and its seat in the pump body. If necessary, install new parts.

Assemble Oil Pump

Refer to Fig. 3, and assemble the oil pump as follows:

1. If the drive gear (23) was removed from the drive shaft (13), insert the Woodruff key (14) in the keyway and apply a light coat of engine oil on the shaft. Start the shaft squarely into the bore of the gear and, as shown in Fig. 5, press the shaft into the gear.

   The gear must be 6-15/16" from the keyway end of the drive shaft (Fig. 7).

2. Press the dowel (88) into the pump body, if removed.

3. Place the idler gear support (82) in position against the forward end of the pump body (Fig. 3) and secure the support to the body with bolt (86).

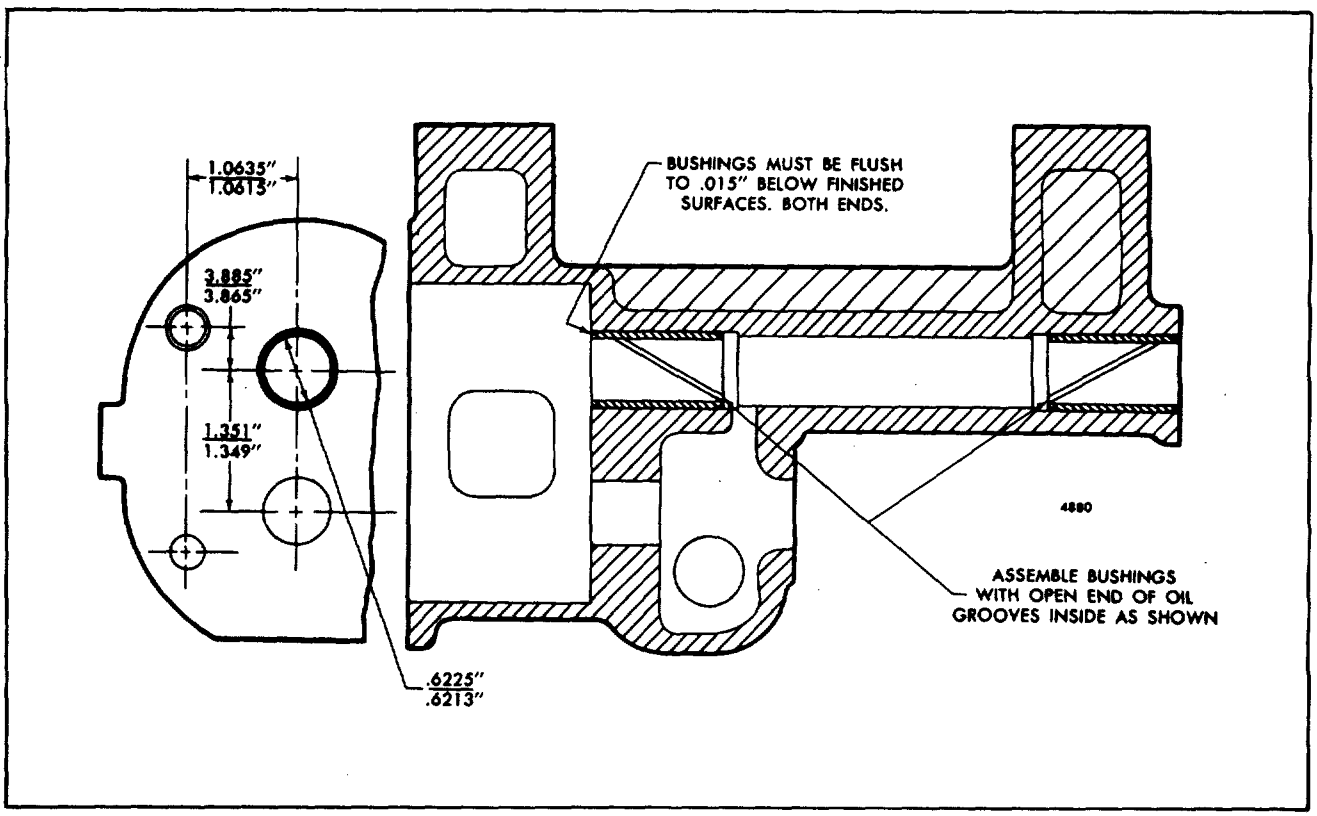


Fig. 6 - Diameter and Location of Bushing in Oil Pump.

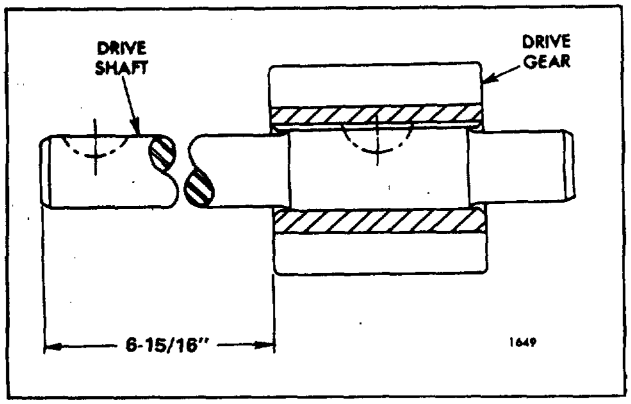


Fig. 7 - Oil Pump Drive Shaft and Gear Assembly.

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 .005" feeler ribbon between the driven gear and the pump body and press the gear on the shaft until the clearance between the gear and the body is .005".

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 Fig. 2, and 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 them with the two bolts (78) and lock washers.

    The oil pump must turn freely after assembly. Any bind in the pump must be removed before it is installed on the engine.

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 (Page 10-2-64).

2. Remove the oil slinger.

3. If required use puller J 3051 (Fig. 8) to pull

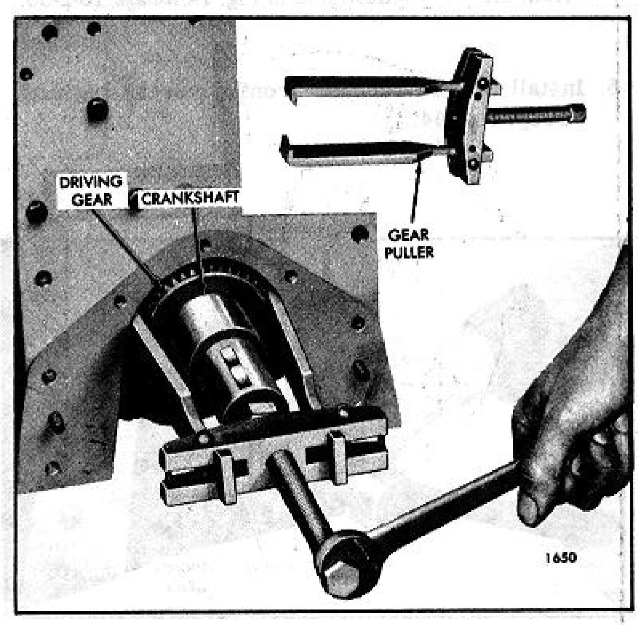


Fig. 8 - Removing Oil Pump Driving Gear from Crankshaft.

the pump driving gear from the front end of the crankshaft as follows:

a. Screw the crankshaft pulley 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.

Install Oil Pump Driving Gear on Crankshaft

1. Install the Woodruff key in the crankshaft.

2. Position the gear (80) so the chamfer on the gear hub is toward the main bearing cap and start the gear on the shaft and over the key.

3. Slide the gear on the crankshaft or use a sleeve if required, as illustrated in Fig. 9, and drive the gear tight against the shoulder on the crankshaft.

4. Install the oil slinger with the dished side away from the gear as illustrated in Fig. 1 on Page 10-2-66.

5. Install the crankshaft front cover as outlined on Page 10-2-64.

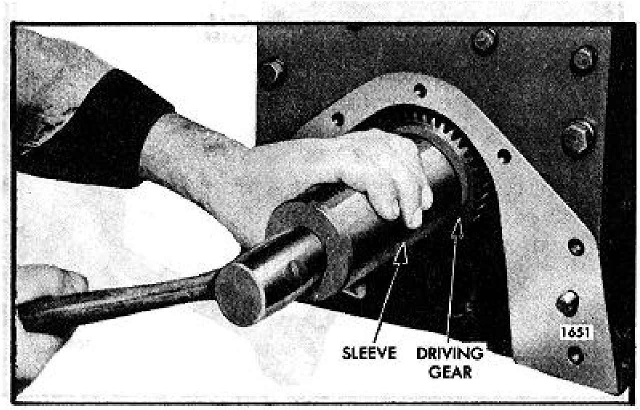


Fig. 9 - Installing Oil Pump Driving Gear on Crankshaft.

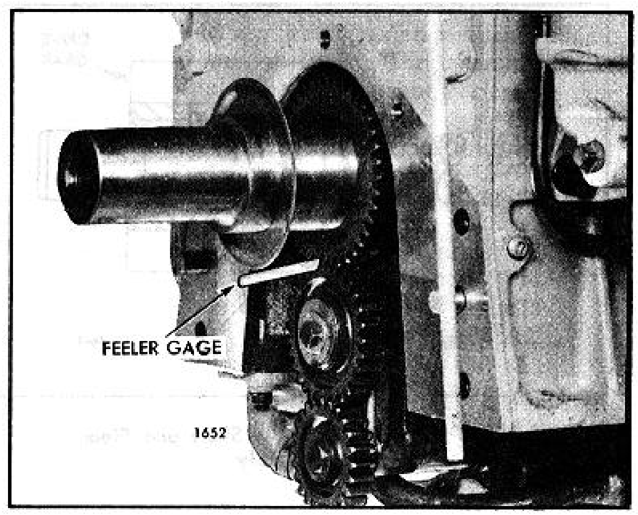


Fig. 10 - Measuring the Clearance Between the Teeth of the Oil Pump Driven Gears.

Install Oil Pump

Refer to Fig. 2 and install the oil pump on the main bearing caps as follows:

1. Hold the pump assembly against the main bearing caps so the idler gear (56) meshes with the driving gear on the crankshaft.

2. Insert the four bolts (55) with 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 the 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 .005" minimum, .012" maximum (Fig. 10).

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

If shims were used between the pump mounting feet and the bearing caps and new gears are <u>not</u> installed, the same shims (cleaned) or the same number of new (identical) shims should be installed and the number then adjusted to obtain the proper clearance between gear teeth. However, if new gears have been installed, a larger number of shims will be required under the mounting feet. In either event, the pump must be tightened on the bearing cap <u>before</u>

the clearance between the gear teeth is measured.

NOTE: When adjusting for gear tooth clearance by installing or removing shims, the same number of shims must be changed under each foot so that the pump will always be level on the main bearing caps. The insertion or removal of one .005" shim will change the gear tooth clearance by .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. Re-check all bolts for tightness to assure there will be no leaks in the oil pump and pipe mounting connections.

9. Place a new gasket on the oil pan and install the oil pan on the cylinder block. All the oil pan bolts should be started before any are tightened. Bolts should be tightened snugly but not excessively, starting with the center bolts and working toward each end of the oil pan. Excessive tightening of the bolts will crush the oil pan gasket unnecessarily.

10. Fill the crankcase to the proper level with the oil recommended in the Lubricating Oil Specifications on Page 10-9-9.

LUBRICATING OIL PRESSURE REGULATOR

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator installed between the oil pump outlet pipe and the cylinder block.

The regulator assembly consists of a regulator body, a hollow piston-type valve, a spring and a plug to retain the valve and spring (Fig. I). A new die cast lubricating oil pressure regulator assembly is now being using (Fig. 2).

The valve is held on its seat by the spring, which is compressed by the plug threaded into the valve opening in the regulator body. The entire assembly is bolted to the lower flange of the cylinder block and sealed against oil leaks by a gasket between the two members. When the oil pressure at the valve exceeds 50 psi (345 kPa), the valve is forced from its seat and oil from the engine oil gallery is by-passed to the oil pan.

Under normal conditions, the pressure regulator should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

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.

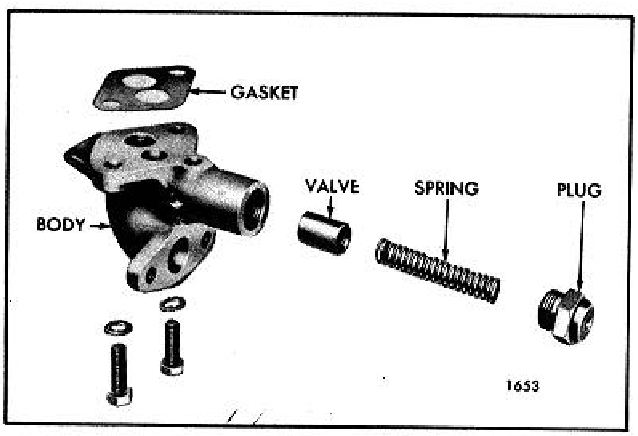


Fig. 1 - Lubricating Oil Pressure Regulator Details and Relative Location of Parts.

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.

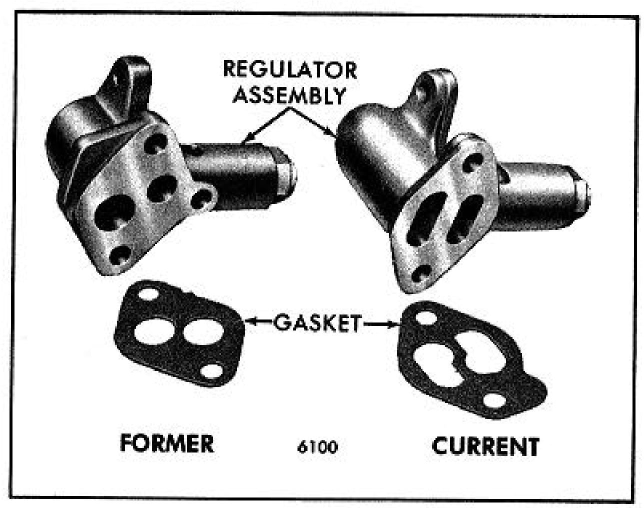


Fig. 2 - Lubricating Oil Pressure Regulator (Former and Current).

Replace a fractured or pitted spring.

Assemble Oil Pressure Regulator

Refer to Fig. 1 and assemble the regulator as follows:

1. Apply clean engine oil to the outer surface of the valve and slide it into the regulator body, closed end first.

2. Insert the spring in the valve and, while compressing the spring, start the plug into the regulator body. Tighten the plug.

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.

LUBRICATING OIL FILTER

Spin-On Oil Filter

A spin-on type oil filter is installed ahead of the oil cooler in the lubrication system. The filter is mounted on the oil cooler adapter plate as shown in Fig. 2.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adapter to the filter. Impurities are filtered out as the oil is forced through the filter and out through another passage in the filter adapter and then to the oil cooler.

A valve, which opens at approximately 18-21 psi (124145 kPa), is located in the filter adapter or base and will bypass the oil directly to the oil cooler should the filter become clogged.

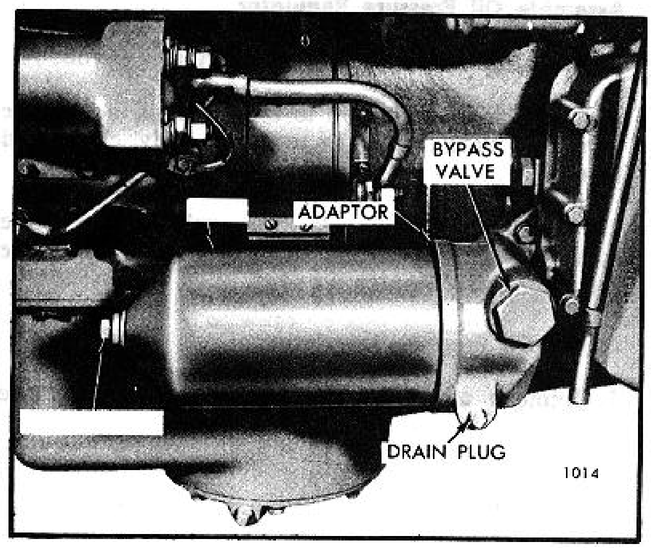


Fig. 1 - Typical Oil Filter Mounting.

Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action. Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found in the filter cartridges at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles and carbon must be ensured by replacement of the oil filter cartridges at the time the engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations and proper filter maintenance will ensure trouble-free lubrication and longer engine life.

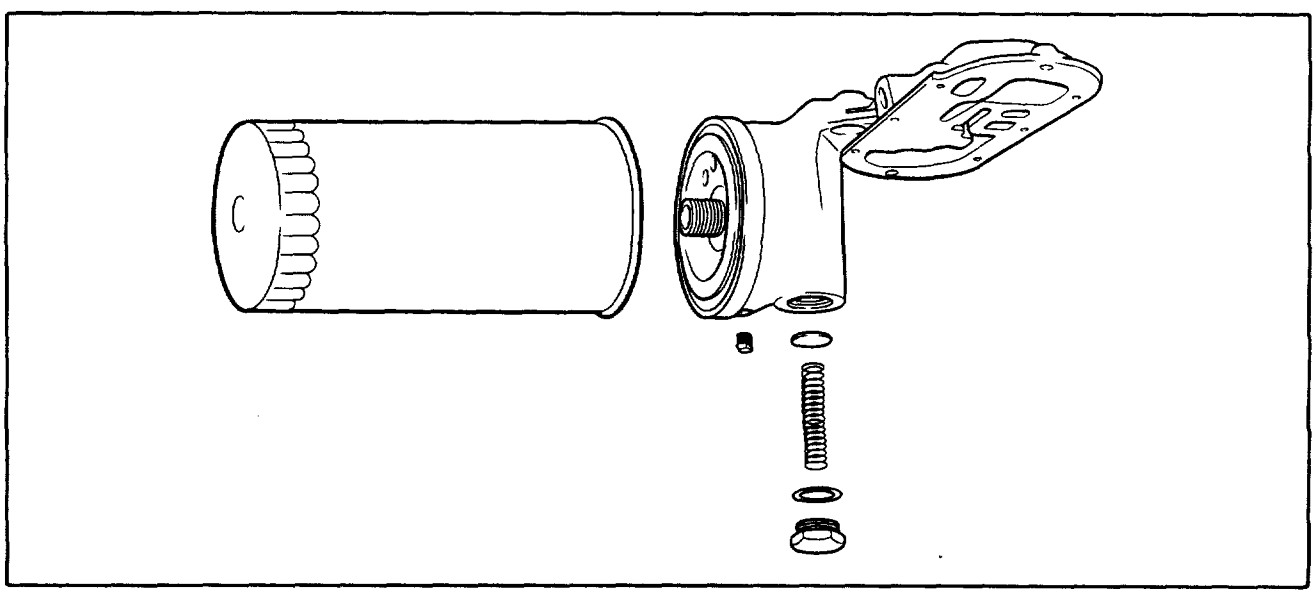


Fig. 2 - Full-Flow Oil Filter Details and Relative Location of Parts.

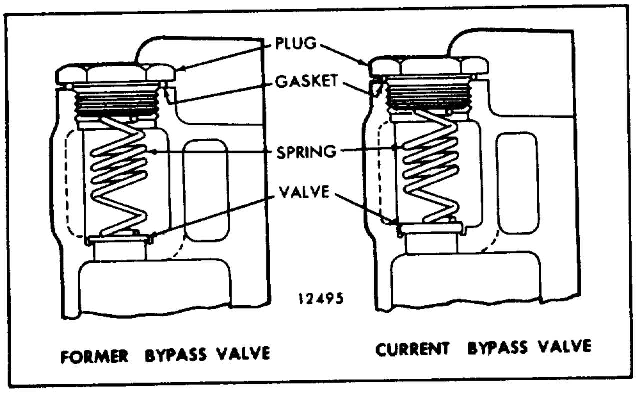


Fig. 3- Bypass Valve

Replace Spin-On Filter

1. Remove the oil filter using strap wrench tool J 24783 which must be used with a 1/2" drive socket wrench and extension.

2. Discard the used oil filter.

3. Clean the filter adaptor with a clean, lint-free cloth.

4. Lightly coat the oil filter gasket (seal) with clean engine oil.

5. Start the new filter on the adaptor and tighten by hand until the gasket touches the mounting adaptor head. Tighten an additional two-thirds turn.

CAUTION:
Mechanical tightening will distort or crack the filter adaptor.

6. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough for oil from the various parts of the engine to drain back to the crankcase (approximately 20 minutes), add sufficient oil to raise the oil level to the proper mark on the dipstick.

Remove and Install Bypass Valve

1. If necessary, remove the filter adaptor from the engine.

2. Remove the plug and gasket and withdraw the spring and bypass valve (Fig. 2).

3. Wash all of the parts in clean fuel oil and dry them with compressed air.

4. Inspect the parts for wear. If necessary, install new parts.

5. Reassemble and install the bypass valve. Use only the current bypass valve and spring for service (Fig. 3). The current thicker valve and stiffer spring increase the bypass pressure from 13-18 psi to 18-21 psi (90-124 kPa to 124-145 kPa) to permit more efficient filtration. Tighten the 1 1/4"-16 bypass valve plug to 95-105 lb-ft (129-143 N•m) torque.

NOTE:
The current and early design bypass valves are not interchangeable (inset, Fig. 2).

6. Use a new gasket and install the filter adaptor.

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 (Fig. 1).

To assure engine lubrication if the oil cooler becomes clogged, a bypass valve located at the oil inlet to the cooler bypasses oil around the cooler directly to the oil gallery in the cylinder block.

The core through which the oil passes while being cooled is sealed to prevent 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.

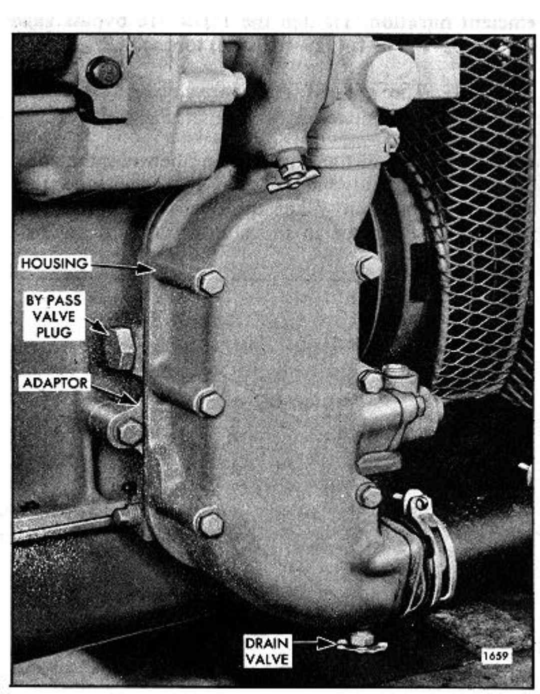


Figure 1. Typical Lubricating Oil Cooler Mounting-Radiator Cooled Engine

Remove Lubricating Oil Cooler

I. Drain the cooling system by opening the drain valve at the bottom of the oil cooler housing (Fig. 1).

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.

WARNING

This operation should be done in the open or in a well ventilated room when trichloroethylene or other toxic chemicals are used for cleaning.

Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate an Oakite or alkaline solution through the core and flush thoroughly with clean hot water.

2. Clean **Water Side of Core** - After cleaning oil side of the core, immerse it in the following solution: add one-half (1/2) pound of oxalic acid to each two and one-half (2 1/2) gallons of solution composed 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 cooler core (Fig. 2).

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.

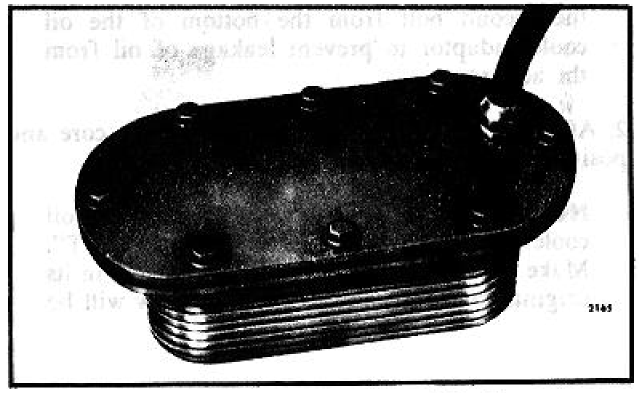


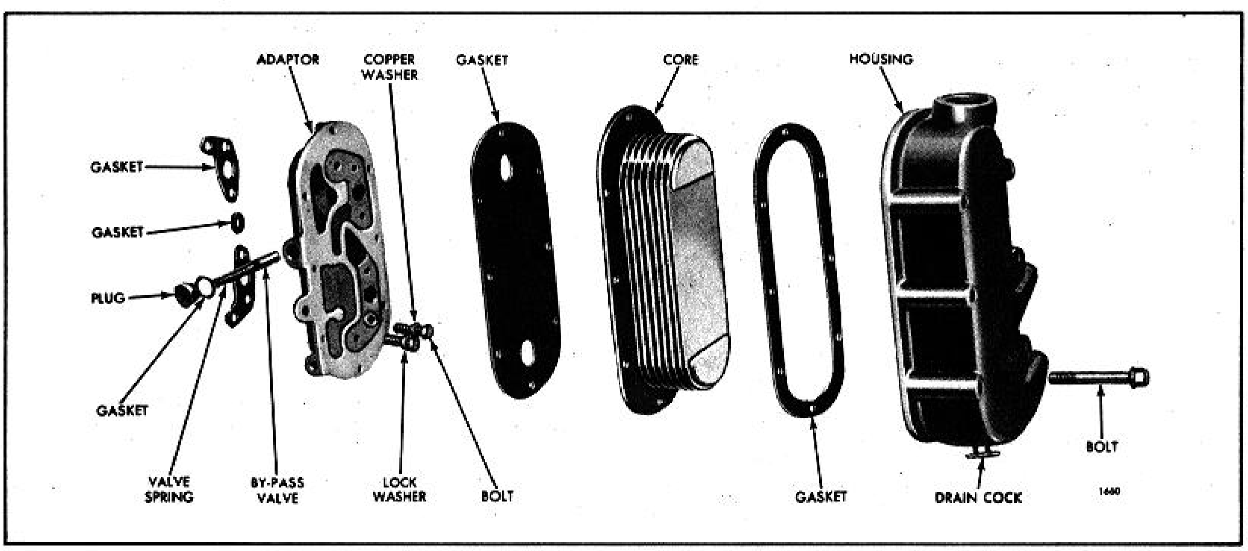
Fig. 2 Oil Cooler Core Prepared for Pressure Check

CAUTION:
In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be flushed immediately to prevent serious damage (refer to Chapter 6).

Install Lubricating Oil Cooler

Refer to Fig. 3 and install the lubricating oil cooler as follows:

1. If the oil cooler adaptor was removed from the cylinder block, remove the old gaskets from the bosses where the adaptor sets against the block. Affix new adaptor to cylinder block gaskets; then secure the adaptor to the cylinder block with bolts, 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 (Fig. 1).

4. Affix a new gasket to the oil cooler water inlet connector and secure with bolts and lock washers.

LUBRICATING OIL COOLER BYPASS VALVE

To assure proper lubrication if the oil cooler core becomes clogged, a valve, located between the oil inlet and the core, bypasses the oil around the cooler directly to the oil gallery in the cylinder block.

The oil cooler is mounted at the side of the engine and the bypass valve, spring, plug and gasket are housed in the oil cooler adaptor (Fig. 1).

The bypass valve should be removed, cleaned and reassembled whenever the cooler core is cleaned or replaced. However, if occasion requires, the bypass valve can be removed without removing the oil cooler.

Remove Bypass Valve

The bypass valve may be removed by removing the plug and lifting the gasket, valve and spring from the adaptor (Fig. 1).

Inspection

Clean the bypass valve components with fuel oil and dry them with compressed air.

Inspect the valve parts for wear and replace the parts if necessary.

Install Bypass Valve.

1. Apply clean engine oil to the outside surface of the bypass valve and place the valve in the adaptor, closed end first.

2. Slide the valve spring into the valve and screw the plug, with the gasket, into the adaptor.

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 current engines include 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 aereation of the oil. Operation below the low mark will expose the pump pick-up causing aereation and/or loss of pressure.

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various parts of the engine to drain back into the oil pan.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade.

Fill the crankcase with oil as follows:

1. Fill the oil pan to the full mark on the dipstick.

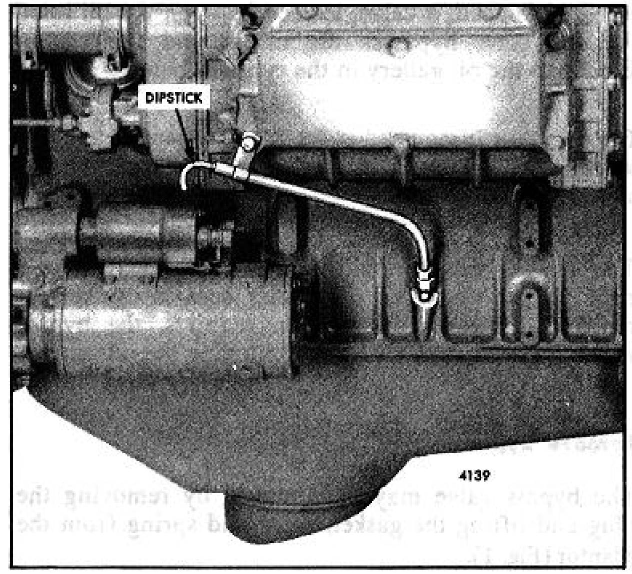


Figure 1. · Typical Dipstick Mounting

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

A cast iron deep sump type oil pan is used, which allows the engine installation to have a longitudinal inclination range from 0° to 20°.

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. Inspect the cast oil pan for porosity or cracks. Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.

5. When installing the oil pan, use a new gasket and, starting with the center bolt on each side and working alternately toward each end of the pan, tighten the bolts to 10-20 lb-ft (14-27 N•m) torque. Do not over-tighten the bolts. Once the bolts are tightened to the specified torque, do not retighten them as it could be detrimental to the current type oil pan gasket. If a leak should 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.

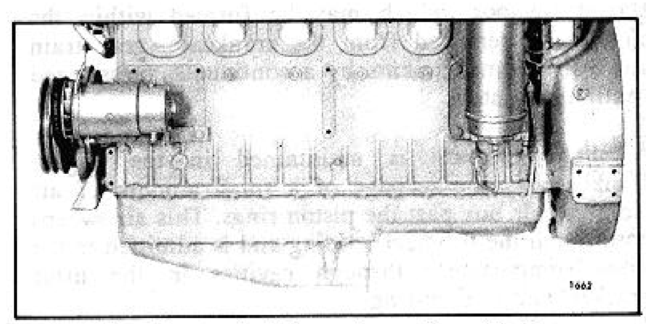


Figure 1. Typical Deep Sump Type Oil Pan

6. Install and tighten the drain plug to 25-35 lb-ft (3447 N•m) (refer to Page 10-5-24).

7. Fill the oil pan with new oil (refer to Pages 10-5-20 and 10-9-9) 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

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartments by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air from the air box past the piston rings. This air sweeps up through the flywheel housing and is admitted to the valve compartment through cavities in the lifter brackets and vent castings.

Ventilating air in the valve compartment is drawn off via the governor control housing through a breather attached to the side of the cylinder block (Fig. 1).

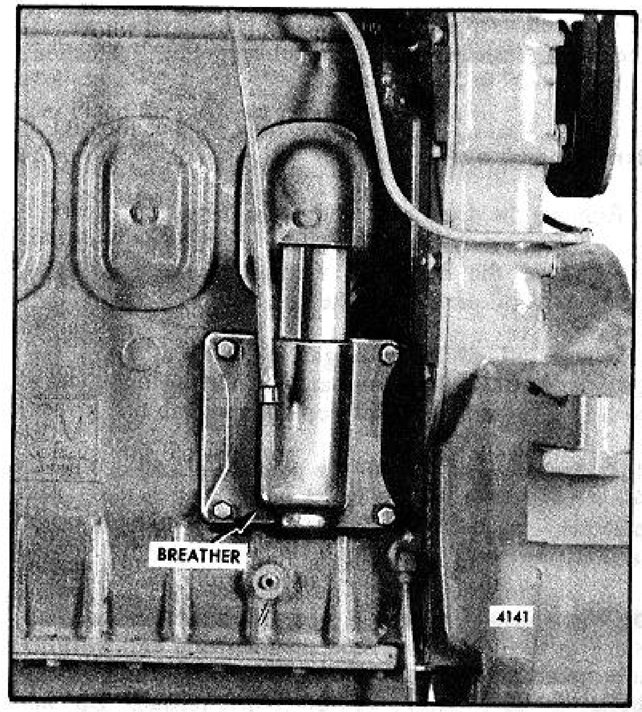


Figure 1. Breather Mounted on Cylinder Block

Service

Inspect and clean the breather and baffle, if necessary, to eliminate the possibility of clogging. Remove the breather and baffle from the cylinder block. Wash with a suitable solvent and dry with compressed air.

The steel mesh pad should be removed and cleaned periodically (refer to Page 10-11-3).

SPECIFICATIONS

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		GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None		GM 255-M	1	No. 6 thru 1 1/2	60,000
None		GM 260-M	2	No. 6 thru 3/4	74,000
				over 3/4 to 1 1/2	60,000
	Bolts and Screws	GM 280-M	5	No. 6 thru 1	120,000
				over 1 to 1 1/2	105,000
	Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
	Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
	Bolts and Screws	GM 300-M	8	1/4 thru I 1/2	150,000
	Bolts and Screws	GM 455-M	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)
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...............................	1/2 -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

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

COOLING SYSTEM **CHAPTER 6**

CONTENTS

COOLING SYSTEM

A radiator and cooling fan is used to effectively dissipate the heat generated by the engine. A centrifugal type water pump attached to and driven by the blower, circulates the engine coolant in each system. A thermostat is utilized to maintain a normal engine operating temperature (refer to Page 10-9-1).

RADIATOR AND COOLING FAN

The engine coolant is circulated through the radiator (Fig. 1) where the heat is absorbed in the air stream developed by 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 part of the cylinder block. Openings in the water jacket around the cylinder bores connect with corresponding openings in the cylinder head through which the liquid rises to circulate around the valves and fuel injectors. Then the coolant passes through a water manifold, bolted to the cylinder head, past the thermostat and into the radiator.

Upon starting a cold engine or when the coolant is below operating temperature (thermostat closed) the coolant is by-passed from the water manifold directly to the pump, thus providing water circulation within the engine during the warm-up period.

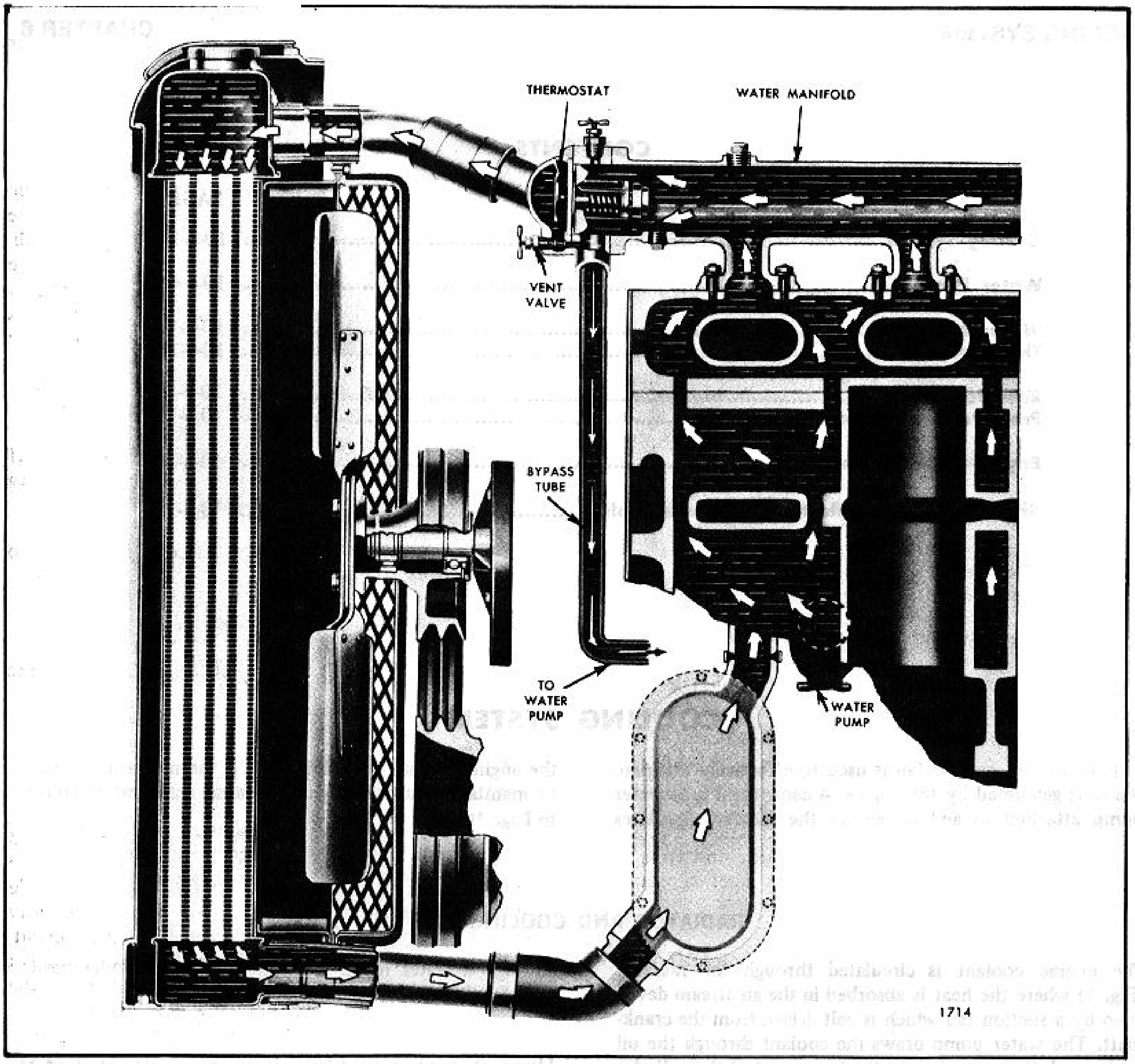


Fig. 1 - Typical Cooling System with Radiator and Fan

ENGINE COOLING SYSTEM MAINTENANCE

A properly maintained and clean cooling system will reduce engine wear and increase the satisfactory engine operating time between engine overhauls. This is accomplished by the elimination of hot spots within the engine. Thus, when operating within the proper engine temperature range and when not exceeding the recommended hosepower output of the unit, all engine parts will be within their 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 component parts such as exhaust valves, cylinder liners and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil-to-water oil cooler. Refer to Page 10-9-13 for coolant recommendations.

Cooling System Capacity

The capacity of the basic engine cooling system (cylinder block, head, thermostat housings and oil cooler housing) is 3.5 gallons (13.2) litres.

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

If a coolant filter is used and properly maintained, the cooling system need not be flushed. Otherwise, the cooling system should be flushed each spring and fall.

The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, preparing the cooling system for a new solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the unit.

2. Refill the cooling system with soft, clean water. If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.

3. Start the engine and operate it for 15 minutes to thoroughly circulate the water.

4. Drain the cooling system completely.

5. Refill the system with the solution required for the coming season.

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.

CAUTION:
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 clogging the radiator tubes or being forced through the pump. Reverse-flushing is accomplished with hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, thus loosening and forcing the scale deposits out.

Reverse-flush the radiator as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.

2. Attach a hose at the top of the radiator to direct the water away from the engine.

3. Attach a hose to the bottom of the radiator and insert a flushing gun in the hose.

4. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.

5. Turn on the water and, when the radiator is full, turn on the air in short blasts.

CAUTION:
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: I. 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 solution. If mixed with the oil in the crankcase, this antifreeze forms a varnish which quickly immobilizes moving engine parts.

To remove such contaminants from the engine, both the cooling system and the lubrication system must be thoroughly flushed as outlined below:

COOLING SYSTEM

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, the following flushing procedure is recommended:

1. Prepare a mixture of Calgon, or its equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.

2. Remove the engine thermostat to permit the Calgon and water mixture to circulate through the engine and the radiator.

3. Fill the cooling system with the Calgon solution.

4. Run the engine for five minutes.

5. Drain the cooling system.

6. Repeat Steps 3 through 5.

7. Fill the cooling system with clean water.

8. Let the engine run five minutes.

9. Drain the cooling system completely.

10. Install the engine thermostat.

11. Close all of the drains and refill the engine with fresh coolant.

LUBRICATION SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution or other soluble material, the following cleaning procedure, using Butyl Cellosolve, or its equivalent, is recommended.

WARNING

Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water.

If the engine is still in running condition, proceed as follows:

1. Drain all of the lubricating oil.

2. Remove and discard the spin-on filter.

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 spin-on filter and install a new spin-on filter.

8. Install the drain plug and fill the crankcase to the proper level with the oil recommended for normal engine operation.

9. To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1,000 to 1,200 rpm) for approximately 30 minutes. Then, stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.

10. If the procedures for cleaning the lubricating oil system were not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

Make certain that the cause of the internal coolant leak has been corrected before returning the engine to service.

WATER PUMP

The centrifugal-type water pump (Fig. 1) circulates the engine coolant through the cylinder block, cylinder head, radiator, and the oil cooler. The drive end of the pump shaft is supported by a sealed double-row combination radial and thrust ball bearing. The pump shaft serves as the inner race of the bearing.

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, which does not include a slinger, to the sealed ball bearing.

The impeller is a press fit on one end of a stainless steel shaft.

The pump is mounted at the front end of the blower (Fig. 2) and is driven by the lower blower rotor shaft. The drive coupling, pressed on the end of the pump shaft, has an integral oil thrower that shrouds the flange end of the pump body and deflects the oil away from the bearing.

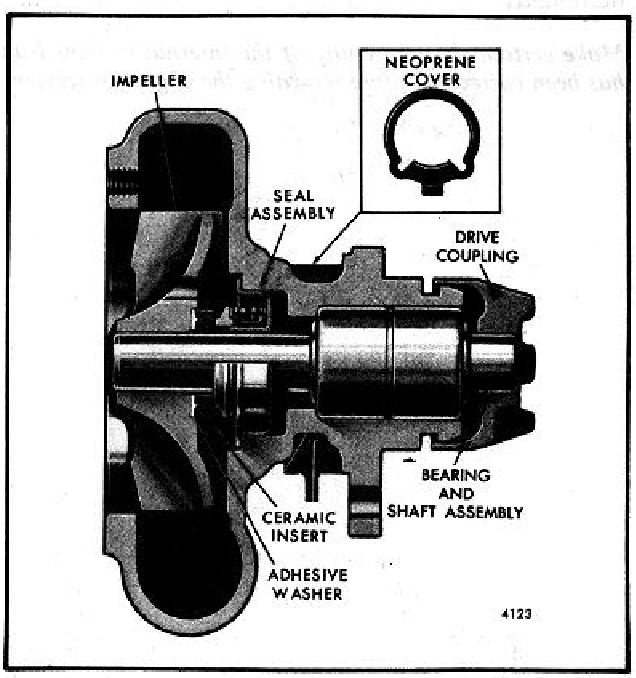


Fig. 1 - Water Pump With Ceramic Insert in Impeller

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 Figs. 2 and 3 and remove the pump as follows:

1. Open the drain cock in the pump body and drain the cooling system.

2. Loosen the hose clamps and slide the water pump inlet hose back against the pump cover.

3. Remove the two bolts and lock washers that attach the pump outlet flange to the cylinder block. Remove the flange and packing ring.

4. Remove the three bolt and seal assemblies that attach the pump to the blower assembly.

5. Withdraw the pump and remove the gasket.

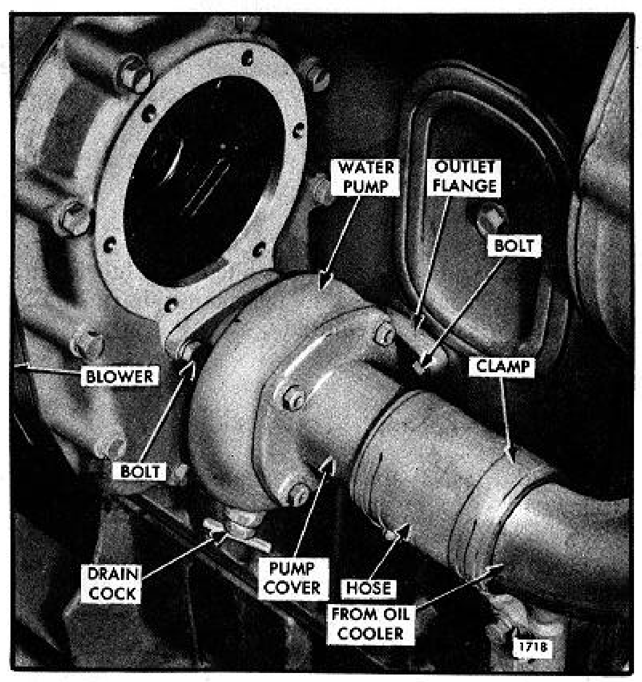


Fig. 2 - Water Pump Mounting

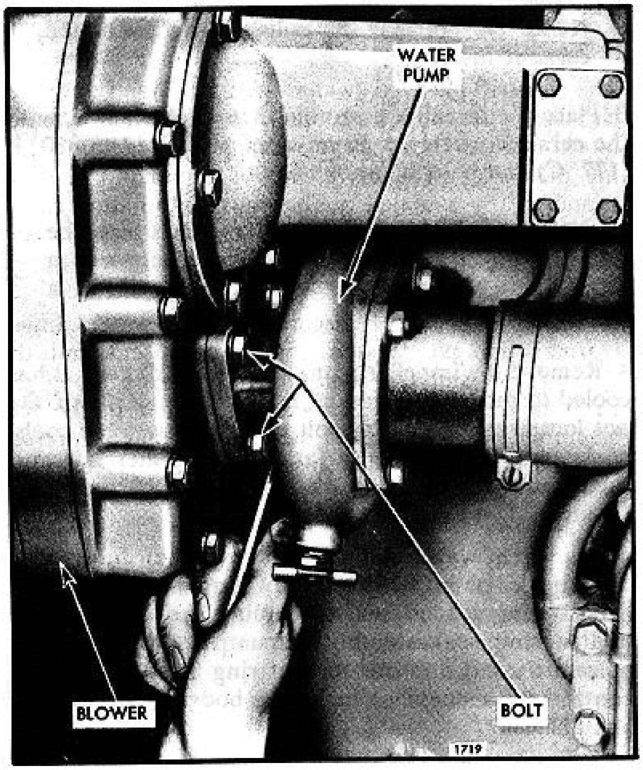


Fig. 3- Loosening Inner Pump-to-Blower Attaching Bolt with Tool J 4242

Disassemble Water Pump

1. Remove the pump cover and gasket.

NOTE:
Clean the corrosion from around the impeller and shaft before separating the shaft and bearing assembly from the impeller, seal and pump body.

2. Support the pump on its mounting flange in an arbor press (Fig. 4). Place a short steel rod on the end of the shaft and press the shaft and bearing assembly from the impeller, seal and pump body.

3. Remove the impeller and seal assembly from the pump body.

CAUTION:
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 Fig. 5.

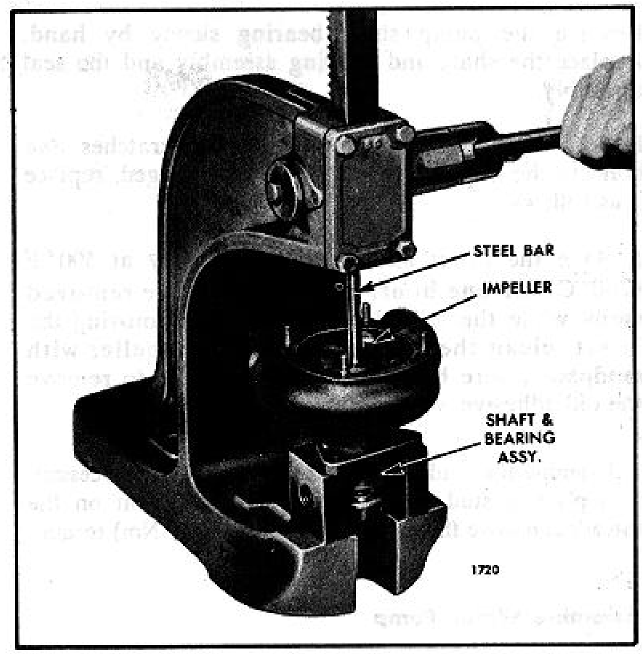


Fig. 4 · Pressing Pump Shaft from Impeller

Inspection

Clean all of the parts except the shaft and bearing assembly. The sealed type pump shaft bearing must not be immersed in a cleaning fluid since dirt may be washed in and the fluid cannot be entirely removed.

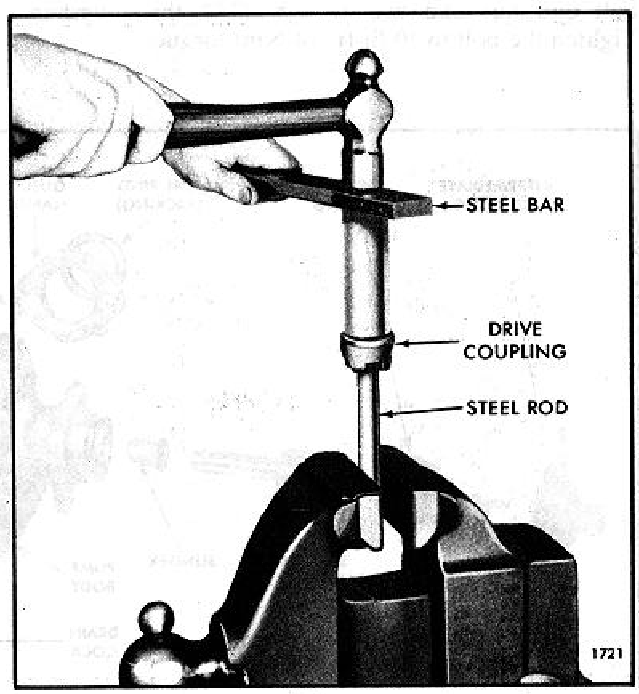


Fig. 5 - Removing Pump Drive Coupling from Shaft with Tool J 1930

Revolve the pump shaft bearing slowly by hand. Replace the shaft and bearing assembly and the seal assembly.

Inspect the ceramic insert for cracks, scratches and bond to the impeller. If the insert is damaged, replace it as follows:

1. Bake the insert and impeller assembly at 500°F (260° C) for one hour. The insert can be removed easily while the adhesive is hot. After removing the insert, clean the insert area on the impeller with sandpaper, wire brush or a buffing wheel to remove the old adhesive, oxide, scale, etc.

2. 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 Figs. 1 and 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 impeller end of the pump body on an arbor press and insert the coupling end of the shaft and bearing assembly into the pump body. Then press against the outer race of the bearing until the bearing contacts the shoulder in the pump body.

NOTE:

When installing the shaft and bearing assembly, it will not be necessary to stake the end of the pump body.

6. With the surface of the pump seal clean and free from dirt and metallic particles, apply a thin coat of liquid soap on the inside diameter of the rubber seal. To reduce possible coolant leakage, apply a light coat of non-hardening sealant on the outside diameter of a

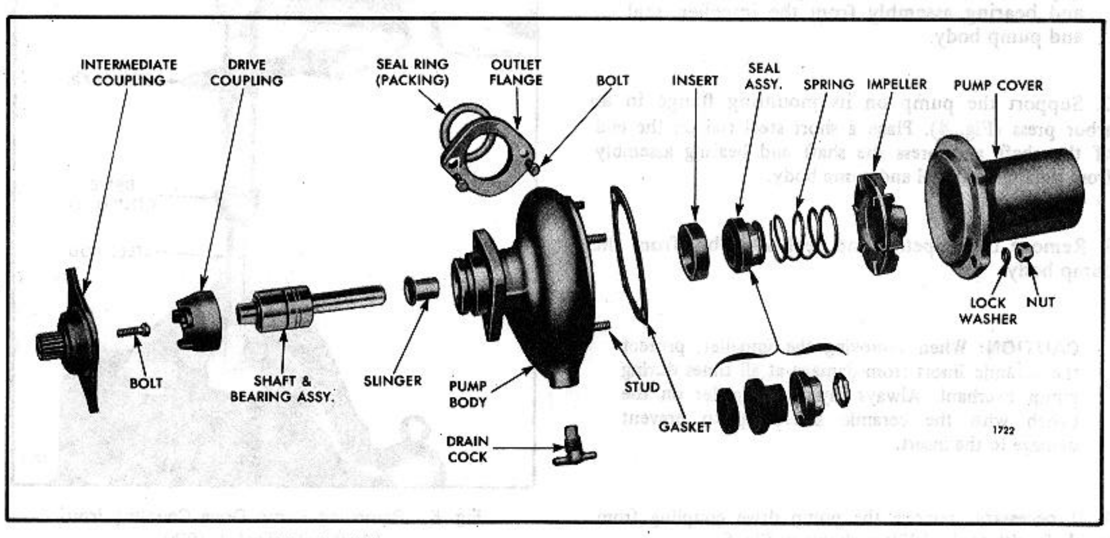


Fig. 6 - Water Pump Details and Relative Location of Parts

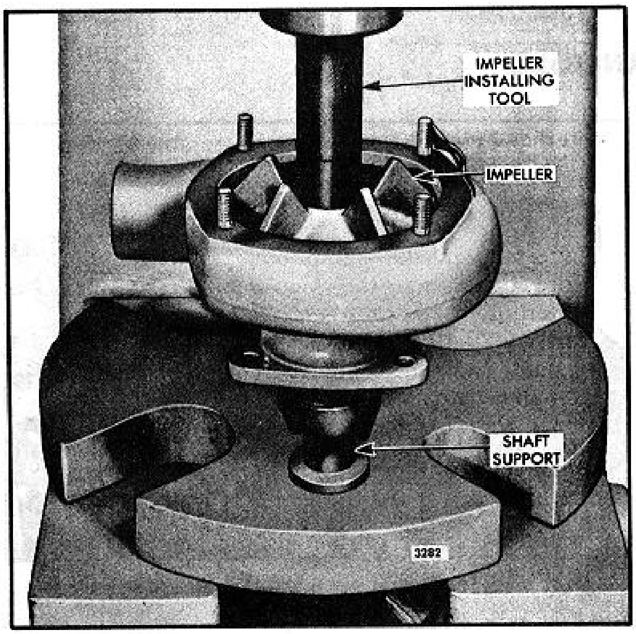


Fig. 7 - Installing Pump Impeller

new water seal. Press the seal assembly in place with a suitable sleeve until it seats firmly against the pump body. Then install the spring with the small end toward the seal.

7. 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 (Fig. 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 .031"-.033", with the bearing held against the shoulder in the pump body.

8. 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.

9. The pump includes a neoprene cover (Fig. 1) 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.

10. Rotate the shaft by hand to be sure the rear face of the impeller blades does not rub the pump body.

11. 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.

12. If previously removed, install the drain cock in the pump body.

Install Water Pump

Refer to Fig. 2 and install the water pump on the engine as follows:

1. Make sure the intermediate shaft coupling is secure. If it was previously removed, insert the splined end of the coupling into the mating splines in the blower rotor shaft. Then draw the coupling in place with the 5/16"-24 x 1-1/2" bolt. Tighten the bolt to 15-19 lb-ft (20-26 Nm) torque.

2. Place the pump outlet flange over the pump outlet with the flat side of the flange facing the pump body. Slip the packing ring over the pump outlet and next to the flange.

3. Use a new gasket at the bolting flange and place the pump against the blower end plate cover so that the lugs on the drive coupling mesh with the lugs on the intermediate shaft coupling. Secure the pump to the blower with the three bolts and seal washers.

4. Slide the pump outlet packing ring and packing flange against the cylinder block and secure the flange with two bolts and lock washers.

5. Slide the water pump inlet hose in place and secure it with the hose clamps.

6. Close the pump drain cock and fill the engine cooling system.

WATER MANIFOLD

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 Fig. 1. 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 either a uniform circular section at the front where a seal and clamp connect the manifold to the thermostat housing, or a 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:

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.

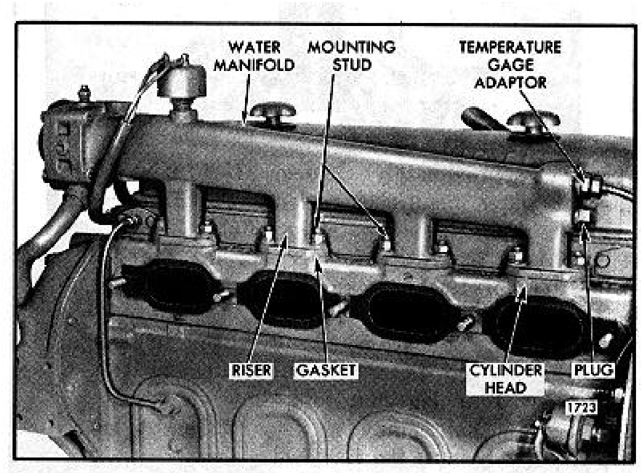


Fig. 1 - Typical Water Manifold Mounting Industrial Unit

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 2530 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 proper level.

THERMOSTAT

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 (Fig. 1) is used in the standard cooling system.

Operation

At coolant temperatures below approximately 160° to 170°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 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° C) 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.

CAUTION: 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

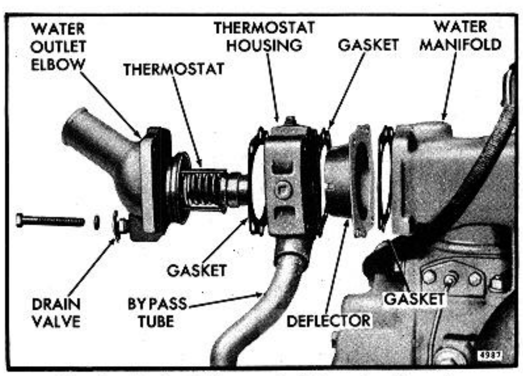


Fig. 1 - Typical thermostat Housing Mounting (Radiator Cooling System)

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 (Fig. 1).

3. Remove the thermostat and clean the seat for the thermostat in the outlet elbow.

4. Remove and discard the seals pressed in the water 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 (Fig. 2).

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.

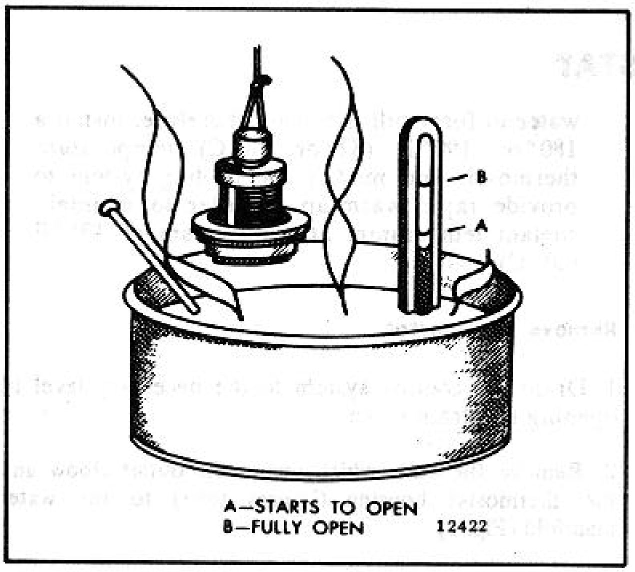


Fig. 2 - Method of Checking Thermostat Operation

Install Thermostat

1. Affix a new gasket to each side of the thermostat housing.

2. Set the new gasket and the thermostat in the housing.

Attach the outlet elbow and the thermostat housing to the water manifold.

Using a new seal connect the thermostat housing to the water manifold.

3. Connect any other piping which may have been disconnected.

4. Fill the cooling system and check for leaks.

RADIATOR

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 considerably 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 (refer to Page 10-9-16). 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 airtight 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 outlined on Page 10-11-3.

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.

WARNING

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 (see Chapter 6).

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 (refer to Page 10-9-16). 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.

2. Remove the five (5) bolts that attach the hood to the radiator shell.

3. Remove the four (4) bolts, two each side that attach the side covers to the radiator shell.

4. Remove the top and bottom radiator hoses.

5. Remove the four (4) bolts that attach the fan shroud to the radiator. Slide shroud over fan and hang on fan.

6. Disconnect headlight wire.

7. Remove the four (4) bolts, two each side that attach the radiator shell to the mixer frame.

8. Using a hoist, lift the radiator shell off the machine. Place the shell in a suitable workplace.

9. Remove the eight (8) bolts, four each side that attach the radiator to the radiator shell and remove radiator.

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 plaint be used.

Ordinary oil paints have an undesirable glossy finish and do not transmit heat as well.

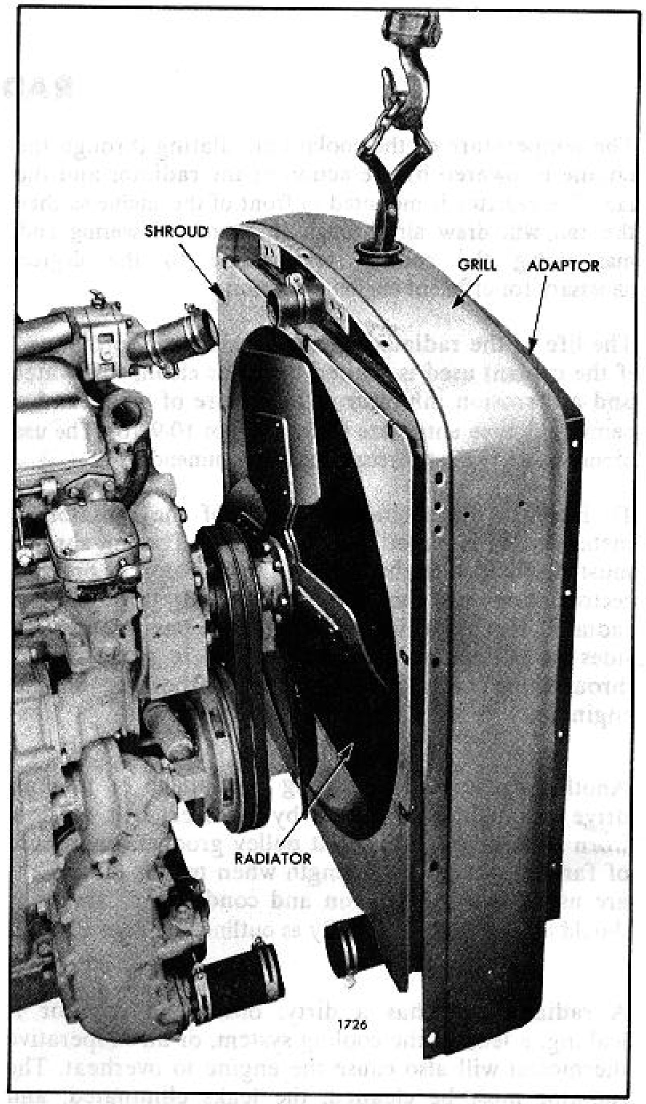


Fig. 1 Removing Radiator, Shell and Shroud with Lifting Hook (Typical)

Check all radiator hoses and clamps. Replace cracked and deteriorated hoses and damaged clamps.

Install Radiator

Assemble the radiator and radiator shell. 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.

COOLANT PRESSURE CONTROL CAP

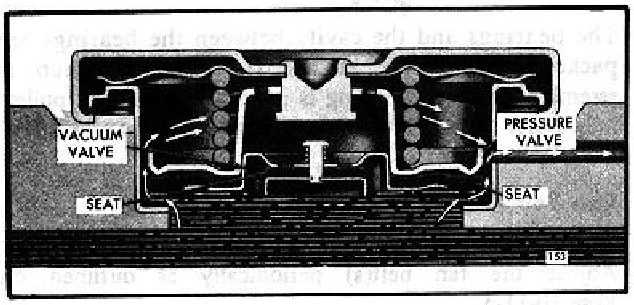


Fig. 1 - Pressure Control Cap (Pressure Valve Open)

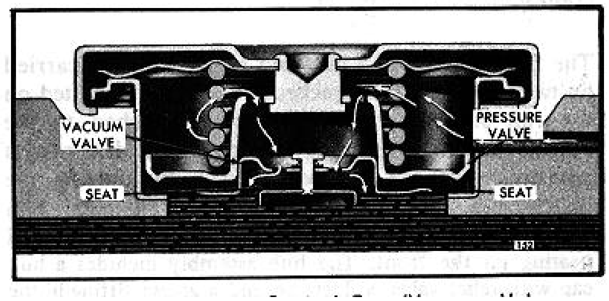


Fig. 2 - Pressure Control Cap (Vacuum Valve Open)

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 valve opens. This pressure raises the boiling point of the cooling liquid and permits somewhat higher engine operating temperatures without loss of any coolant from boiling. To prevent the collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools.

WARNING

Use extreme care when removing the coolant pressure control cap.

Remove the cap slowly after the engine has cooled. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

To ensure against possible damage to the cooling system from either excessive pressure or vacuum, check both valves periodically for proper opening and closing pressures. If the pressure valve does not open between 6.25 psi (43.1 kPa) and 7.5 psi (51.7 kPa) or the vacuum valve does not open at .625 psi (4.3 kPa) (differential pressure), replace the pressure control cap.

ENGINE COOLING FAN

The engine cooling fan is belt driven from the crankshaft pulley (Fig. 1).

The fan is bolted to a hub and pulley which is carried on two bearings. The bracket and shaft is mounted on the fan support which is in turn attached to the balance weight cover. The bracket is slotted to permit adjustment of the fan belt tension by moving the bracket and shaft on the attaching bolts. The pulley hub turns on a tapered roller bearing at the rear and a ball bearing on the front. The hub assembly includes a hub cap with relief valve, a dust cap and a grease fitting in the fan pulley hub (Fig. 2).

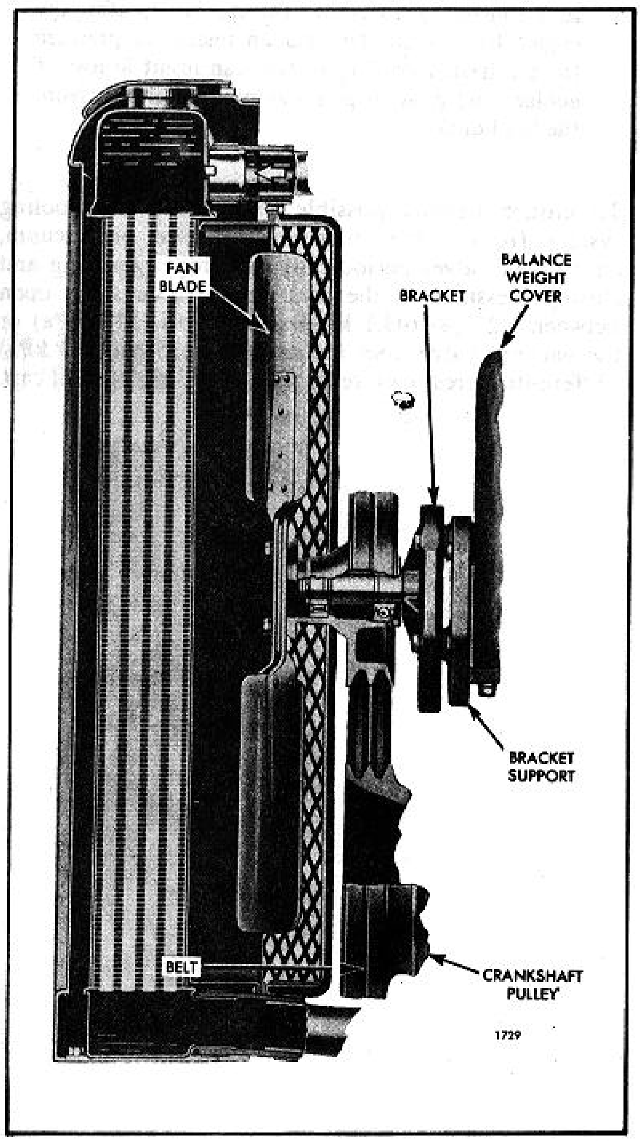


Fig. 1 . Typical Fan and Fan Hub Assembly

Lubrication

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. A grease fitting is provided in the fan pulley hub. Refer to Page 10-11-3 for the maintenance schedule.

Fan Belt Adjustment

Adjust the fan belt(s) periodically as outlined on Page 10-11-3.

Remove and Install Fan Blades

The fan blades may be removed from the fan hub assembly as follows:

1. Remove the four fan guard mounting bolts and move the fan guard to the rear to gain access to the front of the fan.

2. Remove the 6 fan mounting bolts and lockwashers and remove the fan. The fan blades may be installed by reversing the procedure used -for removal.

NOTE: When installing fan guard be sure that it is positioned so that there is equal clearance between the tips of all blades and guard.

Remove Fan, Hub and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core. Before removing the fan, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

1. Remove the four fan guard mounting bolts and move the fan guard to the rear to gain access to the front of the fan.

2. Remove the attaching bolts, lock washers and nuts, then remove the fan.

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 Figs. 2 and 3 and disassemble the fan, hub and adjusting bracket as follows:

1. Remove the fan attaching bolts and lock washers and detach the fan.

2. Remove the fan hub cap.

3. Remove the hub bolt and washer.

4. Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.

5. Remove the bearings and oil sea) as follows:

   a. Remove the snap ring from the grove in the outer (front) of the hub.
   b. Remove the ball bearing by tapping alternately around the oil seal from the hub. Discard the oil seal. outer edge of the bearing with a small brass rod and hammer.
   c. Reverse the pulley hub and remove the dust cap.
   d. Remove the inner (rear) roller in the same manner as outlined in Step b.

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 the outer race or cup slowly by hand. If rough spots are found, replace the bearings.

Check the fan blades for cracks. Replace the fan if the blades are badly bent, since straightening may weaken the blades, particularly in the hub area.

Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severely worn, replace the pulleys.

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.

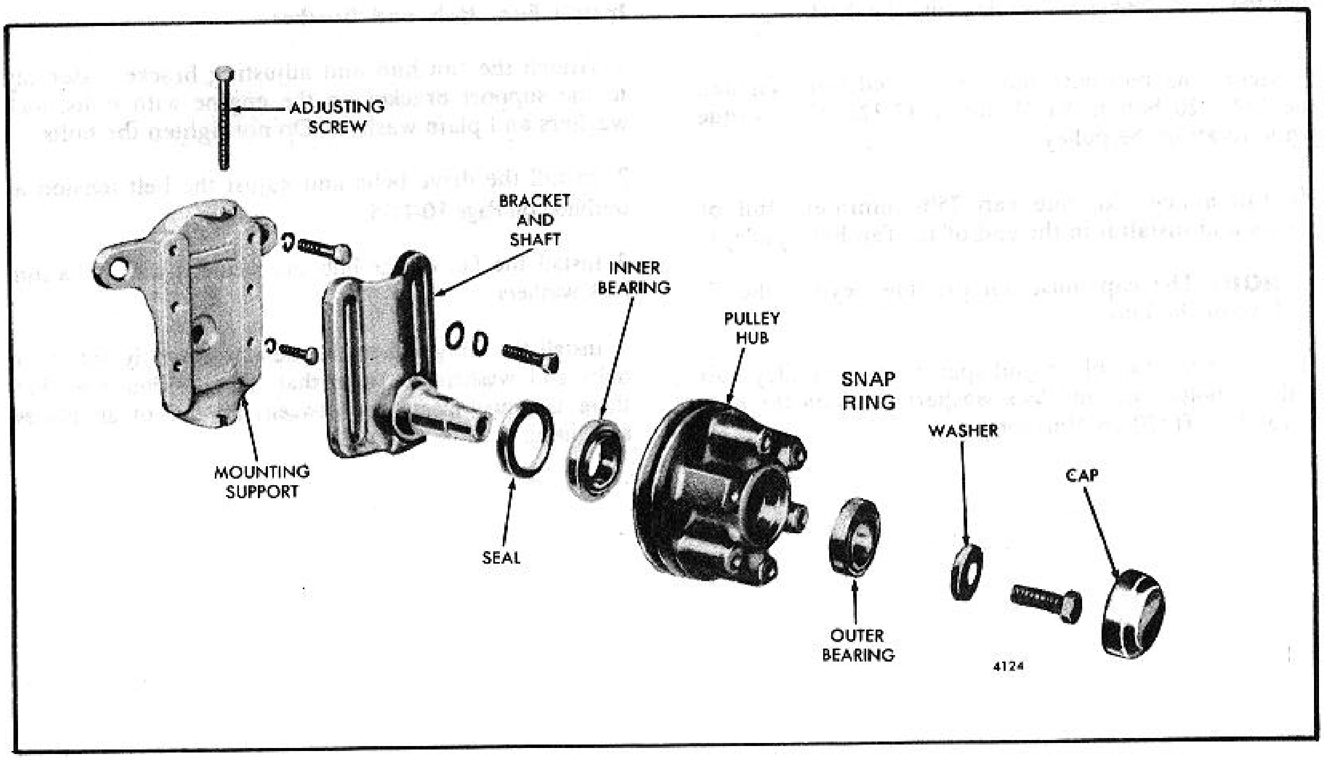


Fig. 2 - Shaft Type Fan Hub Assembly Details for Compact Front End Engine.

Assemble Fan, Hub and Bracket

Assemble the fan hub and bracket shown in Fig. 2 and 3 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 (inner and outer race), with the protruding face of the inner race facing outward from the hub, (1.31 " from end of shaft), by tapping alternately around the face of the bearing outer race with a small brass rod and hammer.

3. Install a new oil seal with the rubber side flush with the outer edge of the hub.

4. Install the dust cap over the oil seal.

5. Place the adjusting bracket assembly on wood blocks setting on the bed of an arbor press. Then press the pulley hub on the fan shaft.

6. Pack the cavity 20-30% full with grease as outlined in Step 1.

7. Install the front ball bearing assembly by tapping alternately around the face of the bearing with a small brass rod and hammer.

8. Install snap ring in the groove of the pulley hub, to lock the outer (front) ball bearing onto the shaft.

9. Secure the hub with the washer and bolt. Tighten the 1/2 "-20 bolt to 83-93 lb-ft (113-126 Nm) torque while rotating the pulley.

10. 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.

11. Secure the fan blade and spacers to the pulley hub with six bolts, nuts and lock washers. Tighten the nuts to 15-19 lb-ft (20-26 Nm) torque.

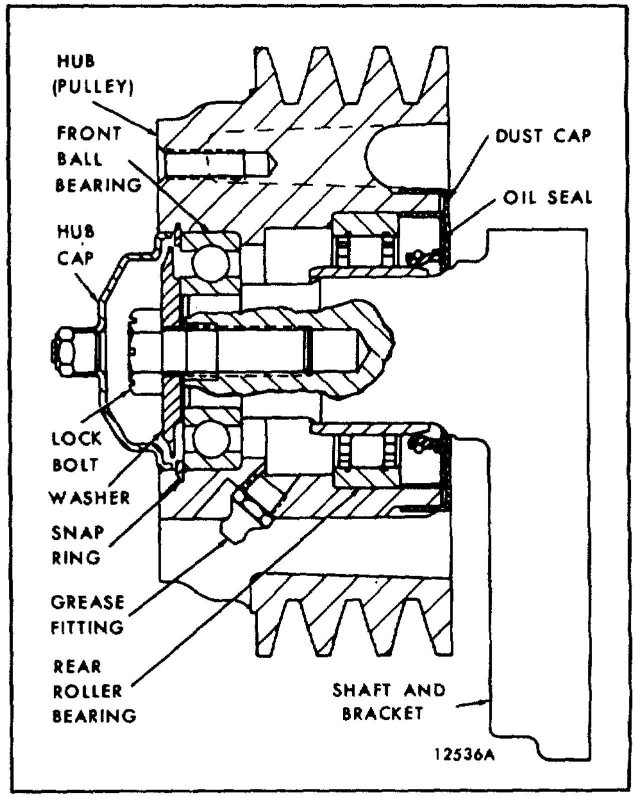


Fig. 3 - Shaft Type Fan Hub Assembly.

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 on Page 10-11-5.

3. Install the fan on the hub and secure it with bolts and lock washers.

4. Install the fan guard to the radiator assembly with four bolts and washers. Be sure that it is positioned so that there is equal clearance between the tips of all blades and guard.

10-6-18

SPECIFICATIONS

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		GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None		GM 255-M	1	No. 6 thru 1 1/2	60,000
None		GM 260-M	2	No. 6 thru 3/4	74,000
				over 3/4 to 1 1/2	60,000
	Bolts and Screws	GM 280-M	5	No. 6 thru 1	120,000
				over 1 to 1 1/2	105,000
	Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
	Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
	Bolts and Screws	GM 300-M	8	1/4 thru I 1/2	150,000
	Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

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

SERVICE TOOLS

TOOL NAME	TOOL NO.
Thermostat seal replacer	J 8550
Water pump and fuel pump wrench	J 4242
Water pump drive coupling remover	J 1930
Water pump impeller installer (.031 "-.033")	J 22437

EXHAUST SYSTEM **CHAPTER 7**

CONTENTS

EXHAUST SYSTEM

The engine is equipped with an air cooled exhaust manifold. The outlet flange is located at the mid-section of the exhaust manifold. A bolt-on exhaust extension is attached to the outlet flange, and extends through the vehicle hood. The muffler with rain cap is clamped to the exhaust extension.

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

The air-cooled exhaust manifold (Fig. I) is mounted on the cylinder head.

A new exhaust manifold hold-down crab is now being used. The new hold-down crab is made of a hardened steel and is heavier than the former hold-down crab. 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. The former and the new hold-down crabs are interchangeable on an engine, however only the new crab will be serviced.

Also a new special washer is now used at the center portions of the exhaust manifolds. This new washer will more accurately control the seating area for the 7/16 " nut or bolt. Only the new special washer will be serviced.

Remove Exhaust Manifold

Remove the manifold as follows:

1. Disconnect the exhaust extension and muffler from the exhaust manifold.

2. Remove the nuts and bevel washers that attach the exhaust manifold to the cylinder head. It is suggested that, as a safety measure, the nut be loosened but left on the center stud until all of the other nuts and washers have been removed.

3. Support the manifold and remove the nut and washer from the center stud.

4. Lift the manifold away from the cylinder head.

5. Remove the manifold gaskets.

Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold.

Examine the exhaust manifold studs for damage. If necessary, replace the studs. New studs are driven in to 25-40 Ib-ft (34-54 Nm) torque.

Install Exhaust Manifold

Install the exhaust manifold on the cylinder head as follows:

1. Place new gaskets over the studs and up against the cylinder head.

2. Position the exhaust manifold over the studs and against the gaskets.

3. Install the bevel washers on the studs.

NOTE:
Install the bevel washers with the crowned sides toward the nuts.

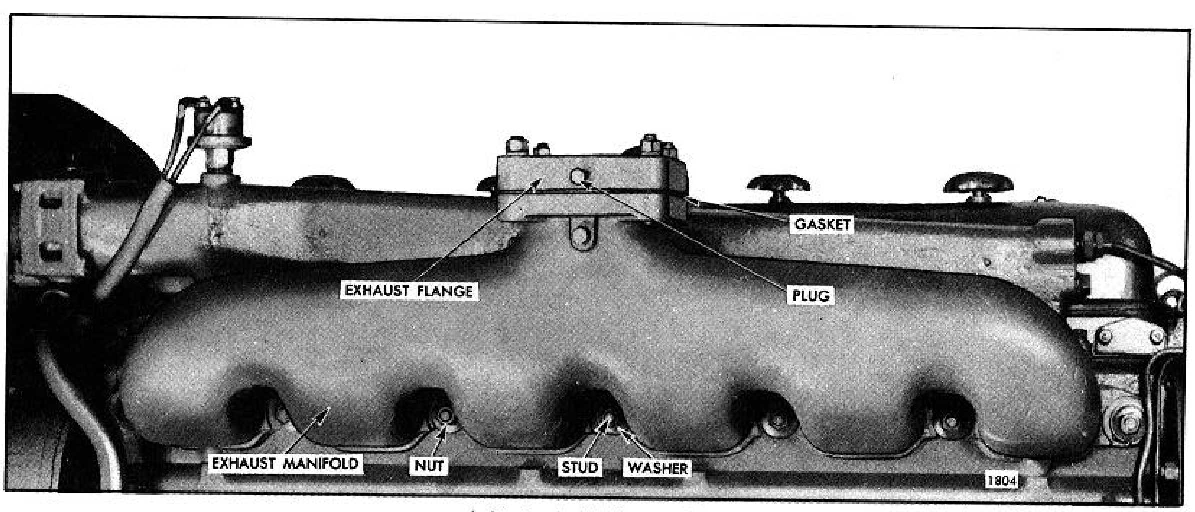


Fig. 1 - Typical Air-Cooled Exhaust Manifold Mounting.

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 extension and muffler to the manifold. Tighten the brass exhaust manifold outlet flange nuts to 20-25 lb-ft (27-34 Nm) torque.

ELECTRICAL EQUIPMENT, INSTRUMENTS AND PROTECTIVE SYSTEMS **CHAPTER 8**

CONTENTS

ELECTRICAL SYSTEM

The engine electrical system consists of a starting motor, battery charging alternator with built-in regulation, protective diode and pressure safety switch to protect the electrical system, two storage batteries and the necessary wiring.

Detailed information on maintenance and repair of the specific types of electrical equipment used can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco-Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from AC-Delco service outlets, or from the Technical Literature Section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Allison. For electrical equipment manufactured by Delco-Remy Division, repair service and parts are available through AC-Delco branches and repair stations.

BATTERY-CHARGING ALTERNATOR

The battery charging circuit consists of alternator with built-in regulation, protective diode and safety switch, batteries and wiring. The battery-charging alternator (Fig. 1) is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the generator or alternator.

HINGE-MOUNTED ALTERNATOR (Belt-driven)

The hinge-mounted alternating current self-rectifying alternator is belt driven from the crankshaft pulley by a ribbed type V-belt.

An adequate alternator drive ratio is necessary for an engine equipped with extra electrical accessories and one that has to operate for extended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase A.C. voltage to provide D.C. voltage at the battery terminal of the alternator, thereby eliminating the need for an external rectifier.

A protective diode is inserted in the wiring harness for alternator diode protection, Fig. 1. Additional alternator protection is provided by the fuel pressure safety switch. The safety switch is mounted on the fuel filter housing (Fig. 2). Electrically it is in series between the alternator and the battery. When the engine is running, fuel pressure causes the switch diaphram to close the switch contacts completing the circuit between alternator and battery. When the engine is stopped, the absence of fuel pressure allows the contacts to open the circuit between alternator and battery.

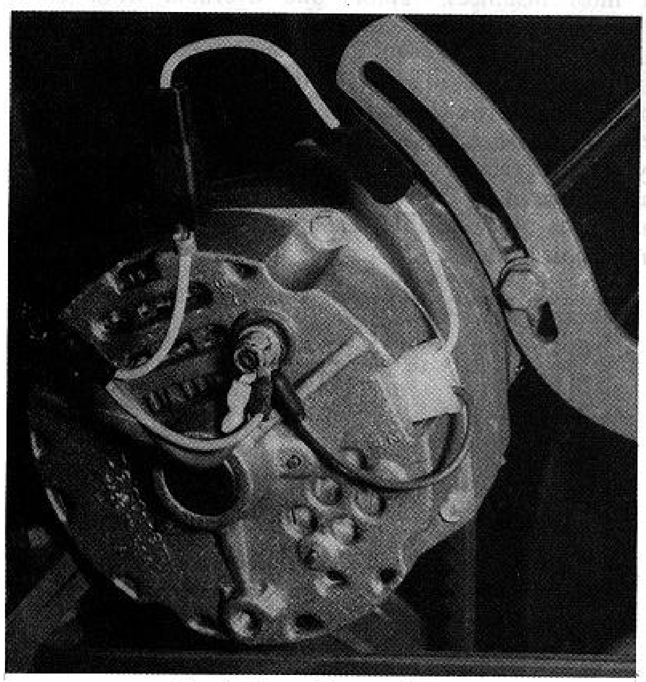


Fig.1 - Hinge-Mounted Alternator.

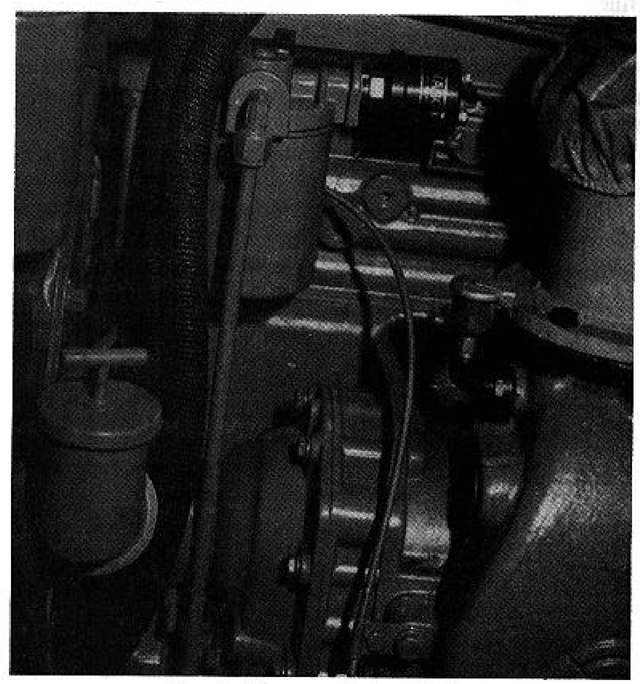


Fig. 2 - Pressure Safety Switch.

ALTERNATOR PRECAUTIONS

Precautions must be taken when working on or around alternators. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding or shorting the output wires. Never run an alternator on an open circuit.

Grounding an alternator's output wire or terminals, which are always "hot" regardless of whether or not the engine is running or accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes.

Accidentally reversing the battery connections must be avoided.

Never disconnect the battery while an alternator is in operation. Disconnecting the battery will result in damage to the diodes due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

If a booster battery is to be used, the batteries must be connected correctly (negative to negative and positive to positive).

Never use a fast charger with the battery connected or as a booster for battery output.

Never attempt to polarize the alternator.

The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc.

Alternator Maintenance

1. Maintain the proper drive belt tension. Replace worn or frayed belts.

NOTE

When installing or adjusting the drive belt, be sure the bolt at the pivot point is properly tightened, as well as the bolt in the adjusting slot.

2. Alternator bearings are permanently lubricated. There are no external oiler fittings.

3. The solid state regulator is mounted inside the alternator slip ring end frame. The regulator voltage setting never needs adjusting and no provision for adjustment is provided.

Remove Alternator

1. Disconnect the cables at the battery supply. Disconnect all other leads from the alternator and tag each one to ensure correct reinstallation.

2. Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.

3. While supporting the alternator, remove the adjusting strap bolt and washers. Then remove the mounting bolts, washers and nuts. Remove the alternator carefully and protect it from costly physical damage.

4. Remove the pulley assembly if the alternator is to be replaced.

Alternator Service

No periodic adjustments or maintenance are required on the alternator assembly. However, Troubleshooting Procedures will indicate when repairs or overhaul are necessary. Shown in Fig. 4 are the terminal connections and the internal parts of the alternator are shown in Fig. 5. The external charging circuit Fig. 6 is complete from the alternator to the battery through the fuel pressure switch and ammeter when the engine is running.

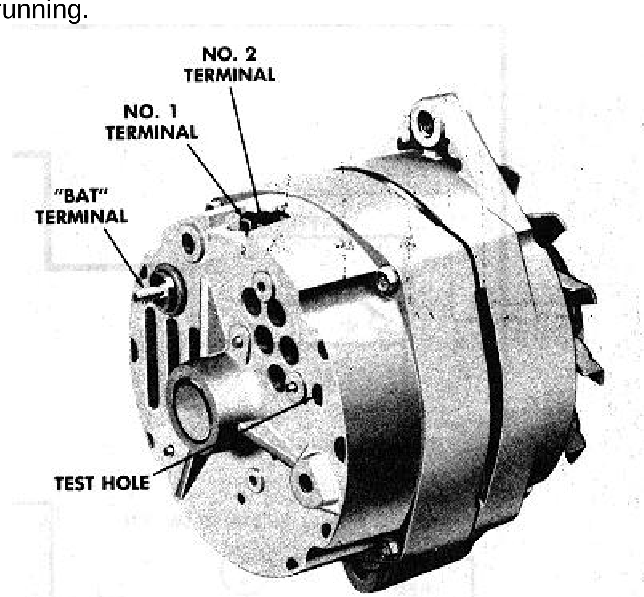


Fig. 4 - Terminal Connections.

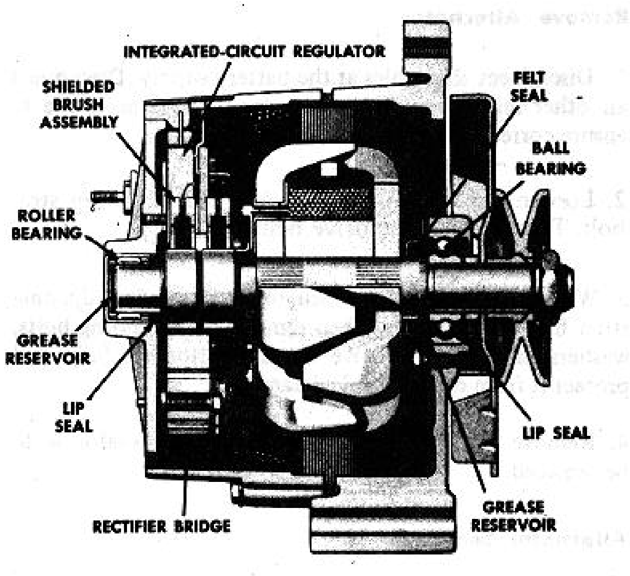


Fig. 5 - Cross Sectional View.

TROUBLESHOOTING PROCEDURE

(Close adherence to the following procedures in the order presented will lead to the location and correction of charging system defects in the shortest possible time. Only a portion of these procedures need be performed. It will never be necessary to perform all the procedures in order to locate the trouble.)

A basic wiring diagram showing lead connections is shown in Fig. 6. To avoid damage to the electrical equipment, always observe the following precautions:

- Do not polarize the alternator.
- Do not short across or ground any of the terminals in the charging circuit, except as specifically instructed herein.
- NEVER operate the alternator with the output terminal open-circuited.
- Make sure the alternator and battery have the same ground polarity.
- When connecting a charge or a booster battery to the vehicle battery, connect negative to negative, and positive to positive.

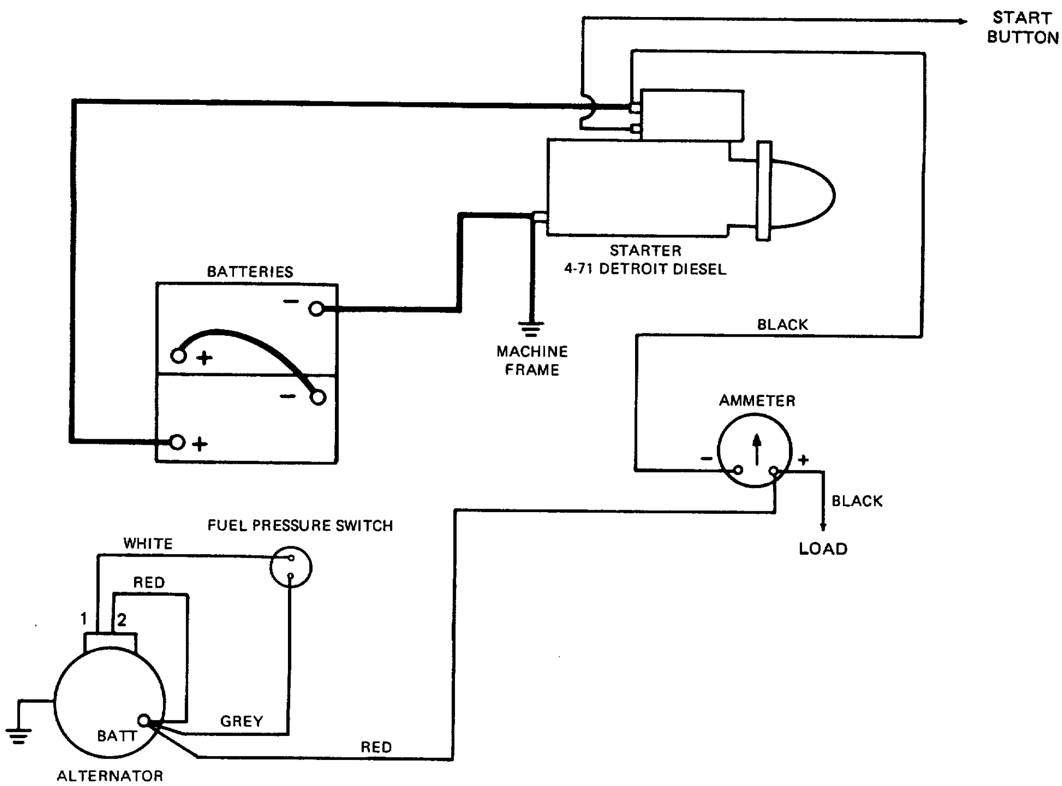


Fig. 6 - Charging Circuit.

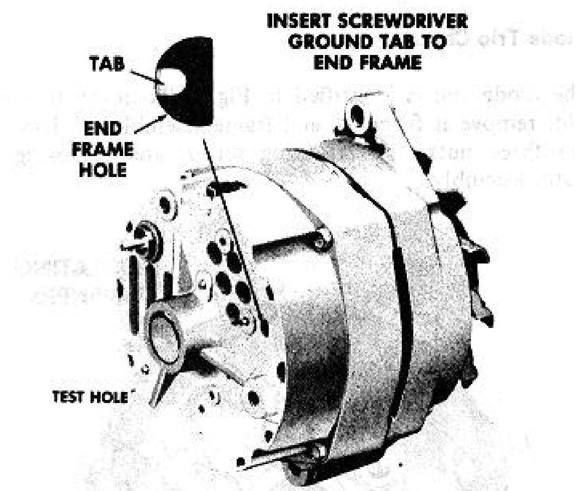


Fig. 7 - End Frame Test Hole.

ABNORMAL CHARGING SYSTEM OPERATION

1. Insure that the undercharged condition has not been caused by accessories having been left on for extended periods.
2. Check the drive belt for proper tension.
3. If battery defect is suspected, check the battery with suitable test equipment.
4. Inspect the wiring for defects. Check all connections for tightness and cleanliness, including the slip connectors at the alternator and connections at the battery.
5. With ignition switch on and all wiring harness leads connected, connect a voltmeter from:

a. alternator "BAT" terminal to ground.
b. alternator No. I terminal to ground.
c. alternator No. 2 terminal to ground.
A zero reading indicates an open between voltmeter connection and battery. Repair if required.

6. With all accessories turned off, connect a voltmeter across the battery. Operate engine at moderate speed. If voltage is 15.5 or more, remove alternator for repair.
7. If previous Steps 1 thru 6 check satisfactorily, check alternator as follows:

a. Disconnect battery ground cable.
b. Connect an ammeter in the circuit at the "BAT" terminal of the alternator.
c. Reconnect battery ground cable.
d. Turn on accessories. Connect a barbon pile across the battery.
e. Operate engine at moderate speed as required, and adjust carbon pile as required to obtain maximum current output.
f. If ampere output is within 10 amperes of rated output as stamped on alternator frame, alternator most likely is not defective; recheck Steps 1 thru 6.
g. If ampere output is not within 10 amperes of rated output, determine if test hole (Fig. 7) is accessible. If accessible go to Step h. If not accessible go to Step 1.
h. Ground the field winding by inserting a screwdriver into the test hole (Fig. 7).

CAUTION

Tab is within 3/4 inch of casting surface. Do not force screwdriver deeper than one inch into end frame.

i. Operate engine at moderate speed as required, and adjust carbon pile as required to obtain maximum current output.
j. If output is within 10 amperes of rated output, check field winding as covered in "REPAIR" section, and test regulator with an approved regulator tester.
k. If output is not within 10 amperes of rated output, check the field winding, diode trio, rectifier bridge, and stator as covered in "REPAIR" section.
l. If test hole is not accessible, disassemble alternator and make tests listed in "REPAIR" section.

REPAIR

To repair the alternator, observe the following procedure:

Disassembly

To disassemble the alternator, take out the four thru-bolts, and separate the drive end frame and rotor assembly from the stator assembly by prying apart with a screwdriver at the stator slot. A scribe mark will help locate the parts in the same position during assembly. After disassembly, place a piece of tape over the slip ring end frame bearing to prevent entry of dirt and other foreign material, and also place a piece of tape over the shaft on the slip ring end. If brushes are to be reused, clean with a soft dry cloth.

CAUTION

Use pressure sensitive tape and not friction tape which would leave a gummy deposit on the shaft.

To remove the drive end frame from the rotor, place the rotor in a vise and tighten only enough to permit removal of the shaft nut.

CAUTION: Avoid excessive tightening as this may cause distortion of the rotor.

Remove the shaft nut, washer, pulley, fan, and the collar, and then separate the drive end frame from the rotor shaft.

Rotor Field Winding Checks

To check for opens, connect the test lamp or ohmmeter to each slip ring. If the lamp fails to light, or if the ohmmeter reading is high (infinite), the winding is open (Fig. 8). Connect test lamp or ohmmeter from one slip ring to shaft. If lamp lights, or if reading is low, the rotor winding is grounded (not illustrated).

The winding is checked for short-circuits or excessive resistance by connecting a battery and ammeter in series with the edges of the two slip rings.

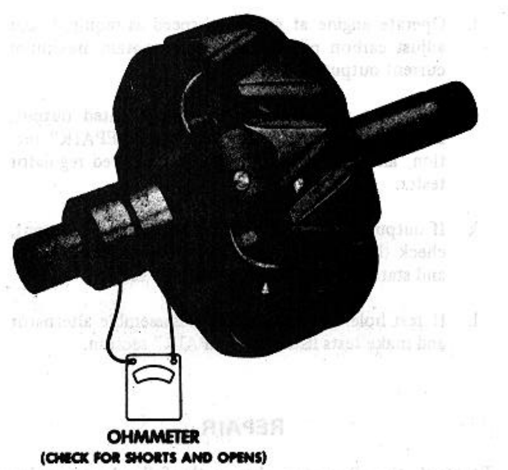


Fig. 8 - Checking Rotor.

The ammeter should indicate a reading of from 4.0 to 5.0 amperes. An ammeter reading above the specified value indicates shorted windings; a reading below the specified value indicates excessive resistance. An alternate method is to check the resistance of the field by connecting an ohmmeter to the two slip rings (Fig. 8). If the resistance reading is below the specified value, the winding is shorted; if above the specified value the winding has excessive resistance. The specified resistance value should be from 2.5 to 3.0 ohms.

Remember that the winding resistance and ammeter readings will vary slightly with winding temperature changes. If the rotor is not defective, but the alternator fails to supply rated output, the defect is in the diode trio, rectifier bridge, stator, or regulator.

Diode Trio Check

The diode trio is identified in Fig. 9. To check the diode trio, remove it from the end frame assembly by detaching the three nuts, the attaching screw, and removing the stator assembly.

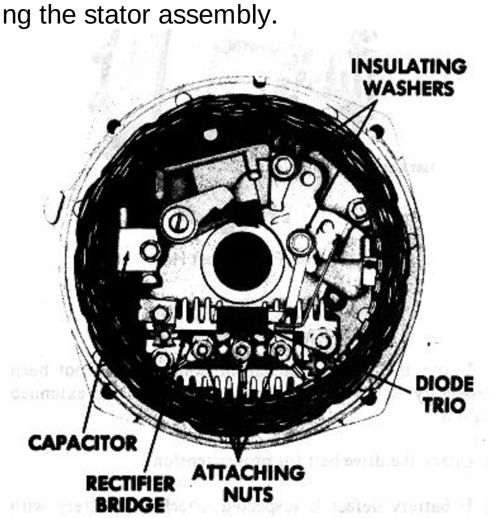


Fig. 9 - View Inside End Frame.

NOTE
That the insulating washer on the screw is assembled over the top of the diode trio connector.

Connect an ohmmeter having a 1l volt cell, and using the lowest range scale, to the single connector and to one of the three connectors (Fig. 10). Observe the reading. Then reverse the ohmmeter leads to the same two connectors. If both readings are the same, replace the diode trio. A good diode trio will give one high and one low reading. Repeat this same test between the single connector and each of the other two connectors. Also, connect the ohmmeter to each pair of the three connectors (not illustrated). If any reading is zero, replace the diode trio.

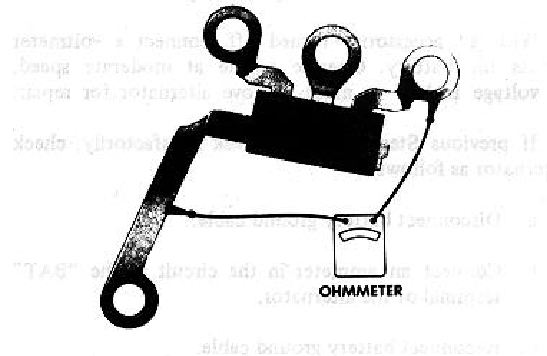


Fig. 10 - Testing Diode Trio.

Rectifier Bridge Check

Note that the rectifier bridge has a grounded heat sink and an insulated heat sink connected to the output terminal.

To check the rectifier bridge, connect the ohmmeter to the grounded heat sink and one of the three terminals (Fig. 11).

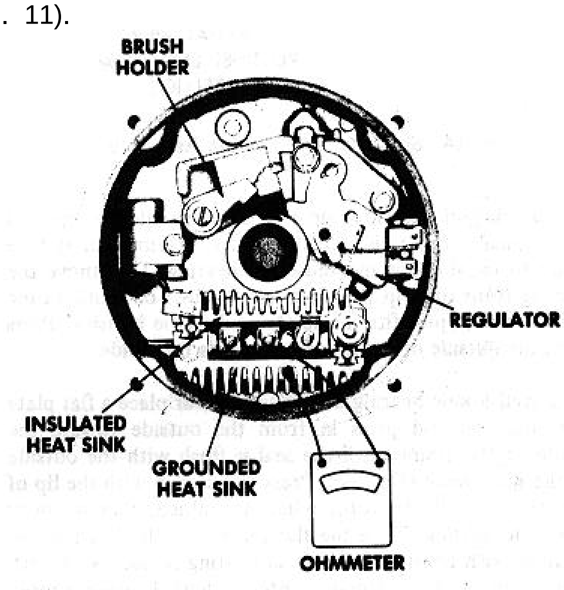


Fig. 11 - Testing Rectifier Bridge.

IMPORTANT

Connect ohmmeter pressing down very firmly onto flat metal connector, then reverse the lead connections to the grounded heat sink and same terminal. If both readings are the same, replace the rectifier bridge. A good rectifier bridge will give one high and one low reading. Repeat this same test between the grounded heat sink and the other two terminals, and between the insulated heat sink and each of the three terminals. This makes a total of six checks, with two readings taken for each check.

The ohmmeter check of the rectifier bridge, and of the diode trio as previously covered, is a valid and accurate check. **DO NOT** replace either unit unless at least one pair of readings is the same.

CAUTION

Do not use high voltage to check these units, such as a 110-volt test lamp.

To replace the rectifier bridge, remove the attaching screws and disconnect the capacitor lead.

Stator Check

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 (Fig. 12).

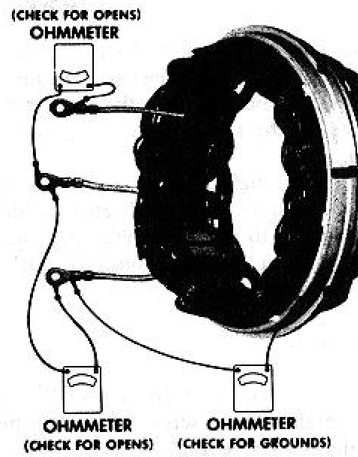


Fig. 12 - Testing Stator.

NOTE

Ohmmeter or test light checks for opens can be made only on "Y" stators, visually identified by three stator leads crimped together.

Delta windings cannot be checked for opens with an ohmmeter or test light. Usually laboratory equipment is required to check Delta windings.

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 generator fails to supply rated output, a shorted stator winding or an open Delta winding is indicated. Also, a shorted stator can cause the indicator lamp to be on with the engine at low speed. Check the regulator in next section before replacing stator.

Brush Holder and Regulator Replacement

To determine if the regulator is defective, an approved regulator tester must be used.

After removing the three attaching nuts, the stator, and diode trio screw (Fig. 11), the brush holder and regulator may be replaced by removing the two remaining screws. Note the two insulators located over the top of the brush clips in Fig. 9, and that these two screws have special insulating sleeves over the screw body above the threads. The third mounting screw may or may not have an insulating sleeve. If not, this screw must not be interchanged with either one of the other two screws, as a ground may result, causing no output or uncontrolled generator output. Regulators may vary in appearance but are completely interchangeable in these generators.

Slip Ring Servicing

If the slip rings are dirty, they may be cleaned and finished with 400 grain or finer polishing cloth. Spin the rotor and hold the polishing cloth against the slip rings until they are clean.

CAUTION

The rotor must be rotated in order that the slip rings will be cleaned evenly. Cleaning the slip rings by hand without spinning the rotor may result in flat spots on the slip rings, causing brush noise.

Slip rings which are rough or out or round should be trued in a lathe to .002 inch maximum indicator reading. Remove only enough material to make the rings smooth and round. Finish with 400 grain or finer polishing cloth and blow away all dust.

Bearing Replacement

The bearing in the drive end frame can be removed by detaching the retainer plate screws, and then pressing the bearing from the end frame. Fig. 13.

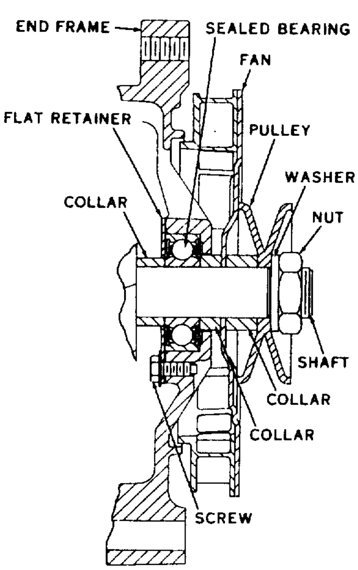


Fig. 13 - Drive End Bearing Assembly.

To install a new bearing, press in with a tube or collar that just fits over the outer race, with the bearing assembled into the end frame as shown in Fig. 14.

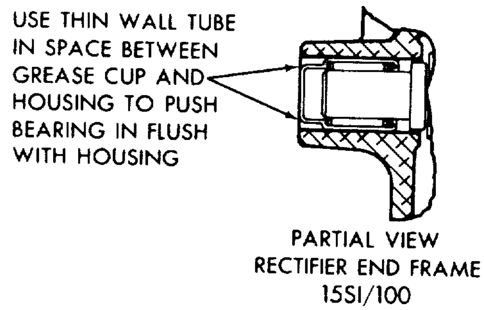


Fig. 14 - Slip Ring End Bearing Assembly.

The bearing in the slip ring end frame should be replaced if its grease supply is exhausted. No attempt should be made to re-lubricate and reuse the bearing. To remove the bearing from the slip ring end frame, press out with a tube or collar that just fits inside the end frame housing. Press from the outside of the housing towards the inside.

To install a new bearing and separate seal place a flat plate over the seal and press in from the outside toward the inside of the frame until the seal is flush with the outside of the end frame (Fig. 14). Press the seal in with the lip of the seal toward the rotor when assembled, that is, away from the bearing. Place the flat plate over the bearing and push in both bearing and seal so bearing is flush with outside of end frame. If seal is integral with bearing, simply press bearing in as described.

Support the inside of the frame with a hollow cylinder to prevent breakage of the end frame. Use extreme care to avoid misalignment or otherwise placing undue stress on the bearing. Lightly coat the seal lip with oil to facilitate assembly of the shaft into the bearing.

Reassembly

Reassembly is the reverse of disassembly.

Remember when assembling the pulley to secure the rotor in a vise only tight enough to permit tightening the shaft nut to 40-60 lb. ft. If excessive pressure is applied against the rotor, the assembly may become distorted. To install the slip ring end frame assembly to the rotor and drive end frame assembly, remove the tape over the bearing and shaft, and make sure the shaft is perfectly clean after removing the tape. Insert a pin through the holes to hold up the brushes. Carefully install the shaft into the slip ring end frame assembly to avoid damage to the seal. After tightening the thru-bolts remove the brush retaining pin to allow the brushes to fall down onto the slip rings.

Generator Bench Check

To check the alternator in a test stand, proceed as follows:

1. Make connections as shown in Fig. 15, except leave the carbon pile disconnected.

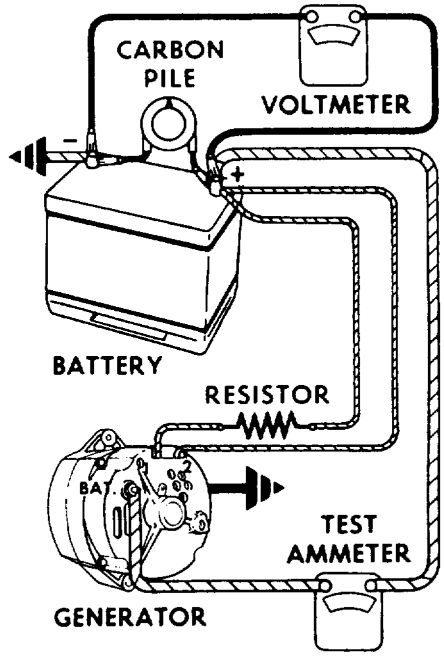


Fig. 15 - Connections for Generator Bench Check

IMPORTANT

Ground polarity of battery and alternator must be the same.

Use a fully charged battery, and a 10 ohm resistor rated at six watts or more between the alternator No. 1 terminal and the battery.

2. Slowly increase the alternator speed and observe the voltage.

3. If the voltage is uncontrolled with speed and increases above 15.5 volts, test regulator with an approved regulator tester, and check field winding.

NOTE

The battery must be fully charged when making this check.

4. If voltage is below 15.5 volts, connect the carbon pile as shown.

5. Operate the alternator at moderate speed as required and adjust the carbon pile as required to obtain maximum current output.

6. If output is within 10 amperes of rated output as stamped on alternator frame, is good.

7. If output is not within 10 amperes of rated output, keep battery loaded with carbon pile, and ground alternator field (Fig. 7).

8. Operate alternator at moderate speed and adjust carbon pile as required to obtain maximum output.

9. If output is within 10 amperes of rated output, test regulator with an approved regulator tester, and check field winding.

10. If output is not within 10 amperes of rated output, check the field winding, diode trio, rectifier bridge, and stator as previously covered.

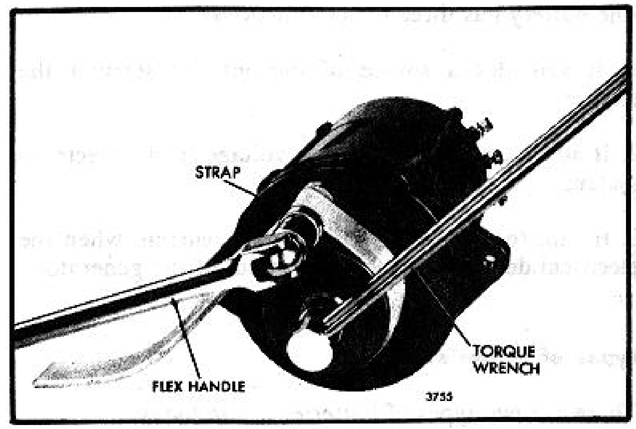


Fig. 16 - Tighten Alternator Pulley Retaining Nut

Install Alternator

1. Install the drive pulley, if it was removed. Tighten the pulley retaining nut to 50-60 lb-ft (68-81 Nm) torque (Fig. 16).

NOTE

If the pulley was not removed, check the retaining nut for proper torque.

2. Position the alternator on the mounting brackets and start the bolts, with washers in place, through the bolt holes in the end frames. 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 belt in the groove of the pulley.

5. Adjust the belt tension as outlined on Page 10-11-5. Tighten all of the bolts after the belt tightening is completed.

6. Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

STORAGE BATTERY(S)

The lead-acid storage battery is an electrochemical device for converting chemical energy into electrical energy. Two 6-volt lead acid storage batteries are connected in series to provide 12 volts for the electrical system.

Function of Battery

The battery has three major functions:

1. It provides a source of current for starting the engine.
2. It acts as a stabilizer to the voltage in the electrical system.
3. It can, for a limited time, furnish current when the electrical demands exceed the output of the generator.

Types of Batteries

There are two types of batteries in use today.

1. The *dry charge* battery contains fully charged positive plates and negative plates separated by separators. The battery contains no electrolyte until it is activated for service in the field and therefore leaves the factory dry. Consequently, it is called a *dry charge* battery.
2. If the battery has been manufactured as a wet battery, it will contain fully charged positive and negative plates plus an electrolyte. This type of battery will not maintain its charged condition during storage and must be charged periodically to keep it ready for service.

NOTE

In the selection of a replacement battery, it is always good practice to select one of an "electrical size" at least equal to the battery originally engineered for the particular equipment by the manufacturer.

Install Battery

While the battery is built to satisfactorily withstand the conditions under which it will normally operate, excessive mechanical abuse leads to early failure.

Install the battery as follows:

1. Be sure the battery carrier is clean and that the battery rests level when installed.
2. Tighten the hold-down clamps evenly until snug. However, do not draw them down too tight or the battery case will become distorted or will crack.
3. Connect the batteries as shown in Fig. 4. Attach the cable clamps after making sure the cables and terminal clamps are clean and in good condition. To make the cable connections as corrosion resistant as possible, place a felt washer at the base of each terminal beneath the cable clamps. Coat the entire connection with a heavy general purpose grease. Be sure the ground cable is clean and tight at the engine block or frame.
4. Check the polarity to be sure the battery is not reversed with respect to the generating system.
5. Connect the *grounded* terminal of the battery last to avoid short circuits which will damage the battery.

Servicing the Battery

A battery is a perishable item which requires periodic servicing. Only when the battery is properly cared for as described below can long and trouble-free service be expected.

1. Check the level of the electrolyte regularly. Add water if necessary, but do not overfill. Overfilling can cause poor performance or early failure.

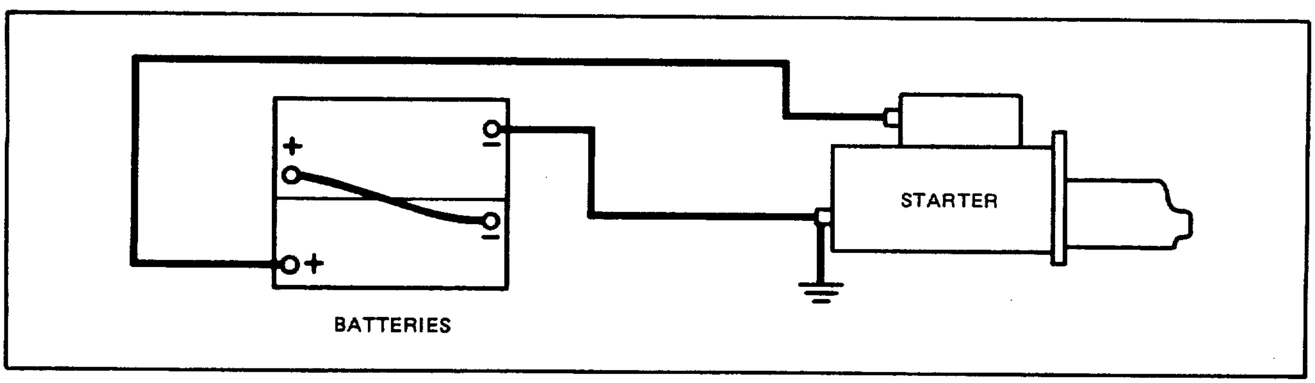


Fig. 17 - Battery Connecting Diagram.

2. Keep the top of the battery clean. When necessary, wash with a baking soda solution and rinse with fresh water. Do not allow the soda solution to enter the cells.

3. Inspect the cables, clamps and hold-down bracket regularly. Clean and re-apply a coat of grease when needed. Replace corroded or damaged parts.

4. Use the standard battery test as the regular service test to check the condition of the battery.

5. Check the electrical system if the battery becomes discharged repeatedly.

Many electrical troubles caused by battery failures can be prevented by systematic battery service. In general, the care and maintenance recommendations for storage batteries are the same today as they have always been.

Battery Safety Precautions

When batteries are being charged, an explosive gas mixture forms beneath the cover of each cell. Part of this gas escapes through the holes in the vent plugs and may form an explosive atmosphere around the battery itself if ventilation is poor.

WARNING

Explosive gas may remain in and around the battery for several hours after it has been charged. Sparks or flames can ignite this gas causing an explosion which could shatter the battery. Flying pieces of the battery structure and splash of electrolyte can cause personal injury.

BATTERY CHARGING

CAUTION

Observe the following procedure before charging the battery to prevent personal injury and prevent damage to the battery or electrical system. The two six volt batteries (Fig. 4) are connected in series to produce 12 volts for the electrical system and the charging equipment must be set for 12 volt operation.

1. Check the level of the electrolyte, add water if necessary but do not overfill.

2. Clean battery terminals if necessary and tighten terminal connections.

3. Set charging equipment for 12 volt operation, be sure charger is OFF.

4. Be sure all vehicle electrical equipment is turned OFF.

5. Connect positive cable of charger to POSITIVE TERMINAL of REAR BATTERY.

6. Connect negative cable of charger to starter ground terminal or convenient point on vehicle frame.

7. Turn charger ON.

When battery is fully charged, turn charger OFF and remove negative cable of charger first, then positive cable.

STARTING MOTOR

The starting motor is mounted on the flywheel housing as illustrated in Fig. 1. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the starting motor. To accomplish this, the starting motor is equipped with a heavy-duty sprag overrunning clutch.

Sprag Overrunning Clutch Type Starting Motor

A solenoid switch, mounted on the starting motor housing, operates the current sprag type overrunning clutch drive by linkage and a shift lever (Fig. 2). When the starting switch is engaged, the solenoid is energized and shifts the starting motor pinion into mesh with the flywheel ring gear and closes the main contacts within the solenoid. Once engaged, the clutch will not disengage during intermittent engine firing. To protect the armature from excessive speed when the engine starts, the clutch "overruns", or turns faster than the armature, which permits the pinion to disengage itself from the flywheel ring gear.

The solenoid plunger and shift lever on this type of starting motor is totally enclosed to protect them from dirt, water and other foreign material.

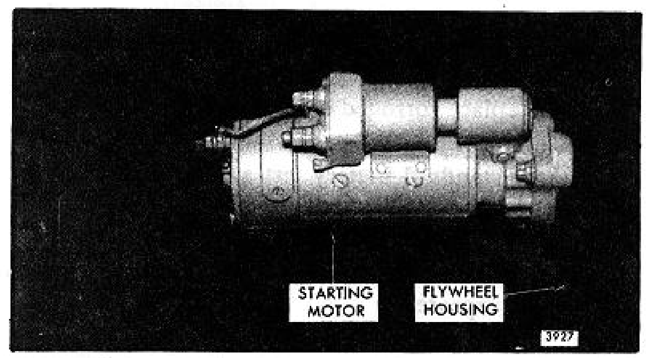


Fig. 1 - Sprag Overrunning Clutch Type Starting Motor Mounting

An oil seal, between the shaft and the lever housing, and a linkage seal (Fig. 2) prevents the entry of transmission oil into the main frame of the starting motor and solenoid case.

Lubrication

Starting motors which are provided with lubrication fittings (hinge cap oilers, oil tubes sealed with pipe plugs, or grease cups) should be lubricated periodically (refer to Page 10-11-5).

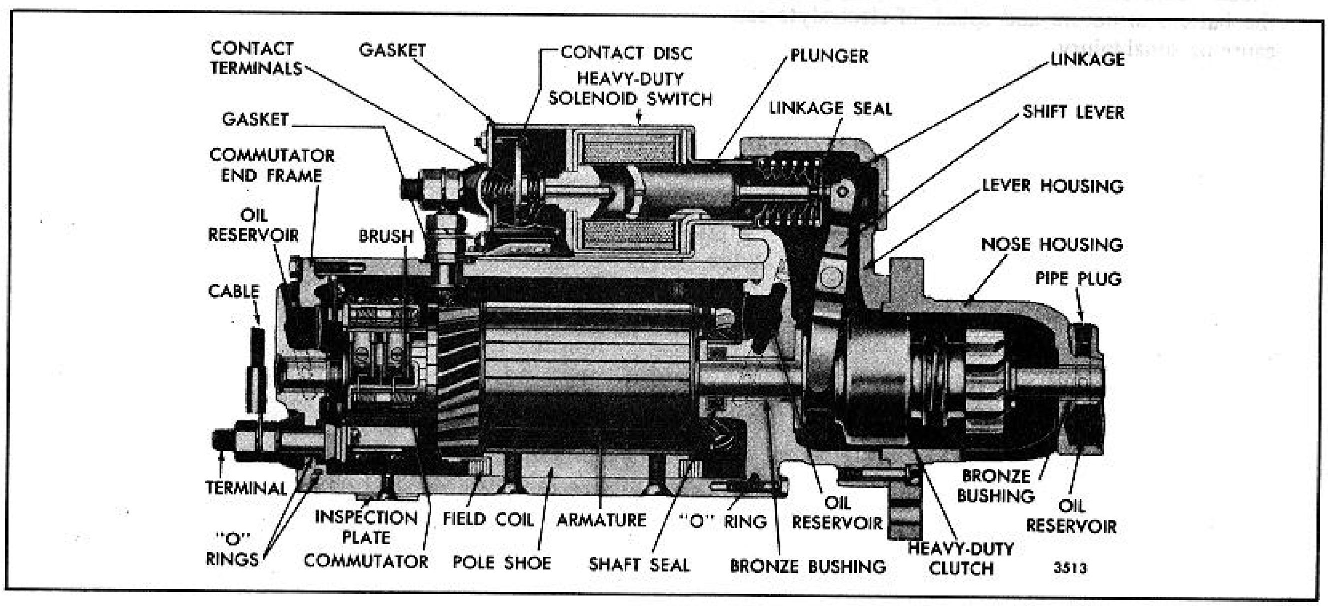


Fig. 2 - Cross-section of Starting Motor with Sprag Heavy-Duty Clutch Drive.

Flywheel Ring Gears

The starting motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth.

Flywheel ring gears with no chamfer are used with starting motors equipped with an overrunning clutch drive.

Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine or a defective starting motor.

If the engine, battery and cranking circuit are in good condition, remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.

2. Disconnect the starting motor cables and solenoid wiring.

NOTE: Tag each lead to ensure correct connections when the starting motor is reinstalled.

3. Support the motor and remove the three bolts and lock washers which secure it to the flywheel housing.

Then pull the motor forward to remove it from the flywheel housing.

TROUBLESHOOTING

With the starting 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.

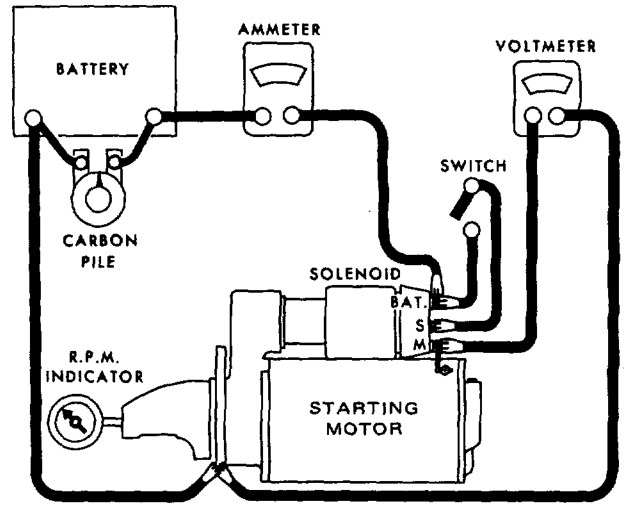


Fig. 3 - No-Load Test Circuit.

No-Load Test (Fig. 3)

Connect a voltmeter from the motor terminal to the motor frame, and use an r.p.m. indicator to measure armature speed. 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 r.p.m., current, and voltage reading with the specifications in the NO LOAD TEST TABLE below.

NO LOAD TEST				
	Min	Max	Min	Max
Volts	Amps.	Amps.	RPM	RPM
10	90	150	3000	7600

It is not necessary to obtain the exact voltage specified in the table as an accurate interpretation can be made by recognizing that if the voltage is slightly higher the r.p.m. will be proportionately higher, with the 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. If more than one 12-volt battery is used, connect the carbon pile to only one of the 12-volt batteries. Make disconnections only with the switch open. Interpret the test results as follows:

Interpreting Results of Tests

1. Rated current draw and no-load speed indicates normal condition of the starting motor.

2. Low free speed and high current draw indicate:

   a. Too much friction-tight, dirty, or worn bearings, bent armature shaft or loose pole shoes allowing 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 indicate:

   a. High internal resistance due to poor connections, defective leads, dirty commutator and causes listed under Number 4.

6. High free speed and high current draw indicate shorted fields. If shorted fields are suspected, replace the field coil assembly and check for improved performance.

DISASSEMBLY

Normally the starting motor should be disassembled only so far as is necessary to make repair or replacement of the defective parts. As a precaution, it is suggested that safety glasses be worn when disassembling or assembling the starting 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 solenoid ground terminal.

3. Remove the brush inspection plugs and then remove the brush lead screws. 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 fields 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 COMMUTATOR.

Brushes and Holders

Inspect the brushes for wear. If they are worn excessively when compared with 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 often 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 the 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 1 10-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 starting 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 field coils can be checked for grounds and opens by using a test lamp.

Grounds-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.

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 shoe 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 (not leading) edge of the pole shoe.

Solenoid Checks

A basic solenoid circuit is shown in Fig. 4. Solenoids can be checked electrically by connecting a 12 volt battery, a switch, and an ammeter to the two solenoid windings. h 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 (Fig. 5).

The hold-in voltage should be 10 volts and the hold-in current 13-15.4 amperes. Use the carbon pile to decrease the battery voltage to 10 volts 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 (Fig. 6).

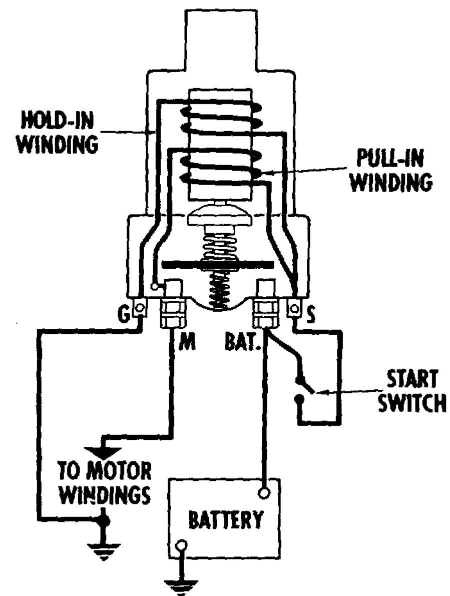


Fig. 4 - Internal Solenoid Circuit. ("G" and "S" Terminals Moved to Clarify Illustration).

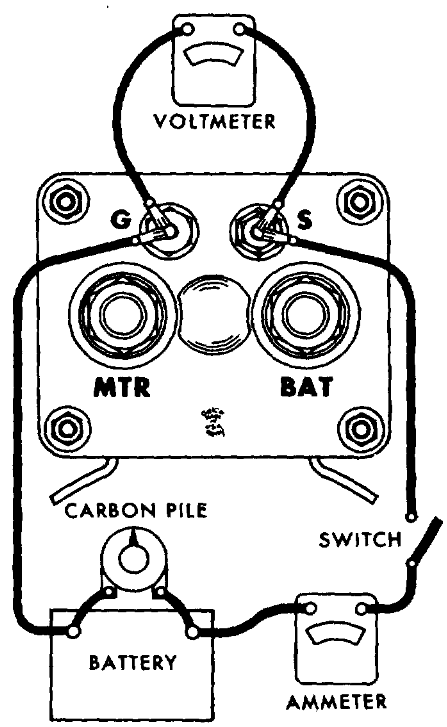


Fig. 5 - Checking Solenoid Hold-In Winding.

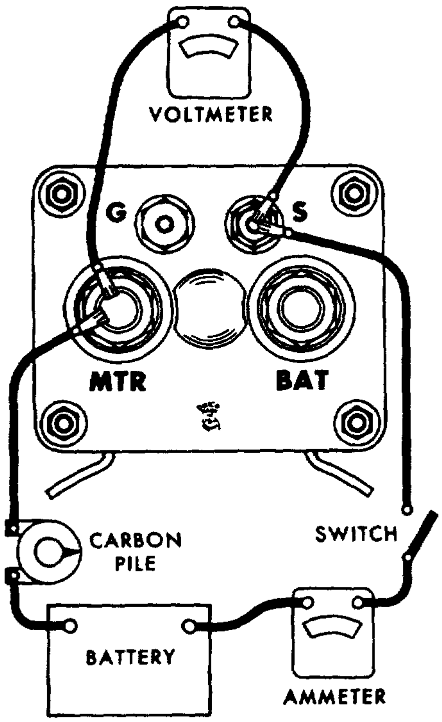


Fig. 6 - Checking Solenoid Pull-In Winding.

The specified pull-in voltage is 5 volts and the pull-in current is 28 to 35.7 amperes.

To check for grounds, move battery lead from "G" (Fig.) and from "MTR" (Fig. 10) to solenoid case, (not shown). meter should read zero. If not, winding is grounded.

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. e current draw will decrease as the winding temperature increases.

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. oil. Also, tangent wicks should be soaked with SAE No. 20 oil. Insert the wick into place first, and then press in the bearing.

DO NOT DRILL, REAM OR MACHINE sintered bearings in any way! These bearings are **supplied to size**. If drilled or reamed, the I.D., (inside diameter) 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 follow the steps listed below.

1. Make connections as shown in Fig. 7.

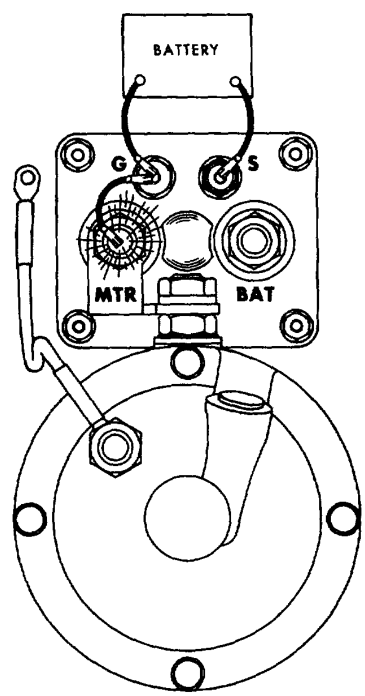


Fig. 7 - Checking Pinion Clearance Circuit.

2. **Momentarily** flash a jumper lead from terminal G to terminal MTR. (Fig. 8). The drive will now shift into cranking position and remain so until the battery is disconnected.

3. Push the pinion or drive back towards the commutator end to eliminate slack movement.

4. Measure the distance between drive and housing (Fig. 8).

5. Adjust clearance by removing plug and turning shaft nut (Fig. 8).

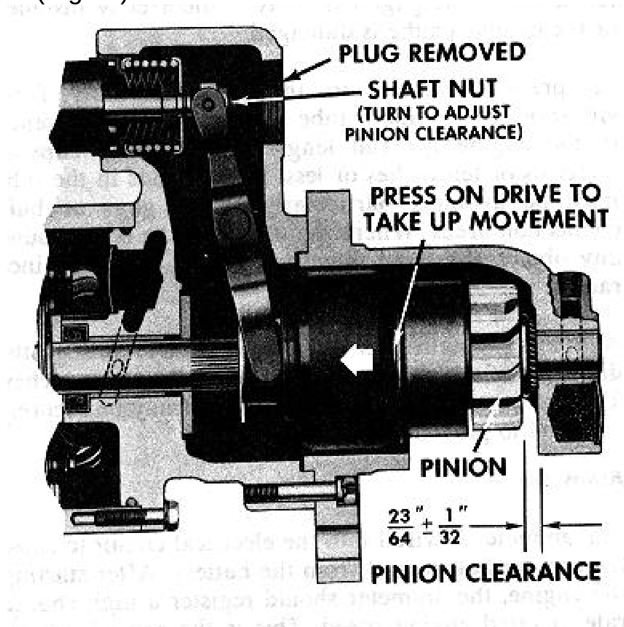


Fig. 8 - Measuring Pinion Clearance.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the 5/8"-11 starter attaching bolts to 137-147 lb-ft (186-200 Nm) torque.

Keep all of the electrical connections clean and tight. en installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connections to 16-30 **lb-in** (2-3 Nm) torque and the 1/2"-13 connections to 20-25 Ib-ft (27-34 Nm) torque.

INSTRUMENTS AND TACHOMETER DRIVE

The instruments generally required in the operation of a diesel engine consist of an oil pressure gage, water temperature gage, an ammeter and a mechanical tachometer. Also, closely related and installed in the general vicinity of these instruments are controls consisting of an engine starting switch, an engine stop knob and an emergency stop knob (Fig. 1).

Anti-Vibration Instrument Mountings

Anti-vibration mountings are used in many places to absorb engine vibration in the mounting of instruments, drop relays, tachometers, etc. When it may become necessary to service a part secured by rubber mounts, care should be exercised, during removal and installation of the part, so twist is not imposed into the rubber diaphragm. At the time the part is removed from the engine for service, the mounts should be inspected for damage and replaced, if necessary.

The attaching screw, through the center of the mount, must be held from turning during final tightening of the nut. Support the screw and tighten the nut only. If this screw turns, it will pre-load the rubber diaphragm in torsion and considerably shorten the life of the mount.

Oil Pressure Gage

The oil pressure gage registers the pressure of the lubricating oil in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure listed in the Operating Conditions on Page 10-9-1, the engine should be stopped and the cause of the low oil pressure determined and corrected before the engine is started again.

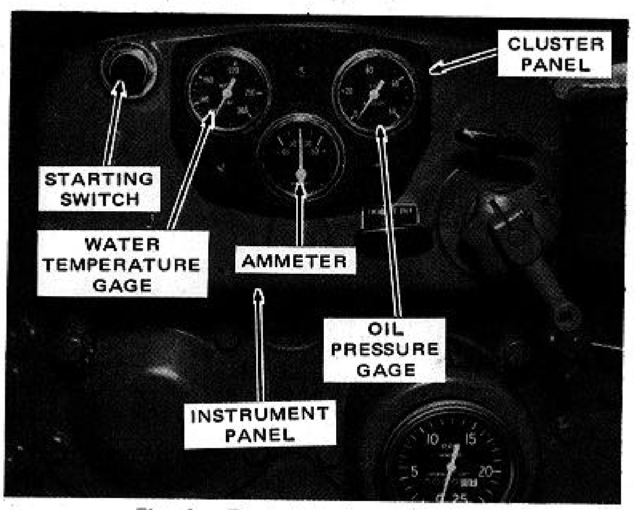


Fig. 1 - Typical Instrument Panel.

Oil pressure gages have male threads and require female fittings.

Water Temperature Gage

The engine coolant temperature is registered on the water temperature gage.

Incorrect coolant temperature readings will be registered if the gage assembly is incorrectly installed or the capillary tube is damaged.

To prevent damage to the gage assembly from vibration, the capillary tube must be securely fastened to the engine the full length with suitable clips at intervals of ten inches or less. Sharp bends in the tube must be avoided, particularly at the gage or bulb connection areas. Where the tube must be bent around any object, the bend must not be less than one inch radius.

Any extra length can be taken up by coiling, the diameter of which should not be less than two inches. e coils must be located so that they may be securely fastened to prevent vibration.

Ammeter

The ammeter is wired into the electrical circuit to show the current flow to and from the battery. After starting the engine, the ammeter should register a high charge rate at rated engine speed. This is the rate of charge received by the battery to replenish the current used to start the engine. As the engine continues to operate, the ammeter should show a decline in the charge rate to the battery. The ammeter will not show zero charge rate since the regulator voltage is set higher than the battery voltage. When lights or other electrical equipment are connected into the circuit, then the ammeter will show discharge when these items are operating and the engine speed is reduced.

Tachometer

The tachometer, driven by the engine, registers the speed of the engine in revolutions per minute (rpm).

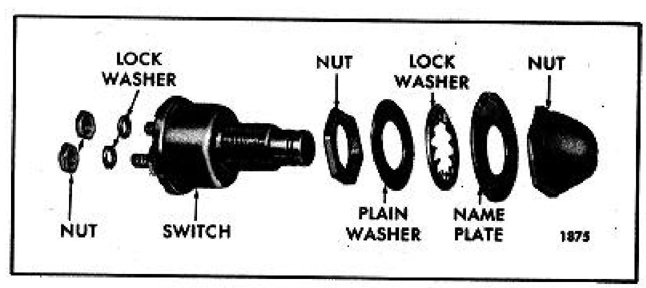


Fig. 2 - Typical Engine Starting Motor Switch.

Throttle Control

The engine throttle is connected to the governor speed control shaft through linkage. Movement of the speed control shaft changes the speed setting of the governor and thus the engine speed.

Engine Starting Switch

To start the engine, a switch (Fig. 2) is used to energize the starting motor. Starting switches may vary in design and their contacts must be rated sufficiently to carry the starter solenoid current.

NOTE: Tighten the starting switch mounting nut to 36-48 **lb-in** (4-5.5 Nm) torque.

Engine Stop Knob

A stop knob is used to stop the engine. When stopping an engine, the engine speed should be reduced to idle and the engine allowed to operate at idle for a few minutes to permit the coolant to reduce the temperature of the engine's moving parts. Then pull the stop knob and hold it until the engine stops. Pulling on the stop knob manually places the injector racks in the no-fuel position. Return the stop knob to its original position after the engine stops.

Emergency Stop Knob

In an emergency, or if the engine continues to operate after pulling the stop knob, the emergency stop knob may be used to stop the engine. When the emergency stop knob is pulled, the air shut-off valve, located between the air intake and the blower, will trip and shut off the air supply to the engine. Lack of air to the engine will prevent further combustion of the fuel and stop the engine.

The emergency stop knob must be pushed back in after the engine is stopped and the air shut-off valve must be re-set manually. The cause of the malfunction should be determined before the engine is started again.

TACHOMETER DRIVE

The tachometer is installed at the rear of the engine and the tachometer drive shaft adaptor is pressed into the end of the camshaft. The shaft assembly consists of a flexible cable with a tang on one end, a drive square on the opposite end and connecting ferrule and ring. Since the shaft assembly is free running no lubrication is necessary.

Remove Tachometer Drive

If replacement is necessary remove the tachometer drive shaft as follows:

1. Remove the two capscrews holding instrument panel to flywheel housing (Fig. 3) and tilt panel enough to allow clearance for tachometer removal.

2. Remove the capscrews holding the tachometer assembly to the flywheel housing.

3. Pull back tachometer assembly to the rear removing it from flywheel housing. Remove drive cover and gasket.

4. To remove adaptor from end of camshaft; thread removing tool J 5901-3 into adaptor; then attach slide hammer J-2619-5 to the remover. A few sharp blows of the weight against the slide hammer rod will remove the tachometer drive shaft.

CAUTION: Use adequate protective measures to prevent metal particles from falling into the gear train and oil pan.

Inspection

Examine the oil seal for wear or damage, replace if necessary.

Examine the shaft assembly for fraying or twisted cable, replace if necessary.

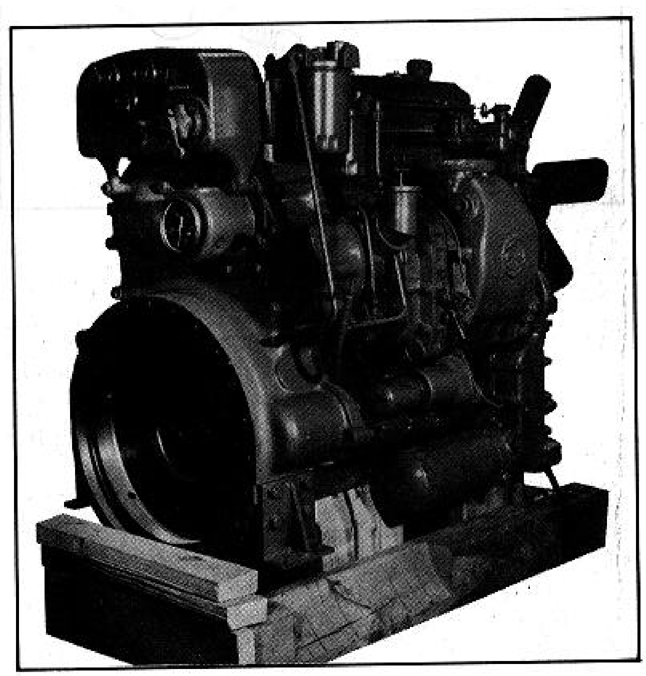


Fig. 3 - Tachometer Mounting.

Install Tachometer Drive

1. Start the tachometer drive shaft adaptor in the end of the camshaft. Then using a suitable sleeve, tap or press against the shoulder on the adaptor until the shoulder contacts the camshaft.

2. Install the drive cover and gasket on the flywheel housing. Use a new gasket.

3. Align the tachometer drive cover and adaptor with the tachometer drive shaft as outlined on Page 10-8-14.

4. Install the tachometer and shaft assembly by connecting tang of flexible shaft to adaptor. Position tachometer assembly to flywheel housing and install and tighten capscrews.

5. Position instrument panel and install and tighten remaining capscrews holding instrument panel to flywheel housing.

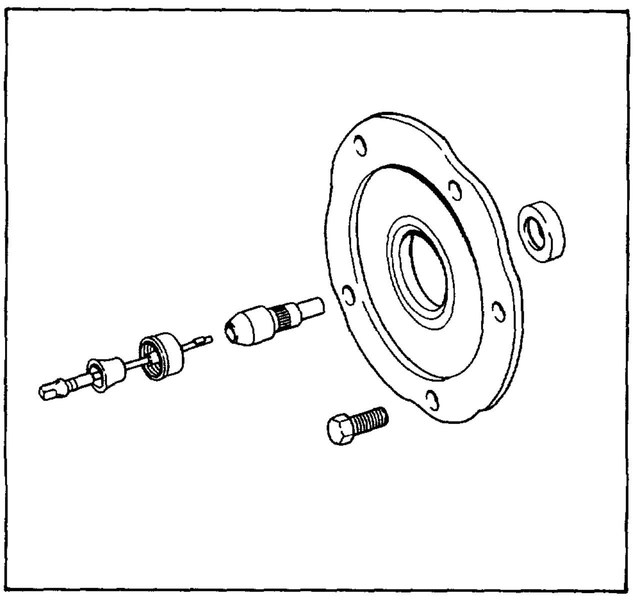


Fig. 4 - Tachometer Drive.

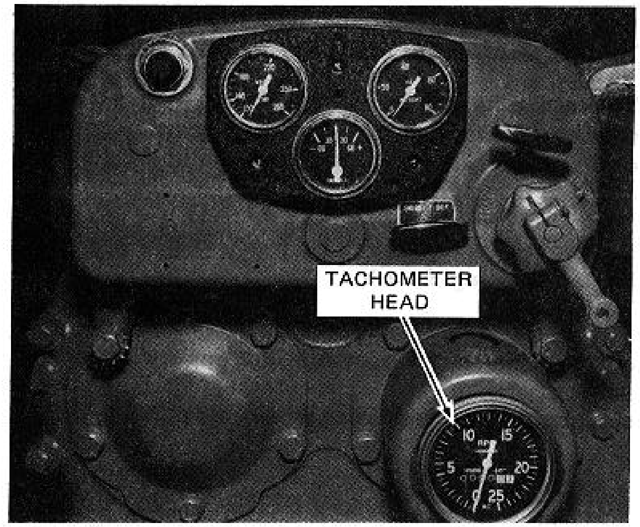


Fig. 5 - Tachometer Head.

ENGINE PROTECTIVE SYSTEM

MANUAL SHUTDOWN SYSTEM

A manually operated emergency engine shutdown device enables the engine operator to stop the engine in the event an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the NO FUEL position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing overspeeding of the engine, the shutdown device will prevent damage to the engine by cutting off the air supply and thus stopping the engine. The shutdown device consists of a flap valve mounted in the air inlet housing and a suitable operating mechanism.

Operation

The manually operated shutdown device is operated by a knob located on the instrument panel and connect to a latch on the valve shaft by a Bowden wire or cable assembly. Pulling the shutdown knob all the way out will stop the engine. Push the knob all the way in and manually reset the air shutdown device in the shutdown housing before the engine is started again.

Service

For disassembly and assembly of the emergency shutdown valve, refer to Page 10-4-5.

COLD WEATHER STARTING

When starting an internal combustion engine in cold weather, a large part of the energy of combustion is absorbed by the pistons, cylinder walls, coolant and in overcoming friction.

Under extremely low outside temperatures, the cold oil in the bearings and between the pistons and cylinder walls creates very high friction and the effort required to crank the engine is much greater than when the engine is warm.

In a diesel engine, the normal means of igniting the fuel sprayed into the combustion chamber is by the heat of the air compressed in the cylinder. This temperature is high enough under ordinary operating conditions, but at extremely low outside temperatures may not be sufficiently high enough to ignite the fuel injected.

To assist in starting an engine under low temperature conditions, an ether starting aid cup is located at the top of the air inlet housing (Fig. 1).

NOTE: Starting aids are not intended to correct deficiencies such as low battery, heavy oil, etc. They are for use when other conditions are normal but the air temperature is too low for the heat of compression to ignite the fuel-air mixture.

ETHER CUP STARTING AID

The ether starting aid cup is located at the top rear of the air inlet housing. It should only be used as a starting aid if necessary in cold weather.

WARNING

Ether should not be injected longer than 1 second duration. Serious engine damage or explosions may result if excessive ether is injected into the engine.

CAUTION: Do not crank the engine more than 30 seconds at a time when using the starting motor. Always allow one minute intervals between cranking attempts to allow the starting motor to cool.

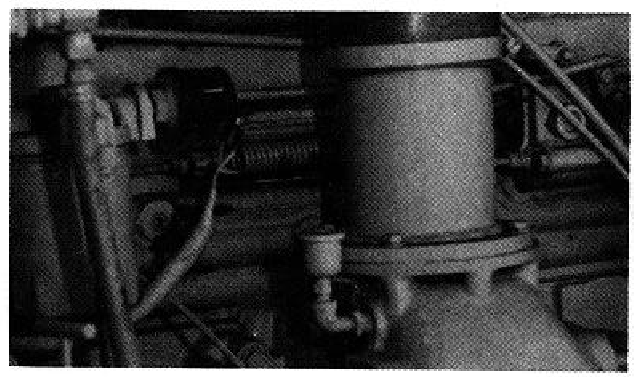


Fig. 1 - Ether Cup Starting Aid.

ALIGNMENT TOOLS FOR TACHOMETER DRIVE COVERS AND ADAPTORS

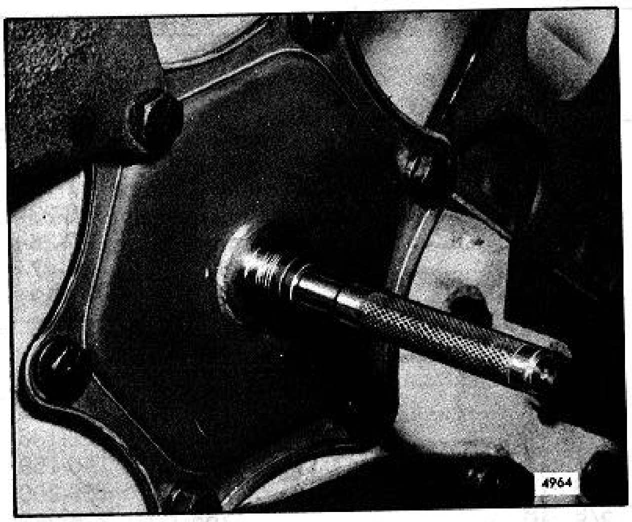


Fig. 1 - Checking Tachometer Drive Shaft Alignment

Whenever a tachometer drive cover assembly or a tachometer drive adaptor is installed on an engine, it is important that the cover assembly or adaptor be aligned properly with the tachometer drive shaft.

Misalignment of a tachometer drive shaft can impose a side load on a tachometer drive cable adaptor resulting in possible gear seizure and damage to other related components.

Use one of the three tools in set J 23068 to establish the proper alignment. Figure 1 illustrates the use of the' tools.

When confronted with an alignment job, test fit each tool to determine which provides the best fit and proceed to make the alignment with that tool.

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand revolution of the engine is made.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft) Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft) Nm
1/4-205-7 ....7-91/4-20 7-910-12			
1/4-286-8 ....8-111/4-28 8-1011-14			
5/16-1810-13 ....14-185/16-1813-17 18-23			
5/16-2411-14 ....15-195/16-2415-19 20-26			
3/8-1623-26 ....31-353/8-1630-3541-47			
3/8-2426-29 ....35-403/8-2435-3947-53			
7/16-1435-38 ....47-517/16-1446-50 62-68			
7/16-2043-46 ....58-627/16-2057-61 77-83			
1/2-1353-56 ....72-761/2-1371-7596-102			
1/2-2062-70 ....84-951/2-2083-93113-126			
9/16-1268-75 ....92-1029/16-1290-100 122-136			
9/16-1880-88 ....109-119 9/16-18107-117 146-159			
5/8-11103-110 ....140-1495/8-11137-147 186-200			
5/8-18126-134 ....171-1815/8-18168-178 228-242			
3/4-10180-188 ....244-2543/4-10240-250 325-339			
3/4-16218-225 ....295-3053/4-16290-300 393-407			
7/8-9308-315 ....417-4277/8-9410-420 556-569			
7/8-14356-364 ....483-4947/8-14475-485 644-657			
1-8435-443............................590-6001-8 580-590 786-800			
1-14514-521...........................697-7051-14685-695 928-942			

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head		GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None		GM 255-M	1	No. 6 thru 1 1/2	60,000
None		GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
	Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
	Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
	Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
	Bolts and Screws	GM 300-M	8	1/4 thru I 1/2	150,000
	Bolts and Screws	GM 455-M	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)
Alternator drive pulley nut		50-60	68-81
Starting motor connector	1/2 -13	20-25	27-34
Starting motor connector	No. 10-32	*	*
Starting motor switch mounting nut		§	§

* 16-30 **lb-in**. (2-3.5 Nm)
§36-48 **lb-in.(**4-5.5 Nm)

SERVICE TOOLS

TOOL NAME	TOOL NO.
Slide hammer	J 23907-1
Tachometer alignment tool set	J 23068
Tachometer drive shaft remover	J 5901-3

OPERATING CONDITIONS

CHAPTER 9
CONTENTS

ENGINE OPERATING CONDITIONS

The engine operating charges are included as an aid for engine operation and trouble shooting. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Make sure that the readings represent true values, and that instruments are accurate, before attempting to make corrections to the engine.

71N ENGINES

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	30-60	43-65	45-65
Minimum for safe operation	18	28	30
*Lubricating oil temperature (degrees F.):			
Normal	200-225	200-225	200-225
Air System			
Air box pressure (inches mercury) - min. at full load:			
At zero exhaust back pressure:			
N injectors	0.1	2.8	4.6
At max. full-load back pressure:			
N injectors	1.2	5.3	7.6
Air inlet restriction (inches water)-max. full-load:			
Dirty air cleaner	12.4	25.0	25.0
Clean air cleaner	5.2	9.1	11.5
Crankcase pressure			
4-71N engine	1.8	2.5	2.8
Exhaust back pressure (inches mercury) - max.			
Full load	1.5	3.3	4.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal (.080" orifice)	30-65	45-70	45-70
Fuel spill (gpm) - min. at no load:			
(.080" orifice)	0.8	0.9	0.9
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 (Veh.)	170-195	170-195	170-195
Compression			
Compression pressure (psi at seal level):			
Average - new engine at 600 rpm	565		
Minimum at 600 rpm	515		

*The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners or bearings, the engine should be "Run-In" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the serviceman to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (160-185°F or 71-85°C) should be maintained throughout the Run-In.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 100 higher than the water inlet temperature. Though a 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 Table 1. The horsepower shown is at SAE conditions: dry air density .0705 lb/cu. ft. (1.129 Kg/m3), air temperature of 85°F(29.4°C), and 500 ft. (152 m) elevation.

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 a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the Basic Engine Run-In Schedule. The following items are included on the basic engine: blower, fuel pump, water pump and governor. The fan and battery-charging generator typify accessories not considered on the basic engine.

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.

TABLE 1

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. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb-ft) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

BHP = (T x RPM)/5250
Where:

BHP = brake horsepower
T = torque in 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 (see sample on Page 10-94).

Instrumentation

Certain instrumentation is necessary so that data required to complete the Engine Test Report may be obtained. The following list contains both the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.

c. Adaptor for connecting a pressure gage or mercury manometer to the engine air box.

d. Water temperature gage installed in the thermostat housing or water outlet manifold.

e. Adaptor for connecting a pressure gage or water manometer to the crankcase.

f. Adaptor for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.

g. Adaptor for connecting a vacuum gage or water manometer to the blower inlet.

h. Adaptor for connecting a fuel pressure gage to the fuel manifold inlet passage.

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 true 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 on Engine Run-in Instructions on Page 10-9-2.

Run-In Procedure

The procedure outlined below will follow the order of the sample Engine Test Report.

A. PRE-STARTING

1. Fill the lubrication system as outlined under Lubrication System on Page 10-5-1.

2. Prime the fuel system as outlined under Fuel System on Page 10-3-1.

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.

3. A preliminary valve clearance adjustment must be made before the engine is started. See *Valve Clearance Adjustment* on Page 10-10-2.

4. A preliminary injector timing check must be made before starting the engine. See *Fuel Injector Timing* on Page 10-10-3.

5. Preliminary governor adjustments must be made as outlined in Chapter 10.

6. Preliminary injector rack adjustment must be made (Chapter 10).

B. BASIC ENGINE RUN-IN

The operator should be observant at all times, so that any malfunction which may develop will be detected.

Since the engine has just been reconditioned, this Run-In will be a test of the workmanship of the serviceman who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also inspect the exhaust system, being sure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 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* on Page 10-9-1 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Any four or six cylinder engine to be run at speeds in excess of 1800 rpm 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.

C. BASIC RUN-IN INSPECTION

While the engine is undergoing the Basic Run-In, check each item indicated in Section "C" of the *Engine Test Report*. Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Basic Run-In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Basic Run-In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN-IN

The primary purpose of this inspection is to provide a fine engine tune-up. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next, complete the applicable tune-up procedure. Refer to Chapter 10.

E. FINAL RUN-IN

After all of the tests have been made and the Engine Test Report is completed through Section "D", the engine is ready for final test. This portion of the test and Run-In procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm-up period of 10 minutes at the same speed and load used for warm-up in the Basic Run-In. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic Run-in, the entire Basic Run-In must be repeated as though the Run-In and test procedure were started anew.

All readings observed during the Final Run-In should fall within the range specified in the *Operating Conditions* on Page 10-9-1 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, Page 10-9-1.

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 gage (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.

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 intake vacuum* at various speeds (at no-load) and compare the results with the *Engine Operating Conditions* on Page 10-9-1. Record these readings on the *Engine Test Report*.

Check the exhaust back pressure at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adaptor installed at the tapped hole. If the exhaust manifold does not provide a 1/8" pipe tapped hole, such a hole can be incorporated by reworking the exhaust manifold. Install a fitting for a pressure gage or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. 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 Page 10-9-1).

Refer to the *Final Engine Run-In Schedule* and determine the maximum rated brake horsepower and the full-load speed to be used during the Final Run-In. Apply the load thus determined to the dynamometer. The engine should be run at this speed and load for 1/2 hour. While making the Final Run-In, the engine should develop, within 5%, the maximum rated brake horsepower indicated for the speed at which it is operating.

If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Basic Run-In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run-In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the Final Run-In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run-In is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the Final Run-In and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system as outlined on Page 10-11-28 and adding a rust inhibitor into the cooling system (refer to Page 10-9-14). The lubricating oil filters should also be changed.

FUEL OILS FOR DETROIT DIESEL ENGINES

DIESEL FUEL OILS

GENERAL CONSIDERATIONS

The quality of fuel oil used for high-speed diesel engine operation is a very Important factor In obtaining satisfactory engine performance, long engine life, and accept
able exhaust emission levels.

COMPLETELY DISTILLED FLUID

Fuel selected should be completely distilled material. That is, the fuel should show at least 98% by volume recovery when subjected to ASTM D-86 distillation. Fuels marketed to meet Federal Specification VV-F-800 (grades DF-1 and DF-2) and ASTM Designation D-975 (grades 1-D and 2-D) meet the completely distilled criteria. The differences In properties of VV-F-800 and ASTM D-975 fuels are shown in the following table.

FEDERAL SPECIFICATION & ASTM
DIESEL FUEL PROPERTIES

Specification or Classification Grade	VV-F-800 DF-1	ASTM D-975 1-D	VV-F-800 DF-2	ASTM D-975 2-D
Flash Point, min.	104°F 40°C	100°F 38°C	122°F 50°C	125°F 52°C
Carbon Residue (10% residuum) % max.	0.15	.015	0.20	0.35
Water & Sediment, % by vol. Max.	0.01	trace	0.01	0.05
Ash, % by wt., max.	0.005	0.01	0.005	0.01
Distillation Temperature				
90% by vol. recovery, min	-	-	-	540°F (282°C)
max.	572°F (300°F)	550°F (288°F)	626°F (330°C)	640°F (338°C)
End Point, max.	626°F (330°F)	-	671°F (355°C)	-
Viscosity 100°F (38°C)				
Kinematic, cSt, min.	1.4	1.4	2.0	2.0
Saybolt, SUS, min.	-	-	-	32.6
Kinematic, cSt, max.	3.0	2.5	4.3	4.3
Saybolt, SUS, max.	-	34.4	-	40.1
Sulfur, % by wt., max.	0.50	0.50	0.50	0.50
Cetane No.	45	40	45	40

FUEL CLEANLINESS

Fuel oil should be clean and free or contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water or water-emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants from storage instability must be resolved with the fuel supplier.

FUEL SULFUR CONTENT

The sulfur content of the fuel should be as low as possible to avoid premature wear, excessive deposit formation, and minimize the sulfur dioxide exhausted into the atmosphere. Limited amounts can be tolerated, but the amount of sulfur in the fuel and engine operating conditions can influence corrosion and deposit formation tendencies.

The deleterious effect of burning high sulfur fuel is reflected in Detroit Diesel lube oil change interval recommendations. Detroit Diesel recommends that the Total Base Number (TBN-ASTM D 664) of the lube oil be monitored frequently and that the oil drain interval be drastically reduced. Consult the FUEL OIL SELECTION CHART.

IGNITION QUALITY - CETANE NUMBER

There is a delay between the time the fuel is injected into the cylinder and the time that ignition occurs. The duration of this delay is expressed In terms of cetane number (rating). Rapidly ignited fuels have high cetane numbers; e.g., 50. Slowly ignited fuels have low cetane numbers; e.g., 40 or less, The lower the ambient temperature, the greater the need for a fuel that will ignite rapidly; i.e., high cetane.

Difficult starting may be experienced it the cetane number of the fuel is too low. Furthermore, engine knock and puffs of white smoke may be experienced during engine warm-up especially In severe cold weather when operating with a low cetane fuel. If this condition is allowed to continue for any prolonged period, harmful fuel derived deposits will accumulate within the combustion chamber. Consult the FUEL OIL SELECTION CHART.

DISTILLATION END POINT

Fuel can be burned In an engine only alter it has been vaporized. The temperature at which fuel is completely vaporized is described as the distillation end point (ASTM D-86). The distillation (boiling) range of diesel) fuels should be low enough to permit complete vaporization at combustion chamber temperatures. The combustion chamber temperature depends on ambient temperature, engine speed, and load. Mediocre to poor vaporization Is more apt to occur during severe cold weather and/or prolonged engine idling and/or light load operation. Therefore, engines will show better performance operating under the conditions described above when lower distillation end point fuels are used. Consult the FUEL OIL SELECTION CHART.

CLOUD POINT

The *cloud point* is that temperature at which wax crystals begin to form in diesel fuel. The selection of a suitable fuel for low temperature operability is the responsibility of the fuel supplier and the engine user. Consult the FUEL OIL SELECTION CHART.

FUEL OIL SELECTION CHART

Application	General Fuel Certification	Final Boilin g Point	Cetane Number	Sulfur Content	Cloud Point
		(Max.)	(Min.)	(Max.)	
City Buses	No. 1-D	550°F 288°C	45	0.30	SEE NOTE 1
	Winter No. 2-D*	675°F 357°C	45	0.50	
	Summer No. 2-D*	357°C	45	0.50	
All Other Applications	Winter No. 2-F	675°C 375°C	45	0.50	SEE NOTE 1
	Summer No. 2-D	675°F 357°C	40	0.50	

*No. 2-D diesel fuse may be used in City coach engine models that have been certified to pass Federal and California emission standards.

Note 1: The cloud point should be 10°F (0°C) below the lowest expected fuel temperatures to prevent clogging of the fuel filters by wax crystals.

Note 2: When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered the use of lighter distillate fuels may be more practical. The same consideration must be made when operating at altitudes above 5,000 ft.

DETROIT DIESEL FUEL OIL SPECIFICATIONS

Detroit Diesel Allison designs, develops and manufactures commercial diesel engines to operate on diesel fuels class)fled by the ASTM as Designation D-975 (grades 1 -D and 2-D). These grades are very similar to grades DF-1 aru3 DF-2 of Federal Specification VV-F.800.

Burner fuels (furnace oils or domestic heating fuels) generally require an open flame for satisfactory combustion. The ignition quality (cetane rating) of burner fuels (ASTM D-396) is poor when compared to diesel) fuels (ASTM D-975).

In some regions, however, fuel suppliers may distribute one curd that is marketed as either diesel fuel (ASTM D-975) or domestic heating fuel (ASTM D-396) some times identified as burner, furnace, or residual fuel, Under these circumstances, the fuel should be investigated to determine whether the properties conform with those indicated in the FUEL OIL SELECTION CHART.

The FUEL OIL SELECTION CHART also will serve as a guide In the selection of the proper fuel for various applications. The fuels used must be clean, completely distilled, stable, and non-corrosive. *Distillation Flange, Cetane Number, Sulfur Content, and Cloud Point* are tour of this most Important properties at diesel fuels that must be controlled to insure satisfactory engine operation. Engine speed, load, and ambient temperature all influence the selection of diesel fuels with respect to distillation range and cetane number.

All diesel fuels contain a certain amount of sulfur. Too high a sulfur content results in excessive cylinder wear. For most satisfactory engine life, fuels containing less than 0.5% sulfur should be used,

During cold weather engine operation the cloud point (the temperature at which wax crystals begin to form in diesel suet) should be 10°F (6°C) below the lowest expected fuel temperature in order to prevent clogging of the fuel inters by wax crystals.

A reputable fuel oil supplier is the only one who can assure you that the fuel you receive meets the *Distillation End Point, Cetane Number, Sulfur Content and -Cloud Point* property limits shown in the FUEL OIL SELECTION CHART. The responsibility for clean fuel and fuel that meets Detroit Diesel Allison specifications lies with the rust supplier as wall as the operator.

At temperatures below + 32. F (0°C) particular attention must be given to cold weather starting aids for efficient engine starting and operation.

NUMEROUS FUELS BURNED IN DDA ENGINES

Numerous fuels meeting the properties shown in the FUEL OIL SELECTION CHART may be used in Detroit Diesel engines. The table (top, right) shows some of the alternate fuels (some with sulfur and/or cetane limits) that have been burned in Detroit Diesel) engines. Among these are No. 1 and No. 2 diesel fuels, kerosene, aviation turbine Led fuels, and burner fuels.

FUELS BURNED IN DETROIT DIESEL ENGINES

ASTM Designation	Federal Standard	Military Spec.	NATO Code	Grade	Description/Comments
D-975				1-D 2-D	Diesel Fuel
D-396				1, 2	Burner Fuel (Furnace Oil) ***Caution: If Used, The Max. Sulfur Content Allowed Is 0.50 WT. % and the Minimum Cetane No. Is 45. (See Fuel Oil Selection Chart).***
	VV-F-800		F-54	1, 2	DF-1 Winter Grade, DF-2 Regular Grade
	VV-F-800		F-56		DF-A (Arctic Grade). *Limited Supply For Military.*
		MIL-T-5624		JP-5	Kerosene
D-1655		MIL-T-83133	F-34	JP-8	Jet A-1, Kerosene Type Plus Special Anti-Icer
D-1655			F-35		Jet A, Kerosene
		MIL-F-16884	F-76	DFM	Diesel Fuel - Marine (DFM). ***Caution: If Used, The Max. Sulfur Content Allowed Is 0.50 WT. %.***
		MIL-F-5161		JP-8	Referee Grade JP-5 Type Jet Fuel. Limited Quantities Supplied To Military Only.

PROPOSED A8TM D.975, GRADE 3.D

Detroit Diesel Allison does NOT recommend the use of proposed grade 3-D diesel fuel in any of its engines. This - trade of fuel has been proposed to, but not accepted by, the American Society for Testing and Materials (ASTM).

The proposed grade 3-D is undesirable in that it possesses poor ignition quality (i.e., lower cetane), allows greater sulfur content (up to 0.70% by weight), allows the formation of more carbon deposits (Conradson car. bon residue), and allows the blending of heavier, more viscous boiling point tractions that are difficult to burn. The latter tend to increase combustion chamber deposits. This type of fuel usually manifests poor cold weather properties (wax formation tendencies). In addition, the poor ignition quality adversely affects noise and emission levels.

A comparison of ASTM D-975 grade 2-D and the proposed grade 3-D fuel properties is shown in the following table.

COMPARISON OF ASTM D.975
GRADE 2-D AND PROPOSED GRADE 3-D PROPERTIES

Property	Grade	
	Recommended 2-D	Not Recommended 3-D
Cetane No., Min.	40.0	37.0
Sulfur, WT. %, Max.	0.50	0.70
Carbon Residue On 10% Residuum, %, Max.	0.35	0.40
Viscosity @ 40° Celsius, Centistokes	*1.9 - 4.1*	*2.0 - 7.0*
Distillation		
deg. Celsius (Fahrenheit)		
90% Recovery, Max.	*338 (640)*	*360 (680)*

USING DRAINED LUBE OIL IN DIESEL FUEL

Detroit Diesel Allison *does not recommend* the use of drained lubricating oil in diesel fuel. Furthermore, Detroit Diesel Allison will not be responsible for any detrimental effects which it determines resulted from this practice.

BURNING MIXTURES OF ALCOHOL, GASOLINE, GASOHOL OR DIESEL WITH DIESEL FUEL

Alcohol, gasoline, gasohol, or diesohol should never be added to diesel sue). An explosive and tire hazard exists it these blends are mixed and/or burned. See DIESEL FUEL LINE DE-ICER below.

DIESEL FUEL LINE DE-ICER

Very small amounts of isopropyl alcohol (isopropanol) may be used to preclude fuel line freeze-up in winter months. No more than ONE PINT of isopropyl alcohol should be added to 125 GALLONS of diesel fuel for ace. quote protection.

LUBRICATING OILS FOR DETROIT DIESEL ENGINES

DIESEL LUBRICATING OILS GENERAL CONSIDERATIONS

All diesel engines require heavy-duty lubricating oils. Basic requirements of such oils are lubricating quality, high heat resistance, and control of contaminants.

LUBRICATING QUALITY. The reduction of friction and wear by maintaining an oil film between moving parts is the primary requisite of a lubricant. Film thickness and its ability to prevent metal-to-metal contact of moving parts is related to oil viscosity. The optimums for Detroit Diesel engines are SAE 40 or 30 weight.

HIGH HEAT RESISTANCE. Temperature is the most important factor in determining the rate at which deterioration or oxidation of the lubricating oil will occur. The oil should have adequate thermal stability at elevated temperatures, thereby precluding formation of harmful carbonaceous and/or ash deposits.

CONTROL OF CONTAMINANTS. The piston and compression rings must ride on a film of oil to minimize wear and prevent cylinder seizure. At normal rates of consumption, oil reaches a temperature zone at the upper part of the piston where rapid oxidation and carbonization can occur. In addition, as oil circulates through the engine, it is continuously contaminated by soot, acids, and water originating from combustion. Until they are exhausted, detergent and dispersant additives aid in keeping sludge and varnish from depositing on engine parts. But such additives in excessive quantities can result in detrimental ash deposits. If abnormal amounts of insoluble deposits form, particularly on the piston in the compression ring area, early engine failure may result.

Oil that is carried up the cylinder liner wall is normally consumed during engine operation. The oil and additives leave carbonaceous and/or ash deposits when subjected to the elevated temperatures of the combustion chamber. The amount of deposits is influenced by the oil composition, additive content, engine temperature, and oil consumption rate.

OIL QUALITY is the responsibility of the oil supplier. (The term "oil supplier" is applicable to refiners, blenders, and rebranders of petroleum products, and does not include distributors of such products).

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The selection of a suitable lubricant in consultation with a reliable oil supplier, observance of his oil drain recommendations (based on used oil sample analysis and experience), and proper filter maintenance will provide the best assurance of satisfactory oil performance.

It should be noted that lube oil manufacturers may reformulate an oil while maintaining the same API classification, or may reformulate to a new API classification and continue the brand name designation. For example, SE oils being reformulated to SF letter code classification may perform differently after this reformulation. A close working relationship with the lube oil manufacturer should be maintained so that any reformulation can be reviewed and decision made as to its affect on continued satisfactory performance.

COLD WEATHER OPERATION

Two important considerations relate to satisfactory operation under cold ambient temperature conditions. These are: (1) the ability to crank the engine fast enough to secure starting, and (2) providing adequate lubrication to internal wearing surfaces during starting and warm-up. Once started and warmed up, external ambient temperatures have little effect on internal engine temperatures. Both cold weather considerations can be adequately met through proper lube oil selection and the use of auxiliary heat prior to starting. Auxiliary heat can be used in the form of jacket water and oil pan heaters, hot air space heaters applied to engine compartments, or some combination of these.

Proper oil selection and oil heat can assure lubricant flow immediately upon starting. Improper oil selection and oil heat may result in starting with cold oil congealed in the oil pan, and little or no oil flow for lubricating internal parts once the engine has started.

Proper oil selection and jacket water heating can assure cranking capability by maintaining an oil film on cylinder walls and bearing surfaces in a condition which provides low friction, and hence, less cranking effort to achieve cranking speeds necessary for reliable starting. Improper oil selection and jacket water heating may result in congealed oil films on cylinder walls and bearing surfaces, which result in high friction loads and more cranking effort than is available, thus preventing sufficient cranking speeds to assure reliable starting.

LUBE OIL SPECIFICATIONS

Detroit Diesel Allison lubricant recommendations are based on general experience with current lubricants of various types and give consideration to the commercial lubricants presently available.

RECOMMENDATION

Detroit Diesel 2-cycle engines have provided optimum performance and experienced the longest service life operating with lubricating oils meeting the following ash limits, zinc requirements, oil performance levels, viscosity grades, and evidence of satisfactory performance.

Sulfated Ash Limit (ASTM D-874)

The sulfated ash content of the lubricant shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.5% by weight is allowed. Lubricants having a sulfated ash content between 0.55% and 0.85% by weight, have a history of excellent performance in Detroit Diesel engines. Lubricants having a sulfated ash content exceeding 0.85% by weight, are prone to produce greater deposit levels in the piston ring grooves, exhaust valve faces and seats.

Zinc Content

The zinc content (zinc diorganodithiophosphate)of all the lubricants recommended for use in Detroit Diesel 2-cycle engines shall be a minimum of 0.07% by weight. This requirement is waived where single grade SAE 40, intermediate viscosity index lubricants qualified for use in Electro-Motive Division (EMD) diesel engines are used.

VISCOSITY GRADE AND OIL PERFORMANCE LEVEL

Single Grade SAE 40 & SAE 30 Lubrlcants

Single grade SAE 40 and SAE 30 grade lubricants are preferred and recommended for use in all Detroit Diesel 2-cycle engines provided they meet the sulfated ash and zinc content requirements indicated above and any of the oil performance levels shown in Table L-1 EVIDENCE OF SATISFACTORY PERFORMANCE (see section under this title) is desired where new formulation SAE 40 or SAE 30 oils will be used. Selection of the appropriate viscosity grade is shown in Table L-2.

Multigrade Lubricants

Multigrade oils have not provided performance comparable to SAE-40 or SAE-30 lubricants in some engine service applications. Because of this experience, the use of 1 5W-40 and all other multigrade oils is not recommended for Series 149 engines, and restrained usage in Series 53, 71 and 92 engines is advised.

If the use of a 1 5W-40 multigrade oil in Series 53, 71 or 92 engines is being considered, it must meet the CD/SE oil performance level shown in Table L-1. Table L-2 indicates that 1 5W-40 multigrades may be selected when ambient temperatures are at, or less than, freezing However, because our experience has disclosed that the performance of straight grade oils has been superior to multigrade oils in some service applications, Detroit Diesel recommends that the user obtain proven service experience and evidence of satisfactory performance supplied by the lube oil manufacturer or follow the guidelines in the section entitled, "EVIDENCE OF SATISFACTORY PERFORMANCE." Upon request, the Detroit Diesel Allison Regional Office will counsel with customers in selecting a lubricating oil that will be suitable for their specific needs

Other Multigrade Oils

Detroit Diesel Allison does not recommend the use of 1 OW-30, 1 OW-40, 20W-40 or any other multigrade oils in 2-cycle engines. As previously indicated, 15W-40 oils are the only lubricants that should be considered if prolonged severe cold, ambient temperatures, are expected.

EVIDENCE OF SATISFACTORY PERFORMANCE

It is recommended that evidence of satisfactory lubricant performance in Detroit Diesel 2-cycle engines be obtained from the oil supplier prior to procurement. Controlled oil performance evaluations in field test engines are recommended. The type of field test used by the oil supplier depends on the Series engine in which the candidate oil will be used and the service application. This information is summarized in Table L-3. The candidate test oil-operated engines should all operate for the mileage/hours indicated. Fuel and lube oil consumption should be monitored during the test period. Any serious mechanical problems experienced should be recorded. All of the oil test engines should be disassembled at the conclusion of the oil test period and inspected. The following oil performance parameters should be compared:

- Ring sticking tendencies and/or ring conditions
- Piston skirt scuffing and cylinder liner wear and scuffing
- Exhaust valve face and seat deposits
- Piston pin and connecting rod bushings
- Overall valve train and bearing wear levels.

USED LUBE OIL ANALYSIS PROGRAM

A used lube oil analysis program should be conducted in conjunction with the oil performance field test. In order to determine the condition of the lube oil that will prevail when subjected to various engine operational modes in specific service applications, it is recommended that frequent oil samples be investigated. This subject is more comprehensively addressed in the OIL CHANGES section below.

OIL CHANGES

Table L-4 shows the initial oil drain intervals for all Series 2-cycle engines used in the various service applications.

Oil drain intervals in all service applications may be increased or decreased with experience using a specific lubricant Detroit Diesel Allison recommends the use of a controlled, used lube oil analysis monitoring program.

This is especially prudent when extended oil drain intervals (e.g , 100,000 miles) are being considered. The frequency at which used lube oil samples are obtained may be scheduled for the same period as when other preventive maintenance is conducted. For example, a used lube oil sample for analysis may be obtained every 10,000 miles when engines are brought in for fuel and coolant filter replacement Table L-5 shows the routine specific laboratory tests that are recommended. Sometimes further confirmatory tests are required, especially when fuel and/or coolant dilution is suspected. Table L-5 indicates the routine and confirmatory tests recommended. The lube oil should be drained if any of the maximum tolerable warning limits are exceeded.

THE INFLUENCE OF DIESEL FUEL SULFUR CONTENT ON LUBE OIL CHANGE INTERVALS

Table L-4 shows the reduced oil drain intervals that are recommended if the use of high sulfur fuel is unavoidable. The use of diesel fuels having a sulfur content exceeding 0.50% by weight can have a negative effect on piston ring life and lube oil deposit levels. For this reason, it is recommended that oil drain intervals be drastically shortened to minimize the adverse effect of acid build-up in the lubricant. These relatively short oil drain intervals may be altered if a lubricant with high alkaline reserve (i.e., high TBN ASTM D-664) and low sulfated ash (i.e., less than 1.000% by weight ASTM D-874) can be obtained. Table L-5 indicates that the TBN of the used oil should never be less than 1.0 (ASTM D-664). If laboratory analysis reveals that the TBN is less than 1 0, this is an indication that the acceptable drain interval has been exceeded.

MIL-L.46167 ARCTIC LUBE OILS FOR NORTH SLOPE AND OTHER EXTREME SUB-ZERO OPERATIONS

Lubricants-meeting this specification are used in Alaska and other extreme sub-zero locations. Generally, they may be described as 5W-20 multigrade lubricants made up of synthetic base stock and manifesting low volatility characteristics. Although they have been used successfully in some severe cold regions, Detroit Diesel Allison does not consider their use as desirable as the use of SAE-40 or SAE-30 oils with auxiliary heating aids.

For this reason, they should be considered only where engine cranking is a severe problem and auxiliary heating aids are not available on the engine.

EMD (RR) OILS

Lubricants qualified for use in Electro-Motive Division (EMD) diesel engines may be used in Detroit Diesel 2-cycle engines provided the sulfated ash (ASTM D-874) content does not exceed 1.000% by weight. These lubricants are frequently desired for use in applications where both Detroit Diesel and Electro-Motive powered units are operated. These fluids may be described as SAE-40 lubricants that possess medium Viscosity Index properties and do not contain any zinc additives.

SYNTHETIC OILS

Synthetic lubricants may be used in Detroit Diesel 2-cycle engines provided the ash limit, zinc requirements, and specified oil performance levels (for example, CDISE or MIL-L-2104B, etc.) shown elsewhere in this specification are met. Viscosity grades SAE-40 or SAE-30 are recommended.

LUBE OIL FILTER CHANGE INTERVAL

Full-Flow Filters

A full-flow filtration system is used in all Detroit Diesel 2-cycle engines. To ensure against physical deterioration of the filter element, it should be replaced at a maximum of 25,000 miles for on-highway vehicles. For all other applications, the filter should be replaced at a maximum of 500 hours.

By-Pass Filters

Auxiliary bypass lube oil filters are not required on Detroit Diesel 2-cycle engines

OIL CHANGE INTERVAL BASED ON SURVEY OF SATISFIED END USERS

A number of successful Detroit Diesel (2-cycle engine) customers in numerous service applications do not utilize oil analysis procedures. They prefer conservative lube oil drain and filter change intervals.

Lubricant and filters were changed based on experience, and the customer felt he saved money in eliminating costly lube oil analysis programs. Naturally, Detroit Diesel supports the lube oil and filter change practices used in these successful service operations.

Highway Truck Service Application

Oil Change Interval	20,000 Miles
Filter Change Interval	20,000 Miles

Large 149 Series Engines Powering Off-Road Equipment (Construction & Mine Site Service Applications)

Oil Change Interval	150 Hours
Filter Change Interval	300 Hours

City Transit Coaches

Oil Change Interval	12,500 Miles
Filter Change Interval	25,000 Miles

Pickup & Delivery Metro Area Truck Service

Oil Change Interval	12,000 Miles
Filter Change Interval	24,000 Miles

Stationary (Usually Stand-By) Engines

Oil Change Interval	150 Hours or One Year
Filter Change Interval	300 Hours or One Year

LUBE OIL PERFORMANCE LEVELS

API Letter Code Service Classification	Military Specification	SAE Grade
CB	MIL-L-2104A (Supplement 1)	40 or 30
CC	MIL-L-2104B	40 or 30
CD	MIL-L-45199B (Series 3)	40 or 30
CC/SE	MIL-L-46152	40 or 30
CD/SC	MIL-L-2104C	40 or 30
Numerous Combinations of Above	Single Grade Universal No MIL- Spec.	40 or 30
CD/SE	Multigrade Universal No MIL- Spec.	15W-40

Table L-1

VISCOSITY GRADE SELECTION

AMBIENT TEMPERATURE degrees Celsius	AMBIENT TEMPERATURE degrees Fahrenheit	RECOMMENDATIONS PRIMARY	RECOMMENDATIONS SECONDARY	RECOMMENDATIONS THIRD
10	50	SAE 40	SAE 30	None
10 – 0	50 – 32	SAE 40 Plus Starting Aids	SAE 30 Usually Unaided	None
0 – 18	32 – 0	SAE 40 Plus Starting Aids	SAE 30 Plus Starting Aids	15W-40 Usually Unaided
18	0	SAE 40 Plus Starting Aids	SAE 30 Plus Starting Aids	15W-40 Plus Starting Aids

Table L-2

INDIVIDUAL USER SERVICE APPLICATION LUBE FIELD TESTING

Engine Series	Service Application	Test Duration	No. Engines on Candidate Test Oil	No. Sister Engines on Reference Baseline SAE 40 or SAE 30
53	Pickup & Delivery Metro Area	50,000 Miles	5	5
71 & 92	Hwy. Truck 72,000 Lbs. GCW	200,000 Miles	5	5
149	Off Road Rear Dump 120 Ton	10,000 Hours	3*	3

*Single Grade Only - No Multigrades Recommended For Series 149 Engines

Table L-3

LUBE OIL DRAIN INTERVAL				
		Max. Luke Oil Drain Interval		
Service Application	Engine Series	Diesel Fuel Sulfur Content Wt. %		
		0 to 0.50	0.51 to 0.75.	0.76 to 1.00
Hwy. Truck (Long Distance Hauls) and Inter-City Buses	71 & 92	100.000 Miles **	20.000 Miles	10,000 Miles
City Transit Coaches and Pickup and Delivery Truck Service (Stop-And-Go Short Distance	53, 71, 92	12,500 Miles	2,500 Miles	1,250 Miles
Industrial and Marine	53, 71, 92	150 Hours	30 Hours	15 Hours +
Large Industrial and Marine	149	(NA) 500 Hours (T) 300 Hours	100 Hours 60 Hours	50 Hours + 30 Hours +

*Maximum lube oil drain intervals must be based on the laboratory test results obtained from used lube oil samples

**It supported by oil analysis at 10,000 mile intervals or when recommended fuel filter maintenance is performed

+ These oil change intervals are based upon worst case with chrome-faced rings Oil change periods with plasma-laced rings can be established by oil analysis

Table L-4

USED LUBE OIL ANALYSIS WARNING VALUES			
	ASTM Designation	Limits	Routine Or Confirmatory
Pentane Insolubles. Wt %, Max.	D-893	1.00	Routine
TGA Carbon (Soot) Content, Wt %, Max.	None	0.80	Routine
Viscosity at 100'F, SUS	D-445		Routine
% Max. Increase	&	40.00	
% Max. Decrease	D-2161	15.00	
Iron Content. PPM., Max.	None	150.00	Routine
Total Base Number (TBN), Min	D0 4	1.00	Routine
Water Content, Vol %, Max	D-95	0 30	Confirmatory
Flash Point, *F. Max Reduction	40.00	D.42	Confirmatory
Fuel Dilution, Vol %, Max	-	2.50	Confirmatory
Glycol Dilution, PPM. Max	D-2982	1000.00	Confirmatory
Sodium Content., PPM.	-		
Max. Allowed Over Lube Oil Baseline		50.00	Routine
Boron Content, PPM,	-		
Max. Allowed Over Lube Oil Baseline		20.00	Routine

Table L-5

MISCELLANEOUS FUEL AND LUBRICANT INFORMATION

ENGINE OIL CLASSIFICATION SYSTEM

The American Petroleum Institute (API), the Society of Automotive Engineers (SAE), and the American Society for Testing and Materials (ASTM) jointly have developed the present commercial system for designating and identifying motor oil classifications. The table in this section shows a cross-reference of current commercial and military lube oil identification and specification systems.

PUBLICATION AVAILABLE SHOWING COMMERCIAL "BRAND" NAME LUBRICANTS

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from

the Engine Manufacturers Association (EMA). The publication is titled EMA Lubricating Oils Data Book for Heavy-Duty Automotive and Industrial Engines. The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

ENGINE MANUFACTURERS ASSOCIATION
111 EAST WACKER DRIVE
CHICAGO, ILLINOIS 60601

Upon request, the Detroit Diesel Allison Regional Office will counsel with customers in selecting a lubricating oil that will be suitable for their specific needs.

STATEMENT OF POLICY ON FUEL AND LUBRICANT ADDITIVES

In answer to requests concerning the use of fuel and lubricating oil additives, the following excerpt has been taken from a policy statement of General Motors Corporation:

> *"It has been and continues to be General Motors policy to build motor vehicles that will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets"*

Therefore, Detroit Diesel Allison does not recommend the use of any supplementary fuel or lubricant additives.

These include all products marketed as fuel conditioners, smoke suppressants. masking agents, reodorants, tuneup compounds, top oils, break-in oils, graphitizers, and friction-reducing compounds.

NOTICE: The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's fuel or lubricating recommendations may not be within the coverage of the warranty.

CROSS REFERENCE OF LUBE OIL CLASSIFICATION SYSTEM

API CODE LETTERS	COMPARABLE MILITARY OR COMMERCIAL INDUSTRY SPECIFICATION
CA	MIL-L-2104A
CB	Supplement 1
CC	MIL-L-2104B (See Note Below)
CD	MIL-L-45199B (Series 3)
╪	MIL-L-46152 (Supersedes MIL-L-2104B Military Only)
□	MIL-L-2104C (Supersedes MIL-L-45199B for Military)
SA	None
SB	None

╪ Oil performance meets or exceeds that of CC and SE oils.
□ Oil performance meets or exceeds that of CD and SC oils.

NOTE: MIL-L-2104B lubricants are obsolete for military service applications only.
MIL-L-2104B lubricants are currently marketed and readily available for commercial use.

Consult the following publications for complete descriptions:

1. Society of Automotive Engineers (SAE) Technical Report J-183a.
2. Federal test Method Standard 791a.

ENGINE COOLANT

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. In general, water containing various materials in solution is used for this purpose.

The function of the coolant is basic to the design and to the successful operation of the engine. Therefore, coolant must be carefully selected and properly maintained.

COOLANT REQUIREMENTS

Coolant solutions must meet the following basic requirements:

1. Provide for adequate heat transfer.

2. Provide a corrosion-resistant environment within the cooling system.

3. Prevent formation of scale or sludge deposits in the cooling system.

4. Be compatible with the cooling system hose and seal materials

5. Provide adequate freeze protection Luring cold weather operation.

The first four requirements are satisfied by combining a suitable water with reliable inhibitors. When freeze protection is required, a solution of suitable water and an antifreeze containing adequate inhibitors will provide a satisfactory coolant. Ethylene glycol-based antifreeze is recommended for use in Detroit Diesel engines.

WATER

Any water, whether of drinking quality or not, will produce a corrosive environment in the cooling system. and the mineral content may permit scale deposits to form on internal cooling system surfaces. Therefore, water selected as a coolant must he properly treated with inhibitors to control corrosion and scale deposition.

To determine if a particular water is suitable for use as a coolant when properly inhibited. the following characteristics must be considered: the concentration of chlorides and sulfates, total hardness and dissolved solids.

Chlorides and/or sulfates tend to accelerate corrosion, while hardness (percentage of magnesium and calcium salts broadly classified as carbonates) causes deposits of scale. Total dissolved solids may cause scale deposits, sludge deposits, corrosion or a combination

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

TABLE 1

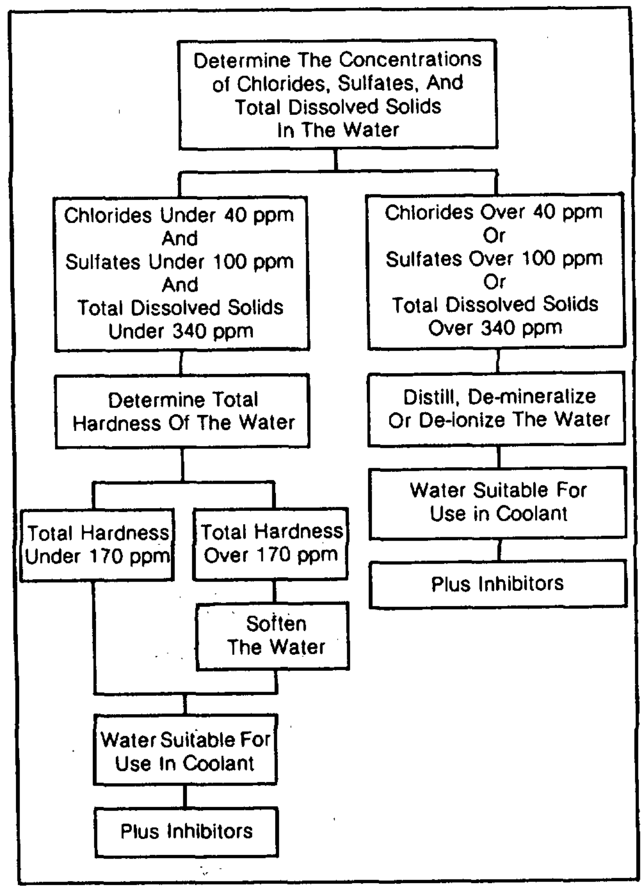

TABLE 2

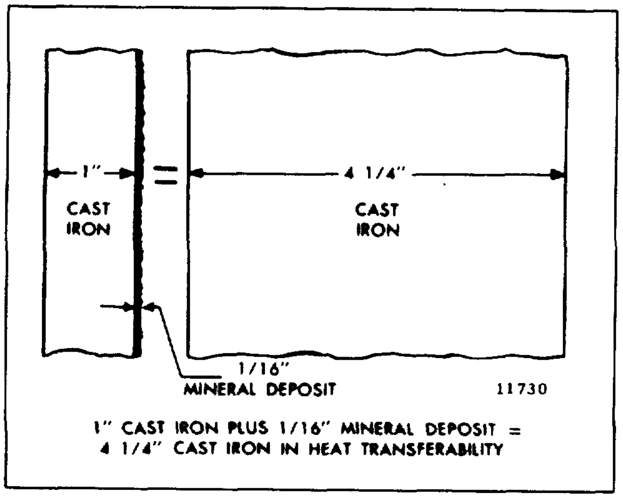

Fig. 1 - Heat Transfer Capacity

of these. Chlorides, sulfates, magnesium and calcium are among the materials which make up dissolved solids. Water, within the limits specified in Table I is satisfactory as an engine coolant when proper inhibitors are added. The procedure for evaluating water intended for use in a coolant solution is shown in Table 2.

CORROSION INHIBITORS VITAL

A corrosion inhibitor is a water-soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosion inhibitors are chromates, borates, nitrates, nitrites and soluble oil.

(Soluble oil is not recommended as a corrosion inhibitor). Depletion of all types of inhibitors occurs through normal operation. Therefore, strength levels must be maintained by the addition of inhibitors at prescribed intervals.

The importance of a properly inhibited coolant cannot be overstressed. A coolant which has insufficient inhibitors, the wrong inhibitors, or-worse-no inhibitors at all invites the formation of rust and scale deposits within the cooling system. Rust, scale, and mineral deposits can wear out water pump seals and coat the walls of the cylinder block water jackets and the outside walls of the cylinder liners. As these deposits build up, they insulate the metal and reduce the rate of heat transfer. For example, a 1/16" deposit of rust or scale on I" of cast iron is equivalent to 4-1/4" of cast iron in heat transferability (Fig. I).

An engine affected in this manner overheats gradually over a period of weeks or months. Liner scuffing, scoring, piston seizure and cylinder head cracking are the inevitable results. An improperly inhibited coolant can also become corrosive enough to "eat away" coolant passages and seal ring grooves and cause coolant leaks to develop. If sufficient coolant accumulates on top of a piston, a hydrostatic lock can occur while the engine is being started. This, in turn, can result in a bent connecting rod. An improperly inhibited coolant can also contribute to cavitation erosion. Cavitation erosion is caused by the collapse of bubbles (vapor pockets) formed at the coolant side of an engine component. The collapse results from a pressure differential in the liquid caused by the vibration of the engine part. As bubbles collapse, they form pin points of very high pressure. Over a period of time, the rapid succession of millions of tiny bursting bubbles can wear away (erode) internal engine surfaces.

Components such as fresh water pump impellers and cylinder liners are especially susceptible to cavitation erosion. In extreme cases their surfaces can become so deeply pitted that they appear to be spongy, and holes can develop completely through them.

Chromates
Sodium chromate and potassium dichromate are two of the best and most commonly used water system corrosion inhibitors. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors should not be used in antifreeze solutions. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with antifreeze. This material deposits on the cooling system passages and reduces the heat transfer rate (Fig. I) which results in engine overheating. Engines which have operated with a chromate-inhibited water must be chemically cleaned before the addition of antifreeze. A commercial heavy duty descaler should be used in accordance with the manufacturer's recommendation for this purpose.

Soluble Oil
Soluble oil has been used as a corrosion inhibitor for many years. It has, however, required very close attention relative to the concentration level due to adverse effects on heat transfer if the concentration exceeds 1% by volume. For example: 1.25% of soluble oil in the cooling system increases fire deck temperatures 6% and a 2.50% concentration raises fire deck temperature up to 15%. Soluble oil is not recommended as a corrosion inhibitor.

Non-Chromates
Non-chromate inhibitors (berates, nitrates, nitrites, etc.) provide corrosion protection in the cooling system with the basic advantage that they can be used with either water or a water-and-antifreeze solution.

INHIBITOR SYSTEMS
An inhibitor system is a combination of chemical compounds which provide corrosion protection, pH control and water-softening ability. Corrosion protection is discussed under the heading Corrosion Inhibitors Vital. The pH control is used to maintain an acid-free solution. The water-softening ability deters formation of mineral deposits. Inhibitor systems are available in various forms such as coolant filter elements, liquid and dry bulk inhibitor additives and as an integral part of antifreeze.

Coolant Filter Elements
Replaceable elements are available with various chemical inhibitor systems. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted.

Problems have developed from the use of the magnesium lower support plate used by some manufacturers in their coolant filters. The magnesium plate will be attacked by solutions which will not be detrimental to other metals in the cooling system. The dissolved magnesium will be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate in preference to magnesium is recommended to eliminate the potential of this type of deposit.

High chloride coolants will have a detrimental effect on the water-softening capabilities of systems using ion-exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by a regenerative process caused by high chloride-content solutions.

Bulk Inhibitor Additives
Commercially packaged inhibitor systems are available which can be added directly to the engine coolant or to bulk storage tanks containing coolant solution.

Both chromate and non-chromate systems are available and care should be taken regarding inhibitor compatibility with other coolant constituents.

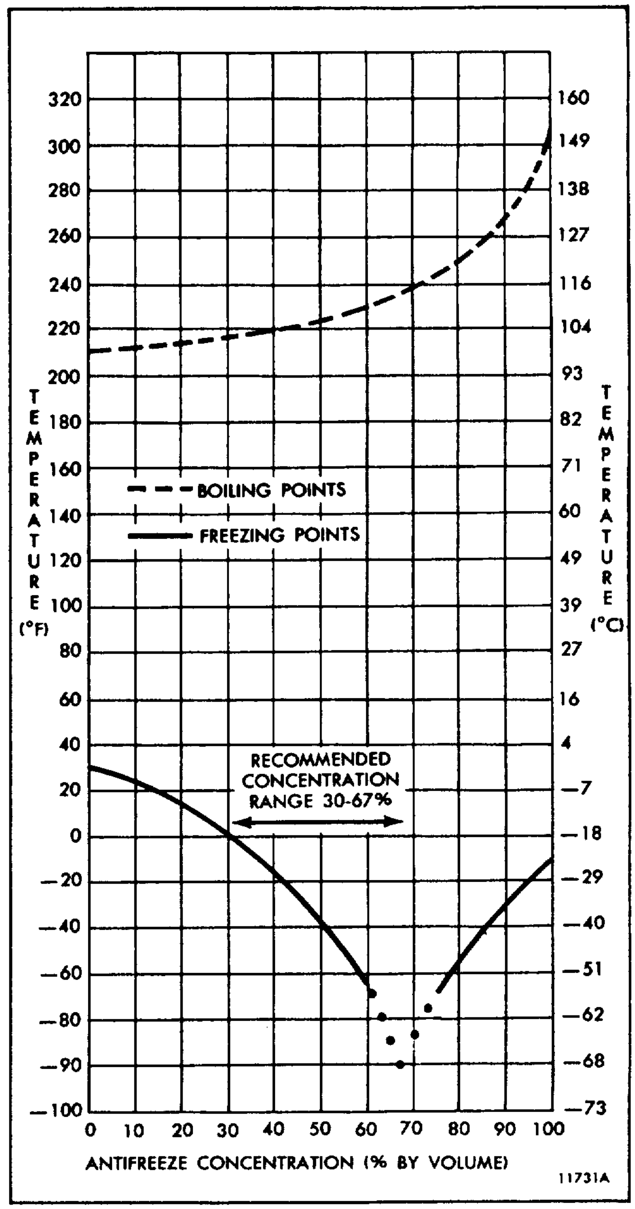

Fig. 2 Coolant Freezing and Boiling Temperatures vs. Antifreeze Concentration (Sea Level)

Non-chromate inhibitor systems are recommended for use in Detroit Diesel engines. These systems can be used with either water or water-and-antifreeze solutions and provide corrosion protection, pH control and water softening. Some non-chromate inhibitor systems offer the additional advantage of a simple on-site test to determine protection level. Since they are added directly to the coolant, require no additional hardware or plumbing.

All inhibitors become depleted through normal operation and additional inhibitor must be added to the coolant at prescribed intervals to maintain original strength levels. Always follow the supplier's recommendations on inhibitor usage and handling.

TEST STRIPS

Some chemical manufacturers have developed test strips for use with their antifreeze or coolant additives. These test strips are used to measure the freeze protection and/or inhibitor strength of ethylene glycol-based antifreeze. To avoid a false reading caused by variations in reserve alkalinity, Detroit Diesel Allison suggests using test strips that measure depletable inhibitor concentration directly. *Do not use one manufacturer's test strips to measure the chemical content of another's antifreeze and/or inhibitors*. Always follow the manufacturer's recommended test procedures.

ANTIFREEZE

When freeze protection is required, an antifreeze meeting GM specification 1899M must be used. An inhibitor system is included in this type of antifreeze and no additional inhibitors are required on initial fill if a minimum antifreeze concentration of 30% by volume is used. Solutions of less than 30% concentration do not provide sufficient corrosion protection. Concentrations over 67% adversely affect freeze protection and heat transfer rates (Fig. 2).

Ethylene glycol base antifreeze is recommended for use in all Detroit Diesel engines. Methyl alcohol base antifreeze is not recommended because of its effect on the non-metallic components of the cooling system and because of its low boiling point. Methoxy propanol base antifreeze is not recommended for use in Detroit Diesel engines due to the presence of fluoroelastomer seals in the cooling system.

Before installing ethylene glycol base antifreeze in a unit that has previously operated with methoxy propanol, the entire cooling system should be drained, flushed with clean water, and examined for rust, scale contaminants, etc. If deposits are present, the cooling system must be chemically cleaned with a commercial grade heavy-duty descaler.

The inhibitors in antifreeze should be replenished at approximately 500 hour intervals or by test with a non-chromate inhibitor system. Commercially available inhibitor systems may be used to reinhibit antifreeze solutions.

Sealer Additives

Antifreeze with sealer additives is not recommended for use in Detroit Diesel engines due to plugging possibilities throughout various areas of the cooling system, including cooling system bleed holes and water pump drain holes.

GENERAL RECOMMENDATIONS

All Detroit Diesel engines incorporate pressurized cooling systems which permit operation at temperatures higher than non-pressurized systems. It is essential that these systems be kept clean and leakfree, that filler caps and pressure relief mechanisms be correctly installed at all times and that coolant levels be properly maintained.

Always maintain engine coolant at the proper level. A low coolant level allows the water pump to mix air with the coolant. Air bubbles in the coolant can "insulate" the cylinder walls, preventing normal heat transfer. An abnormally low coolant level can cause the water pump to become (:air-bound," a condition in which it works feverishly but pumps nothing.

Without proper heat transfer, silicone elastomer head-to-block water hole seals can deteriorate and cylinder components can expand so that pistons rapidly cut through the lubricant on the liner walls. Scuffing and piston seizure may follow.

CAUTION: Use extreme care when removing a radiator pressure-control cap from an engine. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

An engine may contain the correct amount of properly inhibited coolant, but still fail to adequately cool the engine. In cases where this occurs, other causes of low coolant flow, either engine or cooling system related, should be investigated.

I. Always use a properly inhibited coolant.

2. Do not use soluble oil.

3. Maintain the prescribed inhibitor strength.

4. Always follow the manufacturer's recommendations on inhibitor usage and handling.

5. If freeze protection is required, use a solution of water and antifreeze meeting GM specification 1899M.

6. Reinhibit antifreeze with a recommended non-chromate inhibitor system.

7. Do not use a chromate inhibitor with antifreeze.

8. Do not use methoxy propanol base antifreeze in Detroit Diesel engines.

9. Do not mix ethylene glycol base antifreeze with methoxy propanol base antifreeze in the cooling system.

10. Do not use antifreeze containing sealer additives.

11. Do not use methyl alcohol base antifreeze.

12. Use extreme care when removing the radiator pressure-control cap.

ENGINE TUNE-UP **CHAPTER 10**

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ENGINE TUNE-UP PROCEDURES

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, must be checked and adjusted, if necessary (refer to Page 10-10-2).

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if the cylinder head, governor or injectors have been replaced or overhauled, then certain preliminary adjustments are required before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

To tune up an engine completely, perform all of the adjustments, in the applicable tune-up sequence given below after the engine has reached normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Use a new valve rocker cover gasket after the tune-up is completed.

Tune-Up Sequence for Mechanical Governor

NOTE: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the serviceman must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no-fuel with the governor stop lever.

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the buffer screw.
8. Adjust the throttle booster spring.

EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, increased valve face wear and valve lock damage.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting that is close enough to the specified, clearance to prevent damage to the valves when the engine is started.

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of' the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

Valve Clearance Adjustment (Cold Engine) 100°F (38°C) or less

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.

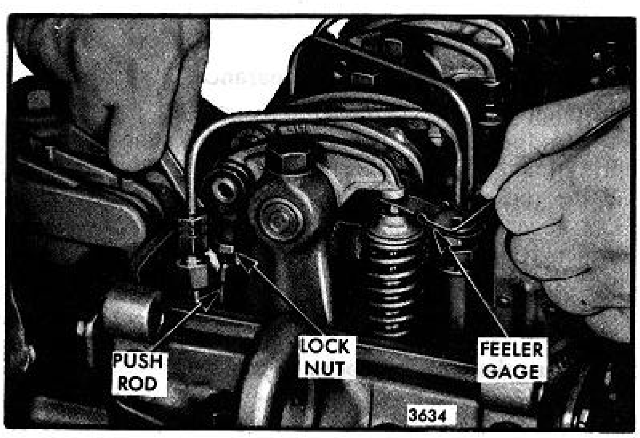

Fig. 1 - Adjusting Valve Clearance (Two Valve Head)

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted.

> **NOTE: 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 because the bolt may loosen.**

4. Loosen the exhaust valve rocker arm push rod locknut.

5. Place a .012" i.004" feeler gage (J 9708-01) between the exhaust valve stem and the rocker arm (Fig. I). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16" wrench and tighten the locknut with a 1/2" wrench.

7. Recheck the clearance. At this time, if the adjustment is correct, the .011" feeler gage will pass freely between the valve stem and the rocker arm, but the .013" feeler gage will not pass through. Readjust the push rod, if necessary.

8. Check and adjust the remaining exhaust valves in the same manner as outlined 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 Page 10-9-2), recheck the exhaust valve clearance with feeler gage J 9708-01. At this time, if the valve clearance is correct, the .008" feeler gage will pass freely between the end of the valve stem and the rocker arm and the .010" 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 (Page 10-10-3).

FUEL INJECTOR TIMING

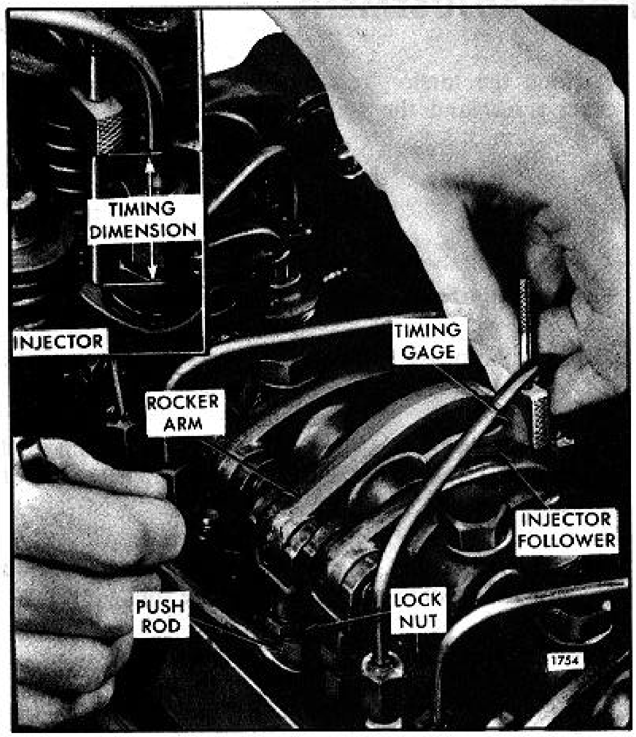

Fig. 1 - Timing Fuel Injector

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

Time Fuel Injector

After the exhaust valve clearance has been adjusted (Page 10-10-2), time the fuel injectors as follows: 1. Place the governor speed control lever in the idle speed position. Secure the stop lever 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.

> **NOTE: 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 (Fig. 1). Refer to Table 1 for the correct timing gage.

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.

Injector	Timing Dimension	Timing Gage	Camshaft Timing
N65 (white tag)	1.460"	J 1853	Standard

TABLE 1 - INJECTOR TIMING

VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves 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 (Fig.1) in the maximum speed position.

4. Insert a .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 cover to the governor housing with three regular screws, one special screw and lock washers.

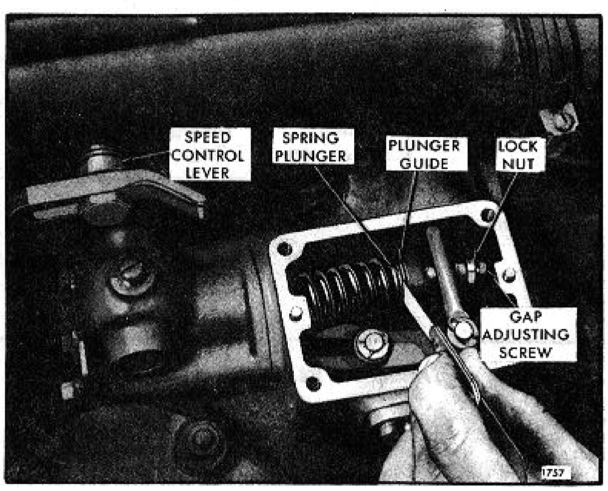

Fig. 1 - Adjusting Governor Cap

7. Hook the torsion retracting spring on the special cover screw and the stop lever (Fig. 2).

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.

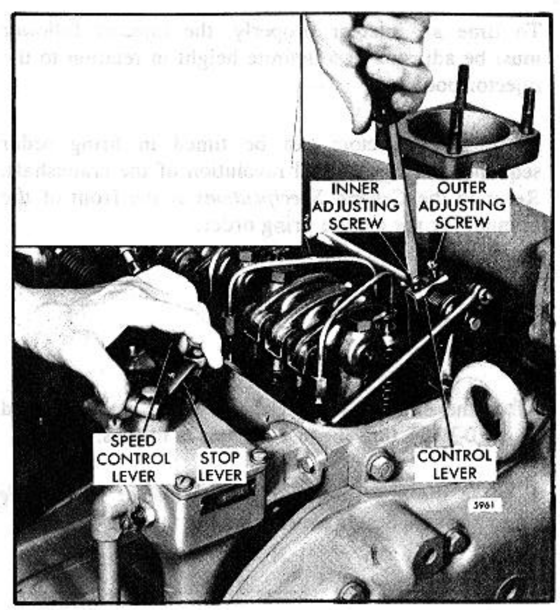

Fig. 2 - Positioning No. 1 injector Rack Control Lever

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 Fig. 2 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 (Fig. 3) and back out the buffer screw approximately 5/8".

3. Loosen all the inner and outer adjusting screws (Fig. 2). 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. I 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.

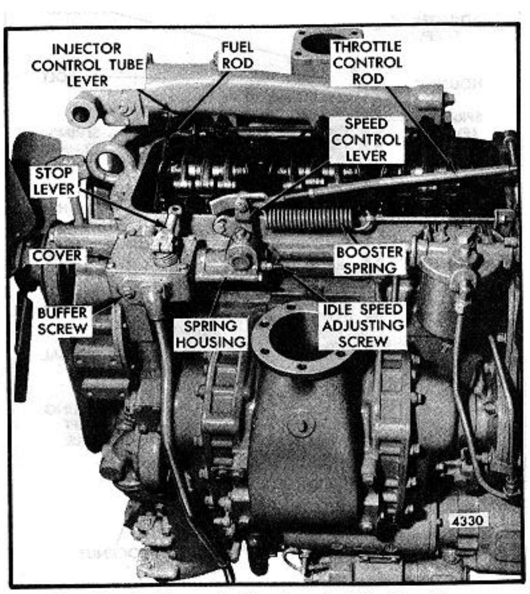

Fig. 3 - Buffer and Idle Speed Adjusting Screw

CAUTION: 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).

IMPORTANT: 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 tip and note "rotating" movement of the injector control rack (Fig. 4) when the speed control lever is in the maximum speed position. Hold the speed control lever in the maximum speed position and, using a screw driver, press downward on the injector control rack. The rack should tilt downward (Fig. 5) and when the pressure of the screw driver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct, back off the outer adjusting screw slightly and tighten the inner adjusting screw 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, hack off the inner adjusting screw slightly and tighten the outer adjusting screw slightly.

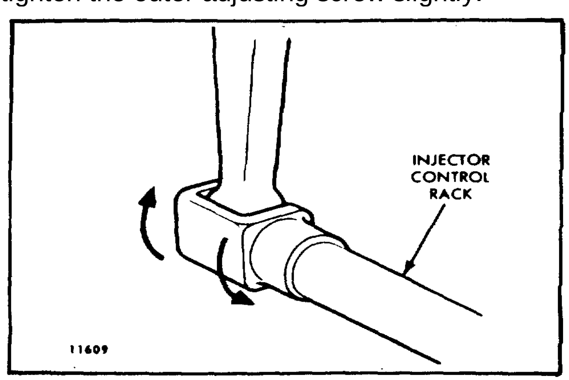

Fig. 4 -Checking Rotating Movement of Injector Control Rack

7. Manually hold the No. 1 injector rack in the full fuel position and turn down the inner adjusting screw (Fig. 2) 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 end 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 Fig. 3 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.

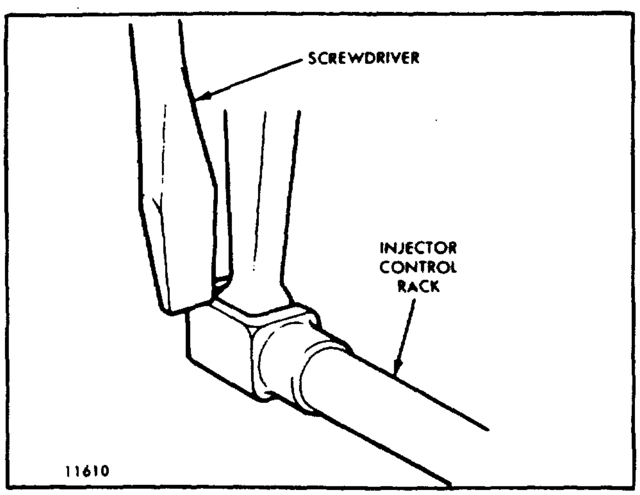

Fig. 5 - Checking Injector Control Rack "Spring"

3. Refer to Table 1 and Fig. 6 and determine the stop or shim required for the desired full load speed.

Full Load Speed	Stops	Shims
1200 to 1425 rpm	2	Up to .325"
1426 to 1825 rpm	1	Up to .325"
1826 to 2100 rpm	0	Amount Required to get necessary speed.

TABLE 1

A split stop can only be used with a solid stop (Fig. 6).

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.

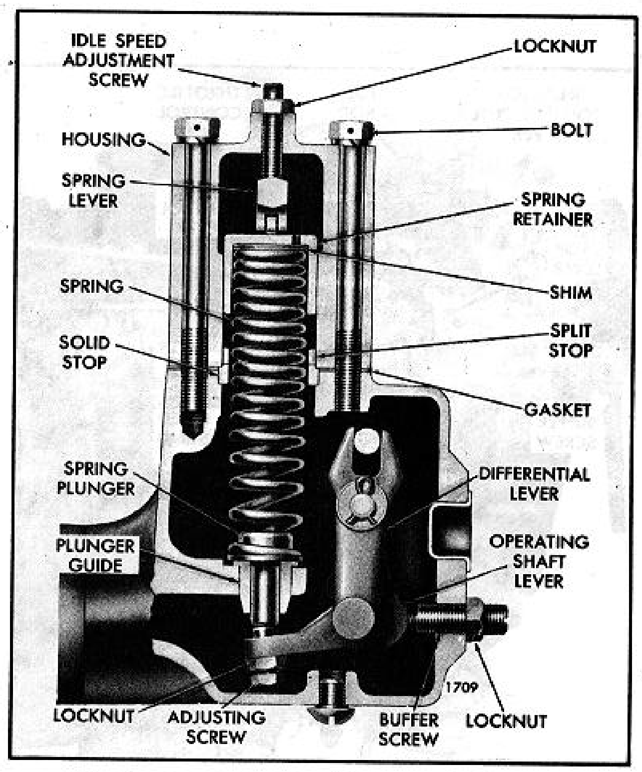

Fig. 6 - Location of Stops and Shims

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 Fig. 3 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 he 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.

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PREVENTIVE MAINTENANCE
TROUBLE SHOOTING - STORAGE -
PLUGGING CHARTS

CHAPTER 11

CONTENTS

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INDUSTRIAL OFF HIGHWAY AND MARINE	TIME INTERVALS										
HRS.	DLY.	8	50	100	150	200	300	500	700	1.000	2,000
MILES		240	1,500	3,000	4,500	6,000	9,000	15,000	20,000	30,000	60,000
1. Lubricating Oil	X				X						
2. Fuel Tank	X							X	X		
3. Fuel Lines	X										
4. Cooling System	X								X	X	
5. Battery				X							
6. Tachometer Drive				X							
7. Air Cleaners*		X						X			
8. Drive Belts		X				X					
9. Throttle and Clutch Controls						X					
10. Lubricating Oil Filter								X		X	
11. Fuel Strainer and Filter							X				
12. Starting Motor*											
13. Air System									X		
14. Exhaust System									X		
15. Air Box Drain Tube										X	
16. Emergency Shutdown									X		
17. Radiator									X		
18. Oil Pressure									X		
19. Alternator				X		X		X			X
20. Engine and Transmission Mounts											X
21. Crankcase Pressure											X
22. Air Box Check Valves'											
23. Fan Hub*											
24. Thermostats and Seals									X		
25. Blower Screen										X	
26. Crankcase Breather										X	
27. Engine Tune-Up*											

* See Item

Item 1 - Lubricating Oil

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately twenty minutes to allow the oil to drain back to the oil pan. Add the proper grade oil as required to maintain the correct level on the dipstick (refer to Page 9-9).

NOTE:

Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and external oil lines.

Change the lubricating oil at the intervals shown in the chart.

ENGINE OIL CHANGE INTERVALS

	Max. Engine Oil Change Interval		
	Diesel Fuel Sulfur Content % by Wt. Max.		
	0 to .50	0.51 to 0.75	0.76 to 1.00
	150 Hours	30 Hours	15 Hours*

*These oil change intervals are based upon worst case with chrome-faced rings. Oil change periods with plasma rings can be established by oil analysis.

The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the used oil sample analysis) until the most practical oil change period has been determined. Select the proper grade of oil in accordance with the instructions given in the *Lubricating Oil Specifications on* Page 10-9-9.

NOTE:

If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily.

Item 2 - Fuel Tank

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the Diesel Fuel Oil Specifications on Page 10-9-7.

Open the drain at the bottom of the fuel tank every 500 hours to drain off any water and/or sediment.

Every 12 months (700 hours) tighten all fuel tank mountings and brackets. At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the crossover fuel line. Repair or replace the parts as necessary.

Diesel Fuel Contamination

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system in itself, but it also promotes the growth of microbiological organisms (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps), contaminated fuel supply or condensation.

Condensation is particularly prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

Water accumulation can be controlled by mixing isopropyl alcohol (dry gas) into the fuel oil at a ratio of one pint (.5 liter) per 125 gallons (473 liters) fuel (or 0.10%' by volume).

Item 3 - Fuel Lines

Make a visual check for fuel leaks at the crossover lines and at the fuel tank suction and return lines.

Since fuel tanks are susceptible to road hazards. leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

Item 4 - Cooling System

Check the coolant level daily and make sure it covers the radiator tubes. Add coolant as necessary. *Do not overfill.*

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.

Clean the cooling system annually or every 1,000 hours, using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then fill the system with soft water, adding a good grade of rust inhibitor or a high boiling point type antifreeze (refer to *Engine Coolant* on Page 10-9-13). With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse flushed.

Inspect all of the cooling system hoses at least once every 700 hours to make sure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses if necessary.

Item 5 - Battery(s)

Check the specific gravity of the electrolyte in each cell of the battery every 100 hours. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 6 - Air Cleaner

Under no engine operating conditions should the air inlet restriction exceed 25 inches of water (6.2 kPa) for non-turbocharged engines or 20 inches of water (5.0 kPa) for turbocharged engines. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Dry type elements should be discarded and replaced with new elements after one year of service or when the maximum allowable air intake restriction has been reached (see Page 10-9-6), whichever comes first. In cases where the air cleaner manufacturer recommends cleaning or washing off-highway elements, the maximum service life is still one year or maximum restriction. Cleaning, washing and inspection must be done per the manufacturer's recommendations. Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations.

Item 7 - Drive Belts

New standard V-belts will stretch after the first few hours of operation. Run the engine for 15 seconds to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, battery-charging alternator drive belts after 1/2 hour and again after 8 hours of operation. Thereafter, check the tension of the drive belts every 200 hours and adjust, if necessary. Too tight a belt is destructive to the bearings of the driven part; a loose belt will slip.

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032" of their specified center distances.

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".

Item 8 - Throttle and Clutch Controls

Lubricate the clutch control levers and all other control mechanisms, as required, with engine oil.

Item 9 - Lubricating Oil Filter

Install a new oil filter at a maximum of 500 hours or each time the engine oil is changed, whichever occurs first.

Any deviation, such as changing filters every other oil change, should be based on a laboratory analysis of the drained oil and the used filter elements to determine if such practice is practical for proper protection of the engine.

Make a visual check of all lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

Check for oil leaks after starting the engine.

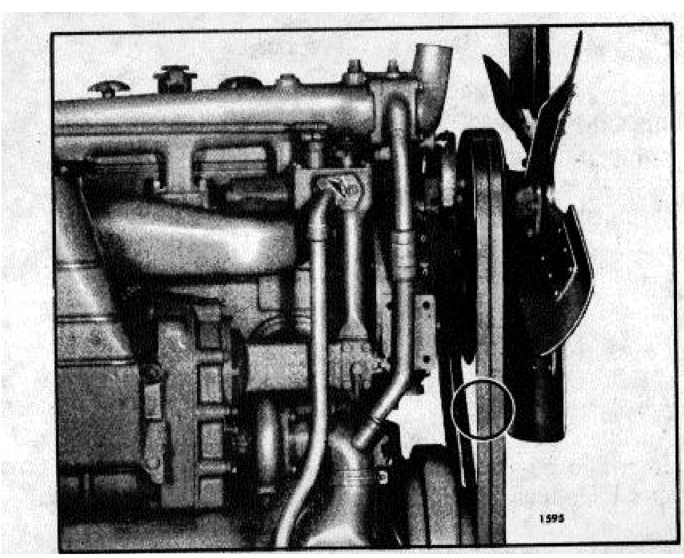
Item 10 - Fuel Strainer and Filter

Install new elements every 6 months or when plugging is indicated.

A method of determining when elements are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury (20.3 kPa). At normal operating speeds (1600-2100 rpm). the fuel pressure is 45 to 70 psi (310 to 483 kPa). Change the fuel filter elements whenever the inlet restriction at the fuel pump reaches 12 inches of mercury (41 kPa) at normal operating speeds and whenever the fuel pressure at the inlet manifold falls to 45 psi (310 kPa).

Item 11 - Starting Motor

The electrical starting motor is lubricated at the original time of assembly. The starting motor (except the sprag clutch drive) does not require lubrication except during overhaul.



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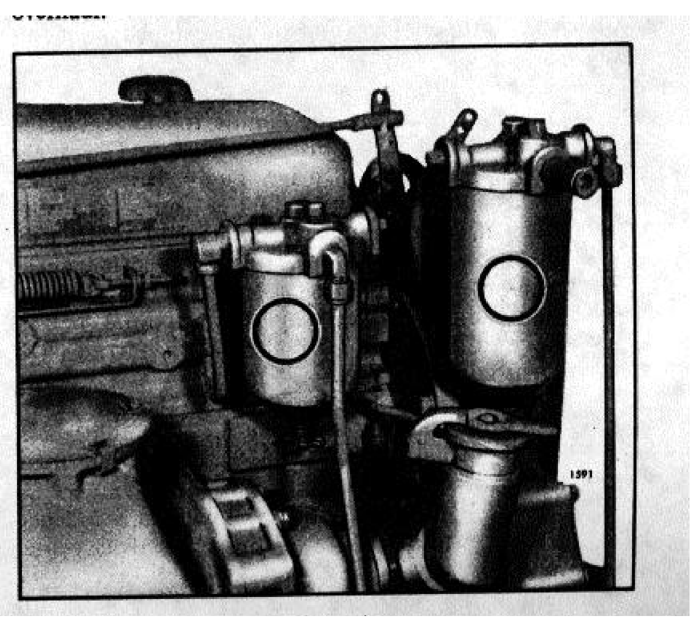
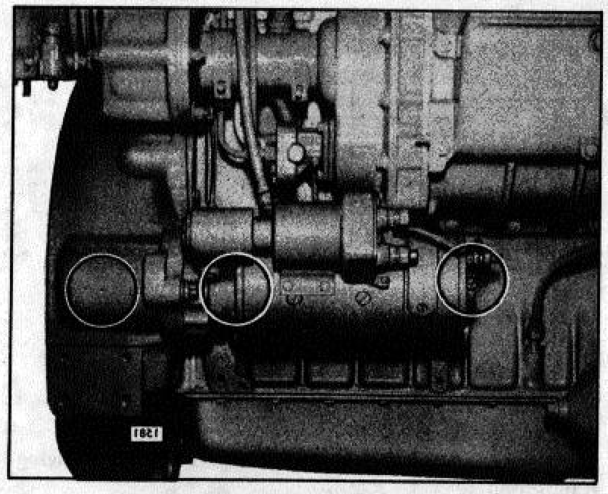
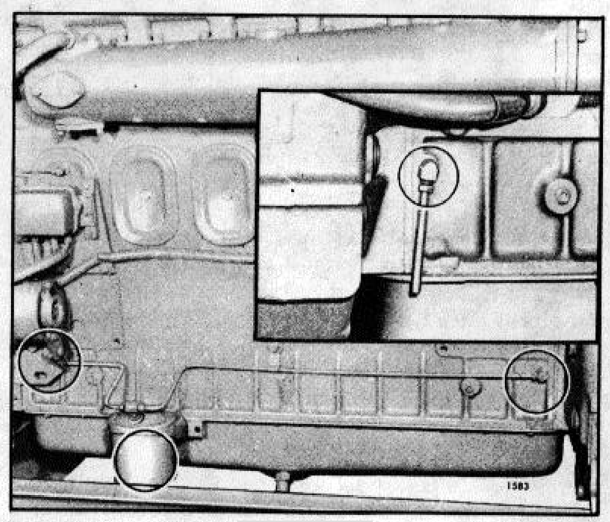


Item 10



Item 11



Item 11

The Sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

Item 12 - Air System

Check all of the connections in the air system to be sure they are tight. Check all hoses for punctures or other damage and replace, if necessary.

Item 13 - Exhaust System

Check the exhaust manifold retaining nuts, exhaust flange clamp and other connections for tightness. Check for proper operation of the exhaust pipe rain cap.

Item 14 - Air Box Drain Tube

With the engine running, check for flow of air from the air box drain tubes every 1,000 hours. If the tubes are clogged, remove, clean and reinstall the tubes. The air box drain tubes should be cleaned periodically even though a clogged condition is not apparent.

Item 15 - Emergency Shutdown

With the engine running at idle speed. check the operation of the emergency shutdown every 700 hours Reset the air shutdown valve in the open position after the check has been made.

Item 16 - Engine (Steam Clean)

Steam clean the engine and engine compartment.

NOTE:
Do not apply steam or solvent directly on the battery-charging alternator, starting motor or electrical components as damage to electrical equipment may result.

Item 17 - Radiator

Inspect the exterior of the radiator core every 12 months (700 hours) and, if necessary, clean it with a quality grease solvent such as mineral spirits and dry it with compressed air. Do not use fuel oil, kerosene or gasoline. It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Item 18 - Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. In the event the engine is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 700 hours.

Item 19 - Governor

Check and record the engine idle speed and no-load speed. Adjust as necessary.

An idle speed lower than recommended will cause the engine to be accelerated from a speed lower than the speed at which the engine was certified.

A no-load speed higher than recommended will result in a full-load speed higher than rated and higher than the speed at which the engine was certified.

Item 20 - Fuel Injectors and Valve Clearance

Check the injector timing and exhaust valve clearance as outline on Page 10-10-3 and 10-10-2. The proper height adjustment between the injector follower and injector body is of primary importance to emission control.

Item 21 - Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

The alternator has sealed bearings and no lubrication is necessary.

The slip rings and brushes can be inspected through the end frame assembly. If the slip rings are dirty, they should be cleaned with 400 grain or finer polishing cloth. Never use emery cloth to clean the slip rings. Hold the polishing cloth against the slip rings with the alternator in operation and blow away all dust after the cleaning operation. If the slip rings are rough or out of round, replace them.

Item 22 - Engine and Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 2000 hours. Tighten and repair as necessary.

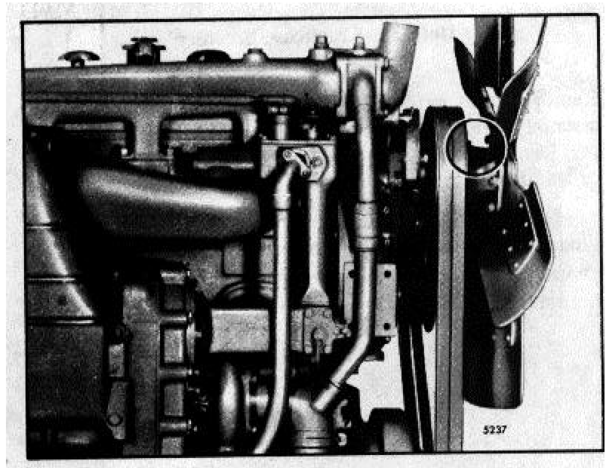
Item 23 - Crankcase Pressure

Check and record the crankcase pressure every 2000 hours (refer to Page 10-11-9).

Item 24 - Fan Hub

Use a hand grease gun and lubricate the bearings with one shot of Texaco Premium RB grease, or an equivalent Lithium base multi-purpose grease, every 700 hours.

At a major engine overhaul, remove and discard the bearings in the fan hub assembly. Pack the hub assembly, using new bearings, with Texaco Premium RB grease or an equivalent Lithium base multi-purpose grease.



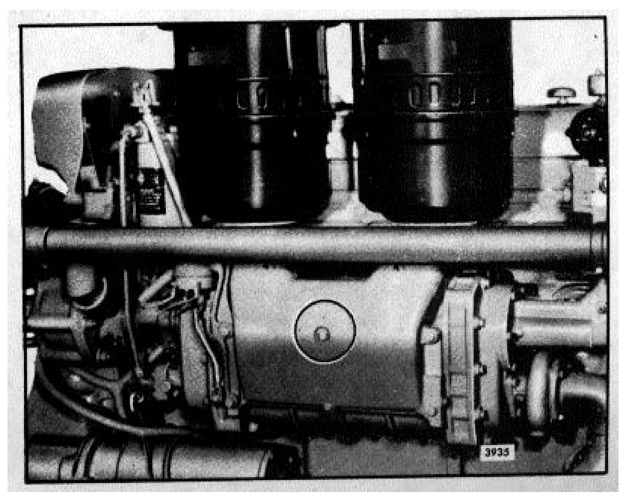
Item 24

Item 25 - Thermostats and Seals

Check the thermostats and seals (preferably at the time the cooling system is prepared for winter operation). Replace the seals if necessary.

Item 26 - Blower Screen

Inspect the blower screen and gasket assembly annually or every 1,000 hours and, if necessary, clean the screen in fuel oil and dry it with compressed air. Install the screen and gasket assembly with the screen side of the assembly toward the blower. Inspect for evidence of blower seal leakage.



Item 26

Item 27 - Crankcase Breather

Remove the externally mounted crankcase breather assembly every 1,000 hours and wash the steel mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to severity of service.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed.

Item 28 - Engine Tune-Up

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanisms, governor, etc. should only be required periodically to compensate for normal wear on parts.

TROUBLE SHOOTING

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

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.

2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

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 (Page 10-10-2).

4. Start the engine. Then hold an injector follower down with a screwdriver to prevent operation of the injector (Fig. 1). If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.

5. If the cylinder is firing properly. repeat the procedure on the other cylinders until the faulty one has been located.

6. If the cylinder is misfiring, check the following:

   a. Check the injector timing (refer to Page 10-10-3).
   b. Check the compression pressure.
   c. Install a new injector.
   d. If the cylinder still misfires, remove the cam follower (refer to Page 10-2-31) 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 1.

Check the compression pressure as follows:

1. Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.

2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.

3. Remove the injector and install an adaptor and pressure gage from Diagnosis Kit J 9531-01 (Fig. 2).

4. Use one of the fuel pipes as a jumper connection

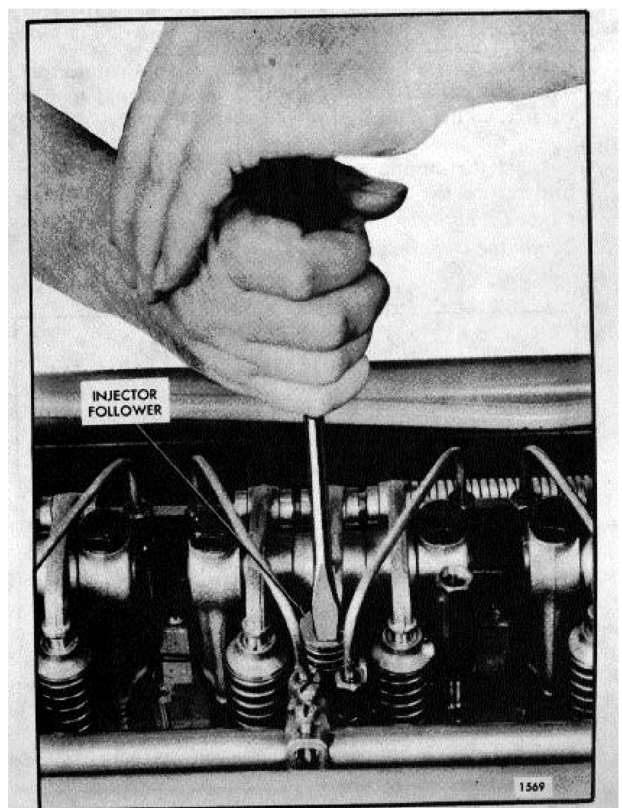


Fig. 1 - Locating a Misfiring Cylinder

Minimum Compression Pressure at 600 rpm 4-71N Engine		Altitude above Sea Level		† Air Density
psi	kPa	feet	meters	
515	3551	500	152	0.715
480	3310	2,500	762	0.663
440	3034	5,000	1,524	0.613
410	2827	7,500	2,286	0.567
380	2620	10,000	3,048	0.525

† Air density at 500 ft. altitude based on 85° F (29.4° C) and 29.38 in Hg (99.49 kPa) wet barometer.

TABLE 1

Cylinder	Gage Reading	
	psi	kPa
1	445	3066
2	440	3032
3	405	2791
4	435	2997

TABLE 2

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 gage. Do not crank the engine with the starting motor to obtain the compression pressure.

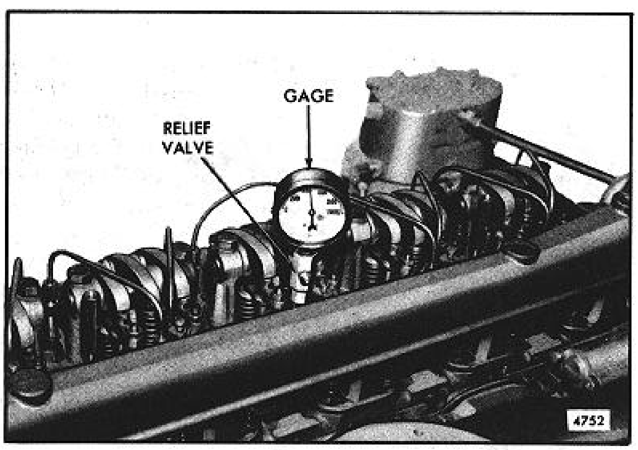


Fig. 2 - Checking Compression Pressure

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

EXAMPLE: If the compression pressure readings were as shown in Table 2, 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 2 are for a 71E engine operating at an altitude near sea level. Note that 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 (Fig. 3). A broken or stuck ring will not have a "spring-like" action.
B. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

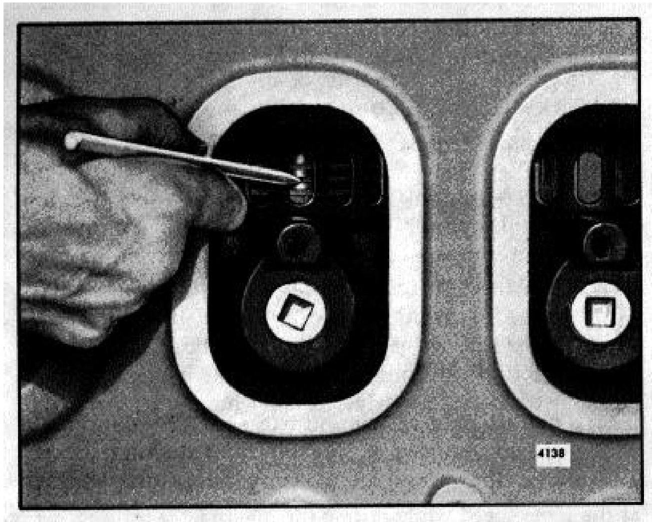


Fig. 3 - Inspecting Piston Rings

Engine Out of Fuel

The problem in restarting an engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons (38 litres) of fuel.

2. Remove the fuel strainer cartridge and fill the cartridge with fuel oil. Install the cartridge.

3. Remove and fill the fuel filter cartridge with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

> **NOTE**: In some instances, it may be necessary to remove the valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

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 outline on Page 10-3-57 under Trouble Shooting.

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder head or end plate gaskets, or excessive exhaust 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 Operating Conditions* on Page 10-9-1.

> **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 formation or foreign matter in the exhaust system.

Check the exhaust back pressure, measured in inches of mercury, with a manometer. Connect the manometer to the exhaust manifold by removing the 1/8" pipe plug which is provided for that purpose. If no opening is provided, drill an 11/32" hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8" pipe plug.

Check the readings obtained at various speeds (at no-load) with the *Engine Operating Conditions* on Page 10-9-1.

Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen. Lack of power or black or grey exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

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* on Page 10-9-1.

Air Inlet Restriction Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air 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* on Page 10-9-1.

PROPER USE OF MANOMETER

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 4) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside

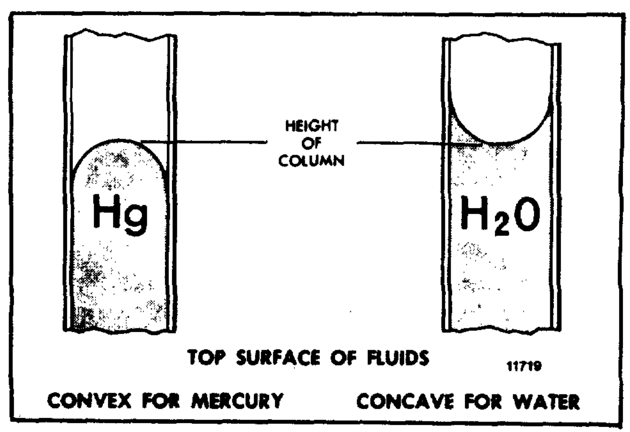


Fig. 4 - Comparison of Column Height for Mercury and Water Manometers

PRESSURE CONVERSION CHART		
1" water	=	.0735" mercury
1' water	=	.0361 psi
1" mercury	=	13.6000" water
1" mercury	=	.4910 psi
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury
1 psi	=	6.895 kPa
1 kPa	=	.145 psi

TABLE 3

diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 3 to convert the manometer reading into other units of measurement.

SHOP NOTES

10-11-13

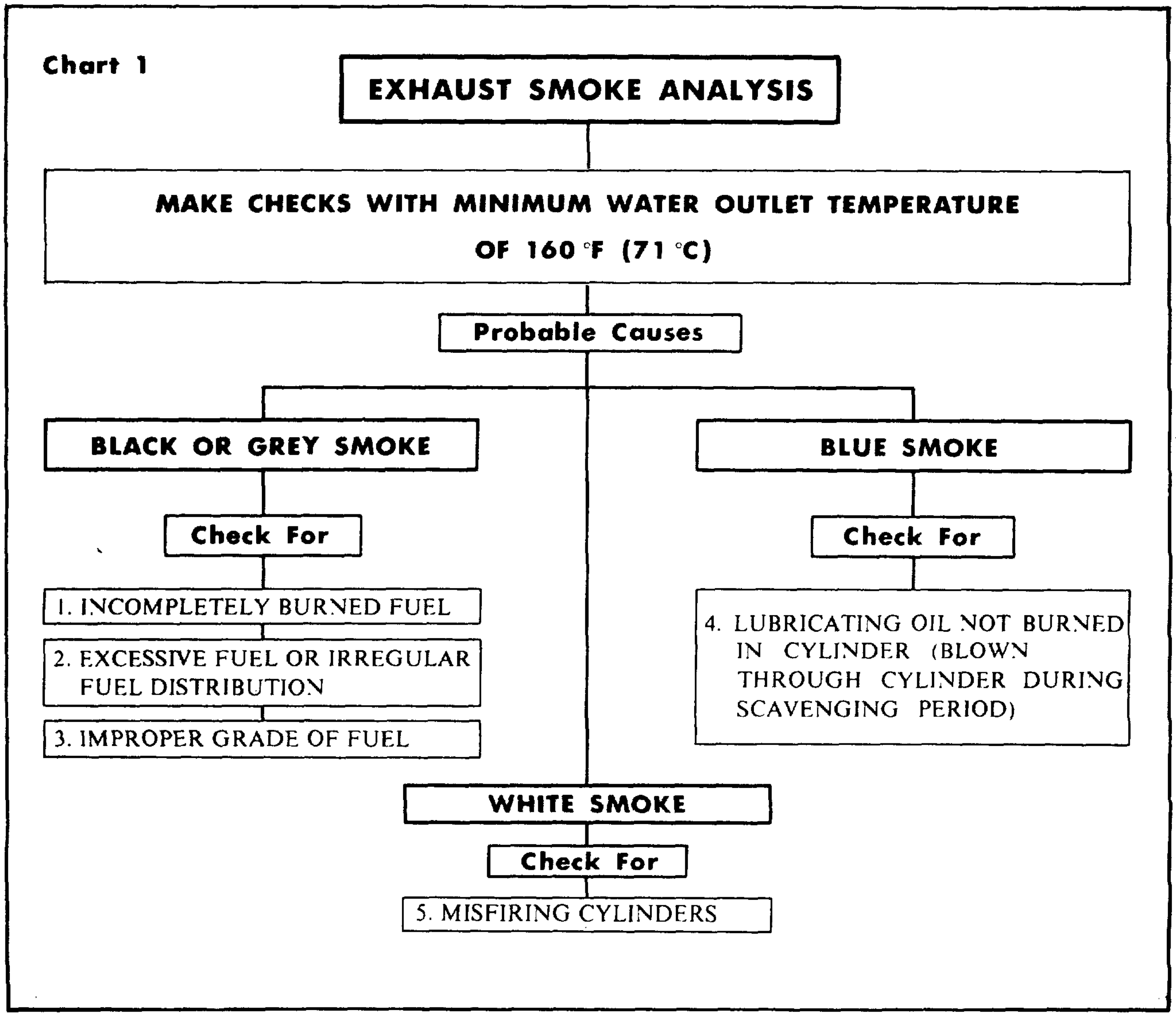


Chart 1
EXHAUST SMOKE ANALYSIS
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160 °F (71 °C)
Probable Causes
BLACK OR GREY SMOKE
Check For
1. INCOMPLETELY BURNED FUEL
2. EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION
3. IMPROPER GRADE OF FUEL
BLUE SMOKE
Check For
4. LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)
WHITE SMOKE
Check For
5. MISFIRING CYLINDERS

Chart 1

EXHAUST SMOKE ANALYSIS

SUGGESTED REMEDY

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune-up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up.

Avoid lugging the engine as this will cause incomplete combustion.

2. Check for use of an improper grade of fuel. Refer to *Fuel Oil Specifications* on Page 10-9-7.

3. Check for internal lubricating oil leaks and refer to the *High Lubricating Oil Consumption* chart.

4. Check for faulty injectors and replace as necessary.

Check for low compression and consult the *Hard Starting* chart.

The use of low cetane fuel will cause this condition. Refer to *Fuel Oil Specifications* on Page 10-9-7.

Chart 2

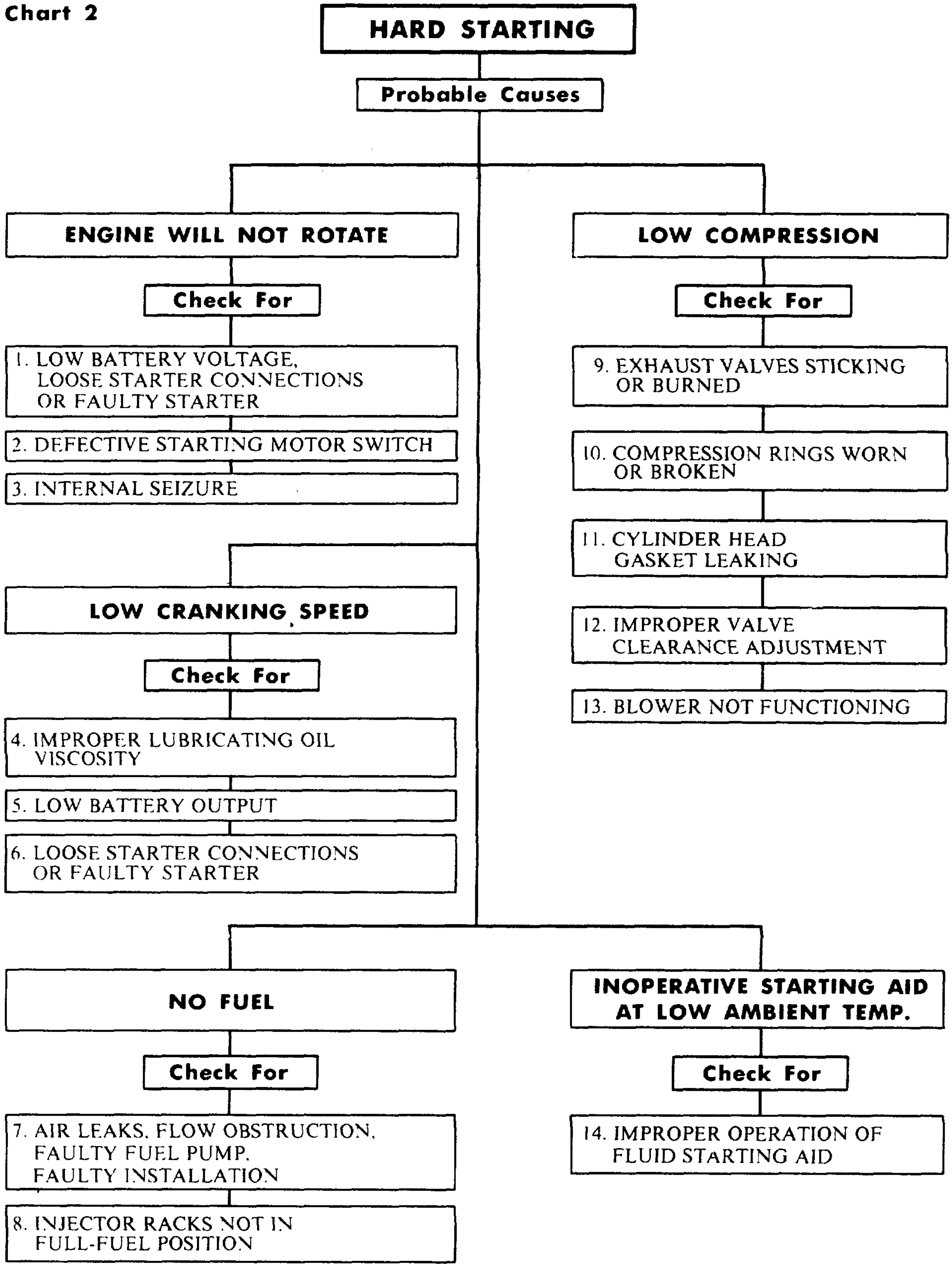

HARD STARTING
Probable Causes
ENGINE WILL NOT ROTATE
Check For
1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE
LOW CRANKING SPEED
Check For
4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER
NO FUEL
Check For
7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION
LOW COMPRESSION
Check For
9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.
Check For
14. IMPROPER OPERATION OF FLUID STARTING AID

Chart 2

HARD STARTING

SUGGESTED REMEDY

1. Refer to Items 2, 3 and 5 and perform the operations listed.

2. Replace the starting motor switch.

3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.

4. Refer to *Lubricating Oil Specifications* on Page 10-9-9 for the recommended grade of oil.

5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

Replace terminals that are damaged or corroded.

At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.

6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.

7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for bind in the governor-to-injector linkage. Readjust the governor and injector controls if necessary.

9. Remove the cylinder head and recondition the exhaust valves.

10. Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.

11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.

12. Adjust the exhaust valve clearance.

13. Remove the flywheel housing cover at the blower drive support. Then remove the snap ring and withdraw the blower drive shaft from the blower. Inspect the blower drive shaft and drive coupling. Replace the damaged parts. Bar the engine over. If the blower does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If visual distress is noted, remove the blower (refer to Page 10-4-9).

14. Operate the starting aid according to the instructions under *Cold Weather Starting Aid*.

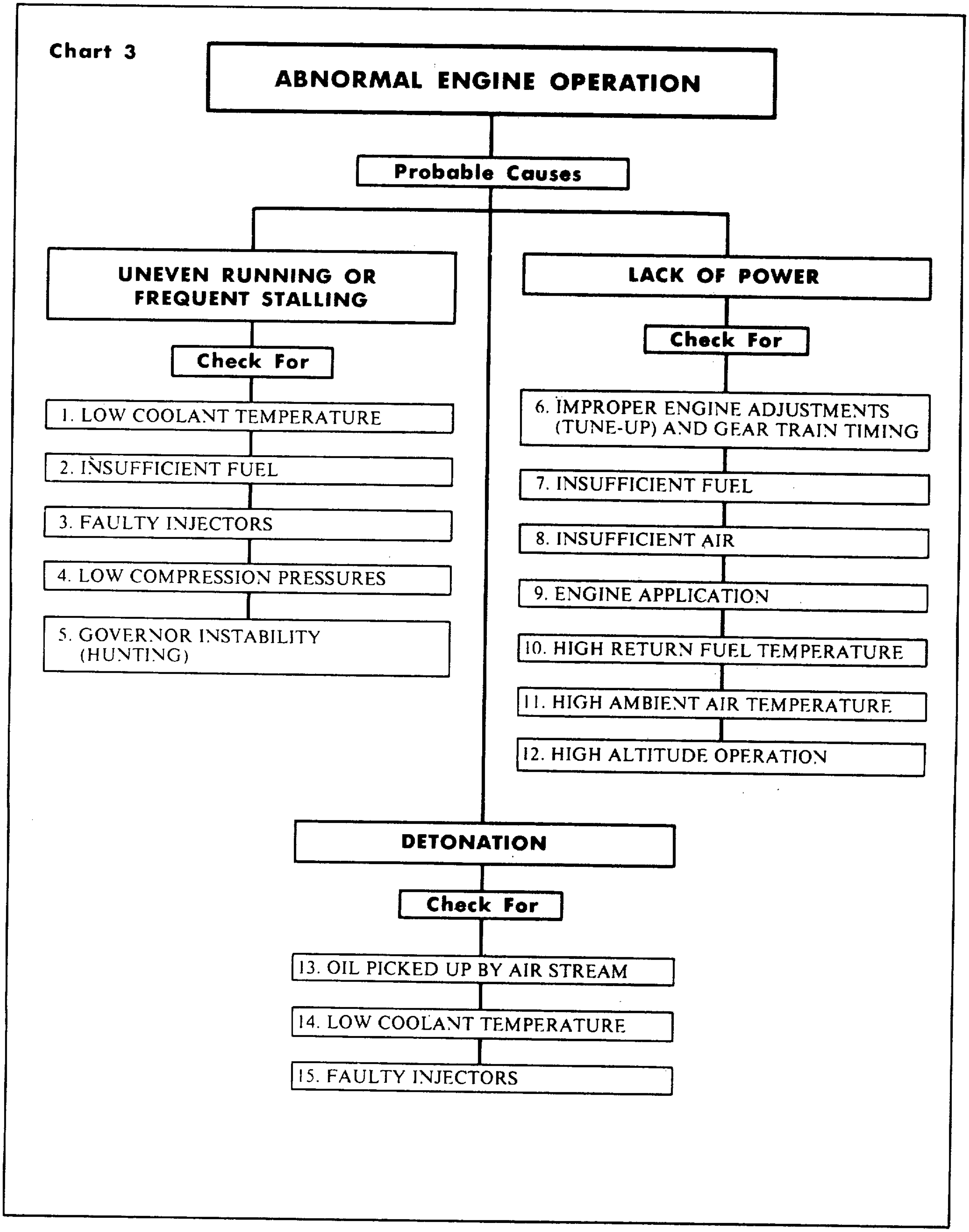


Chart 3
ABNORMAL ENGINE OPERATION
Probable Causes
UNEVEN RUNNING OR FREQUENT STALLING
Check For
1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)
LACK OF POWER
Check For
6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION
DETONATION
Check For
13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

Chart 3

ABNORMAL ENGINE OPERATION

SUGGESTED REMEDY

1. Check the engine coolant temperature gage and, if the temperature does not reach 160-185° "F (71-85 "°C) while the engine is operating, consult the Abnormal Engine Coolant Temperature chart.

2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* chart.

3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinders and consult the *Hard Starting* chart if compression pressures are low.

5. Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

6. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* chart.

7. Check for damaged or dirty air cleaner and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* chart).

8. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

9. Refer to Item 13 on Chart 4.

10. Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size, for each 10 °F (6 °C) temperature rise above 90 °F (32 °C) will occur. Relocate the engine air intake to provide a cooler source of air.

11. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Check for a defective blower-to-block gasket. Replace the gasket, if necessary.

12. Refer to Item 1 of this chart.

13. Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

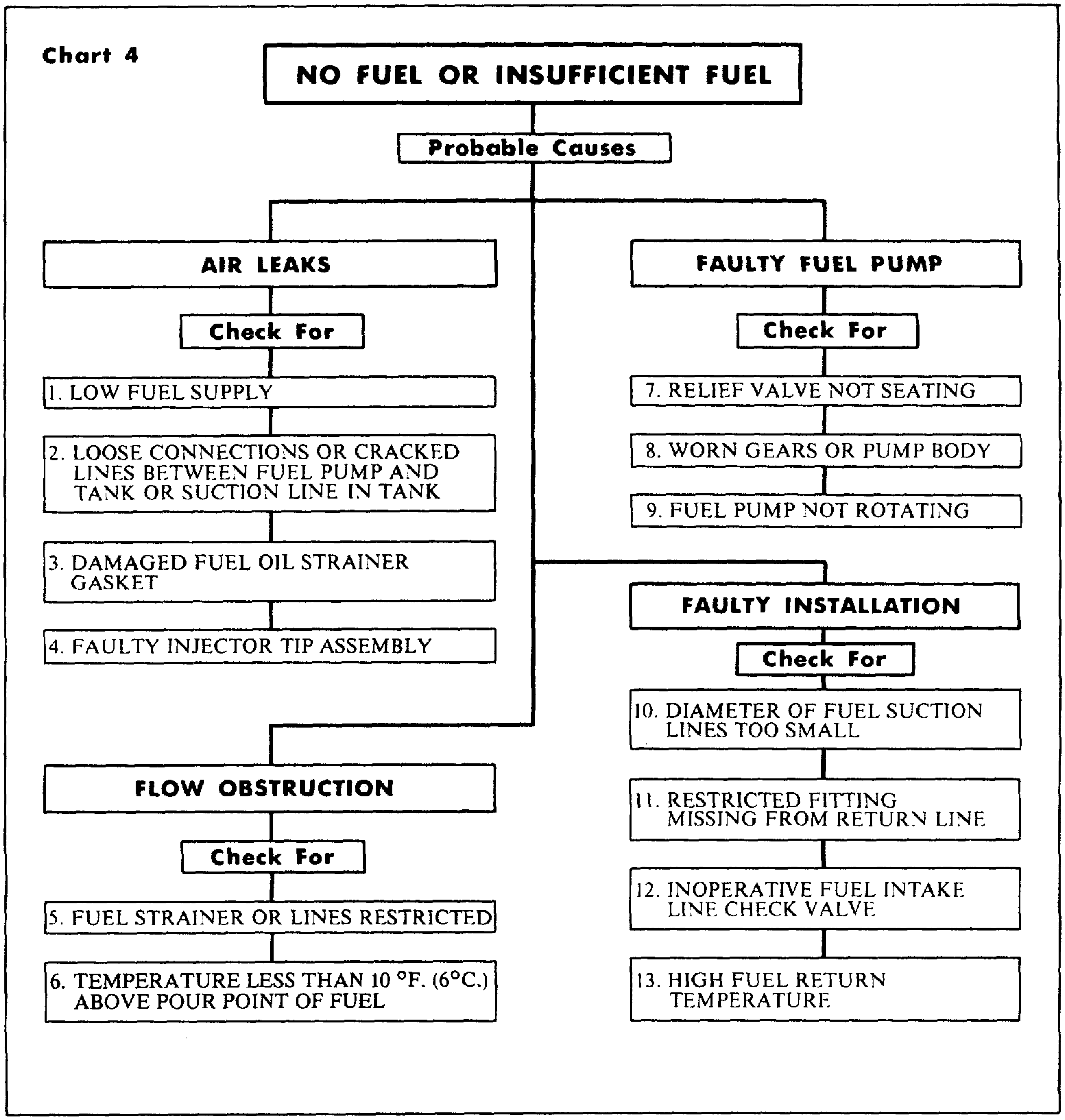


Chart 4
NO FUEL OR INSUFFICIENT FUEL
Probable Causes
AIR LEAKS
Check For
1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY
FAULTY FUEL PUMP
Check For
7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING
FAULTY INSTALLATION
Check For
10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE
FLOW OBSTRUCTION
Check For
5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURE LESS THAN 10 °F. (6°C.) ABOVE POUR POINT OF FUEL

Chart 4

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.

2. Perform a *Fuel Flow Test* and, if air is present, tighten loose connections and replace cracked lines.

3. Perform a *Fuel Flow Test* and, if air is present, replace the fuel strainer gasket when changing the strainer element.

4. Perform a *Fuel Flow Test* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.

5. Perform a *Fuel Flow Test* and replace the fuel strainer and filter elements and the fuel lines, if necessary, 6. Consult the Fuel Oil Specifications for the recommended grade of fuel.

7. Perform a *Fuel Flow Test* and, if inadequate, clean and inspect the valve seat assembly.

8. Replace the gear and shaft assembly or the pump body.

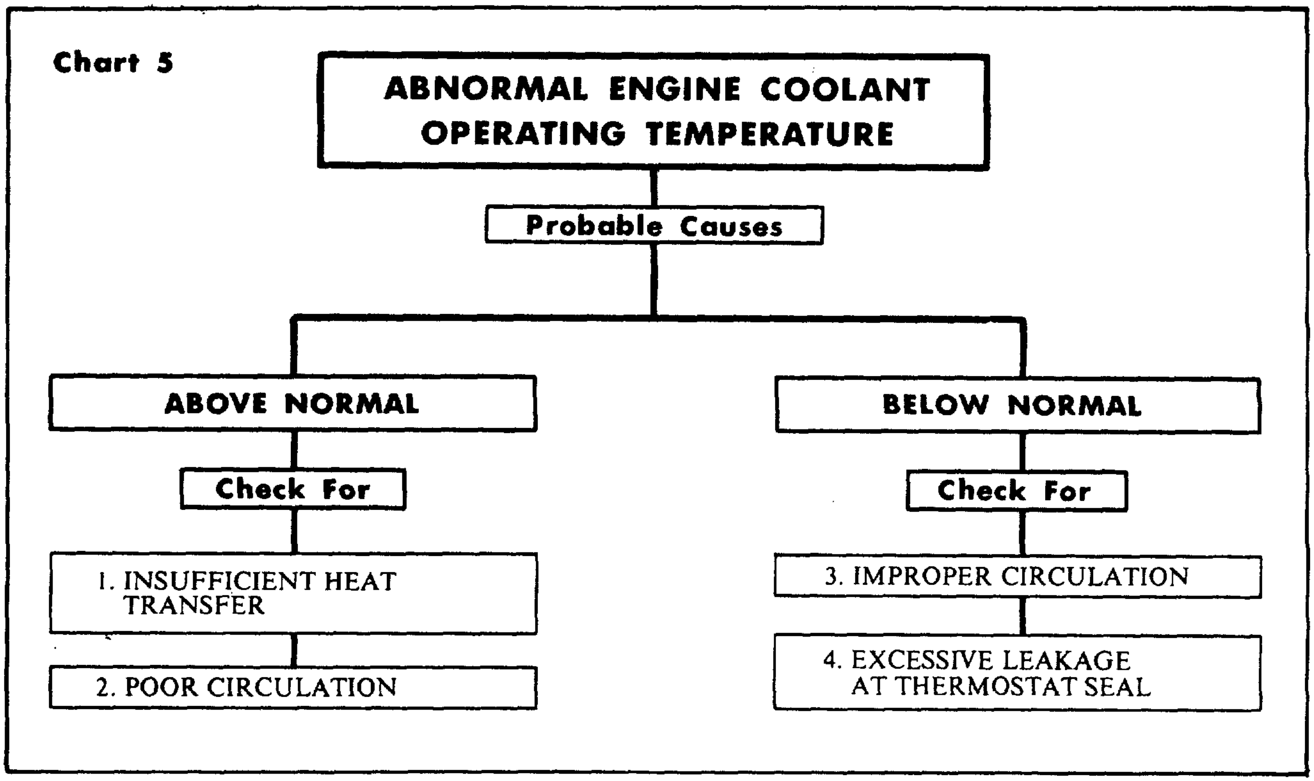
9. Check the condition of the fuel pump drive and blower drive and replace defective parts.

10. Replace with larger tank-to-engine fuel lines.

11. Install a restricted fitting in the return line.

12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.

13. Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150° F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.



SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

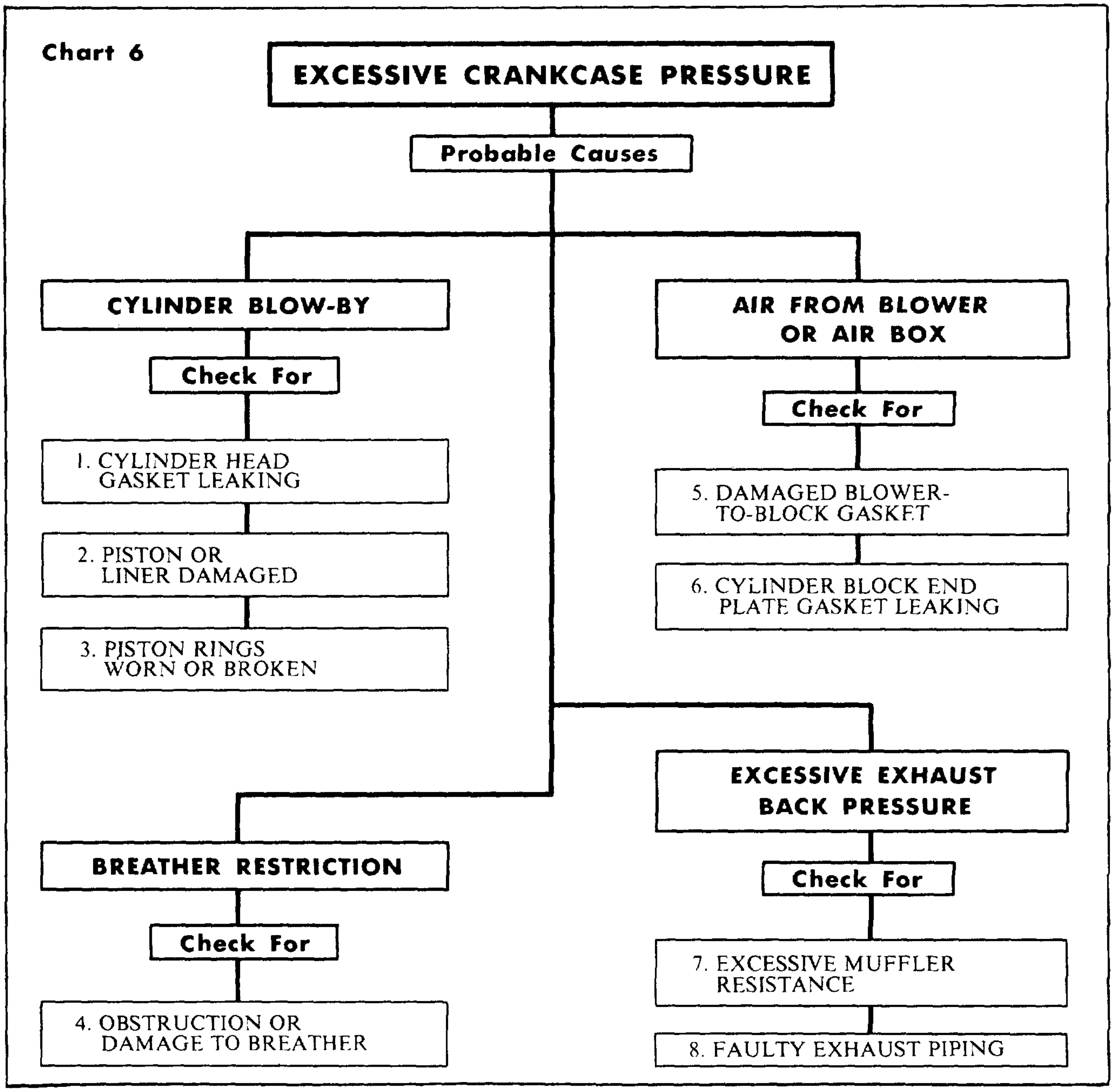
Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

4. Excessive leakage of coolant past the thermostat seal is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal



SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression. remove the cylinder head and replace the head gaskets.

2. Inspect the piston and liner and replace damaged parts.

3. Install new piston rings.

4. Clean and repair or replace the breather assembly.

5. Replace the blower-to-block gasket.

6. Replace the end plate gasket.

7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.

8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

Chart 7

LOW OIL PRESSURE

MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160 °F (71 °C)

Probable Causes

LUBRICATING OIL

Check For

1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY

POOR CIRCULATION

Check For

3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING

PRESSURE GAGE

Check For

8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY

OIL PUMP

Check For

12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. LOOSE END COVER BOLTS
17. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

2. Consult the Lubricating Oil Specifications on Page 10-9-9 for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution. Refer to Fuel Leak Detection on Page 10-3-56.

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

4. Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

6. Change the bearings. Consult the *Lubricating Oil Specifications* on Page 10-9-9 for the proper grade and viscosity of oil. Change the oil filters.

7. Replace missing plugs.

8. Check the oil pressure with a reliable gage and replace the gage if found faulty.

9. Remove and clean the gage line; replace it, if necessary.

10. Remove and clean the gage orifice.

11. Repair or replace defective electrical equipment.

12. Remove and clean the oil pan and oil intake screen. Consult the *Lubricating Oil Specifications* on Page 10-9-9 for the proper grade and viscosity of oil. Change the oil filters.

13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.

14. Disassemble the piping and install new gaskets.

15. Remove the pump. Clean and replace defective parts.

16. Remove the oil pan and tighten the oil pump end cover bolts.

17. Remove the flange and replace the gasket.

Chart 8

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. OVER-FILLED CRANKCASE
4. PLUGGED BREATHERS
5. HIGH CRANKCASE PRESSURE
6. BLUE EXHAUST SMOKE
7. EXCESSIVE OIL IN AIR BOX

OIL CONTROL AT CYLINDER

Check For

11. LOW COMPRESSION
12. PISTON PIN RETAINER LOOSE
13. OIL CONTROL RINGS WORN, BROKEN, IMPROPERLY INSTALLED OR SCORED.
14. EXCESSIVE OIL IN AIR BOX
15. DIRT IN AIR INTAKE SYSTEM
16. SCORED LINERS OR PISTONS
17. EXCESSIVE OIL IN CRANKCASE

INTERNAL LEAKS

Check For

8. BLOWER OIL SEALS LEAKING
9. OIL COOLER CORE LEAKING
10. WORN EXHAUST VALVE GUIDES

Chart 8

HIGH LUBRICATING OIL CONSUMPTION

SUGGESTED REMEDY

NOTE: Lube oil consumption must be verified after each repair is made.

1 & 2. Repair oil leaks by replacing necessary gaskets, seals or tightening connections. Steam cleaning the engine and operating at no-load rpm, (engine at operating temperature) will often reveal excessive oil leaks.

3. Check dipstick and tube for proper oil pan levels to correct overfilled crankcase.

4. Check crankcase pressure. Clean breathers and recheck crankcase pressure.

5. Overhaul blower, or rekit engine (refer to Items 9, 13 and 14). Also, refer to the Excessive Crankcase Pressure chart.

6. Remove and inspect exhaust manifolds and stacks for wetness or oil discharge. Excessive clearance between the valve stem and the valve guide can produce oil in the cylinders and stack. Repair the valve guides and/or install valve stem seals.

7. Refer to the *Abnormal Engine Operation* chart.

8. Remove the piping from the air inlet housing and remove from the to blower. Operate the engine at approximately one-half throttle and at idle and inspect blower end plates for evidence of oil leakage past the seals. Use a flashlight to illuminate the end plates. If excessive oil leakage is evident on the end plates, overhaul blower.

Extreme care should be taken to prevent personal injury.

9. Pressure test cooling system. If leak is found, remove and replace the oil cooler.

Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.

10. Replace worn exhaust valve guides.

11. Take compression test refer to Item 14.

12. Run engine at idle speed with the air box cover removed (one at a time) to determine if oil is uncontrolled as evidenced by slobbering out the liner ports. Inspect all cylinders as more than one may be slobbering. Repair affected cylinders. Slobbering can also be caused by worn oil control rings.

> **CAUTION**: Extreme care should be taken to prevent personal injury.

13. Check for faulty engine air induction system allowing contaminated air to enter the engine. A compression test with excessively low readings will indicate worn out cylinders. Remove and replace cylinder kits.

14. Refer to Items 9, 13 and 14.

15. Refer to Item 14.

16. Check the crankshaft thrust washers for wear. Replace wore and defective parts.

17. Decrease the installation angle.

18. Fill the crankcase to the proper level only.

STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 days or less)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.

2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.

3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

> **NOTE**: Do not drain the fuel system or the crankcase after this run.

4. Check the air cleaner and service it, if necessary, as outlined on Page 104-2.

5. If freezing weather is expected during the storage period, add an ethylene glycol base antifreeze solution in accordance with the manufacturer's recommendations. Drain the raw water system and leave the drain cocks open.

6. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with compressed air.

7. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, and lubricating oil.

EXTENDED STORAGE (more than 30 days)

To prepare an engine for extended storage, (more than 30 days), follow this procedure:

1. Drain the cooling system and flush with clean, soft water. Refill with clean, soft water and add a rust inhibitor to the cooling system (refer to *Corrosion Inhibitor* under Engine Coolant on Page 10-9-14).

2. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.

3. Reinstall the injectors, time them and adjust the exhaust valve clearance.

4. Circulate the coolant by operating the engine until normal operating temperature is reached (see Page 10-9-13).

5. Stop the engine.

6. Drain the engine crankcase, then reinstall and tighten the drain plug. Install new lubricating oil filter.

7. Fill the crankcase to the proper level with a 30 weight preservative lubricating oil MIL-L-21260B, Grade 2.

8. Drain the fuel tank. Refill with enough clean fuel oil to permit the engine to operate for about ten minutes.

9. Remove and discard the fuel filter and fuel strainer cartridges. Fill new cartridges two-thirds full of fuel oil and reinstall on the engine.

10. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine.

11. Refer to Page 10-4-3 and service the air cleaner.

12. Apply a non-friction rust preventive compound to all exposed parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

> **NOTE**: 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.

13. Drain the engine cooling system.

14. Drain the preservative oil from the engine crankcase. Reinstall and tighten the drain plug.

15. Remove and clean the battery(s) and battery cables with a baking soda solution and rinse them with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte, if necessary, and fully charge the battery. Store the battery in a cool (never below 32 °F or 0 °C) dry place. Keep the battery fully charged and check the level and the specific gravity of the electrolyte regularly.

16. Insert heavy paper strips between the pulleys and belts to prevent sticking.

17. Seal all engine openings, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

18. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.

19. Protect the engine with a good weather-resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

Detroit Diesel Allison does not recommend the outdoor storage of engines (or transmission). Nevertheless, DDA recognizes that in some cases outdoor storage may be unavoidable. If units must be kept out-off-doors, follow the preparation and storage instructions already given. Protect units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide air circulation.

> **NOTE**: Do not use plastic sheeting for outdoor storage. Plastic is fine for indoor storage. When used outdoors. however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. *Do not overlook the exhaust outlet.*

2. Wash the exterior of the engine with fuel oil to remove the rust preventive.

3. Remove the rust preventive from the flywheel.

4. Remove the paper strips from between the pulleys and the belts.

5. Remove the drain plug and drain the preservative oil from the crankcase. Reinstall the drain plug. Then refer to *Lubrication System* on Page 10-5-3 and fill the crankcase to the proper level, using a pressure prelubricator, with the recommended grade of lubricating oil.

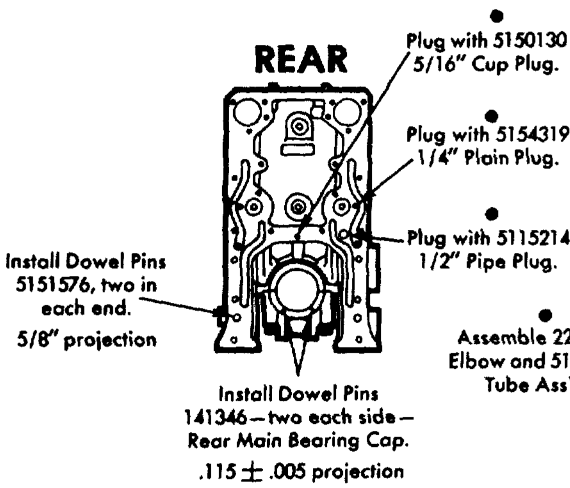
6. Fill the fuel tank with the fuel specified under *Fuel Specifications* (Page 10-9-7).

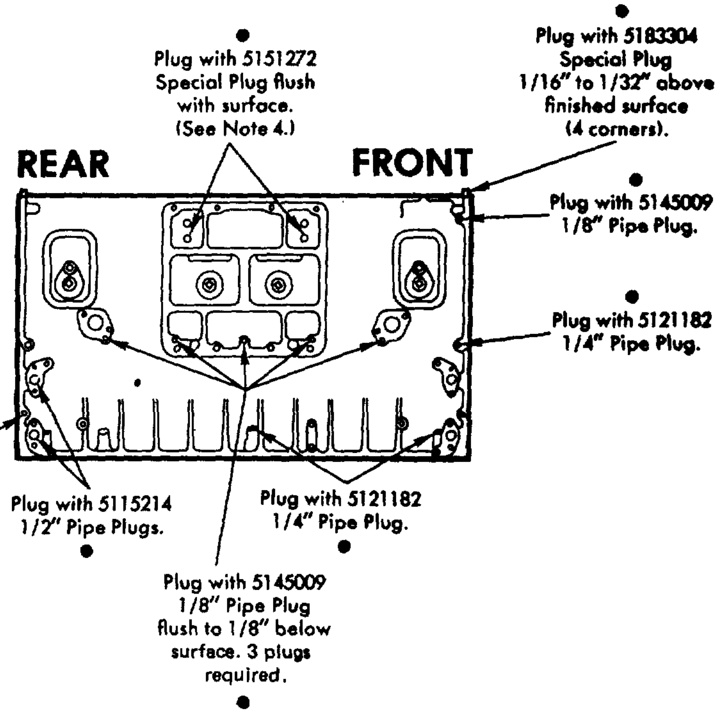
7. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with a solution of water and an ethylene glycol base antifreeze (refer to Page 10-9-16).

8. Install and connect the battery.

9. Service the air cleaner as outlined on Page 10-4-3.

PLUGGING CHARTS
LC and RC ENGINES



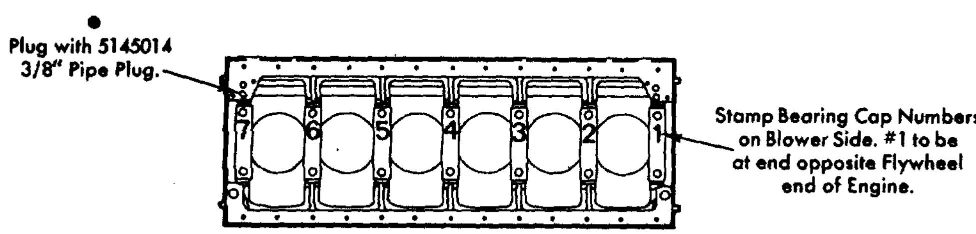


STANDARD PIPE PLUG TORQUE*

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

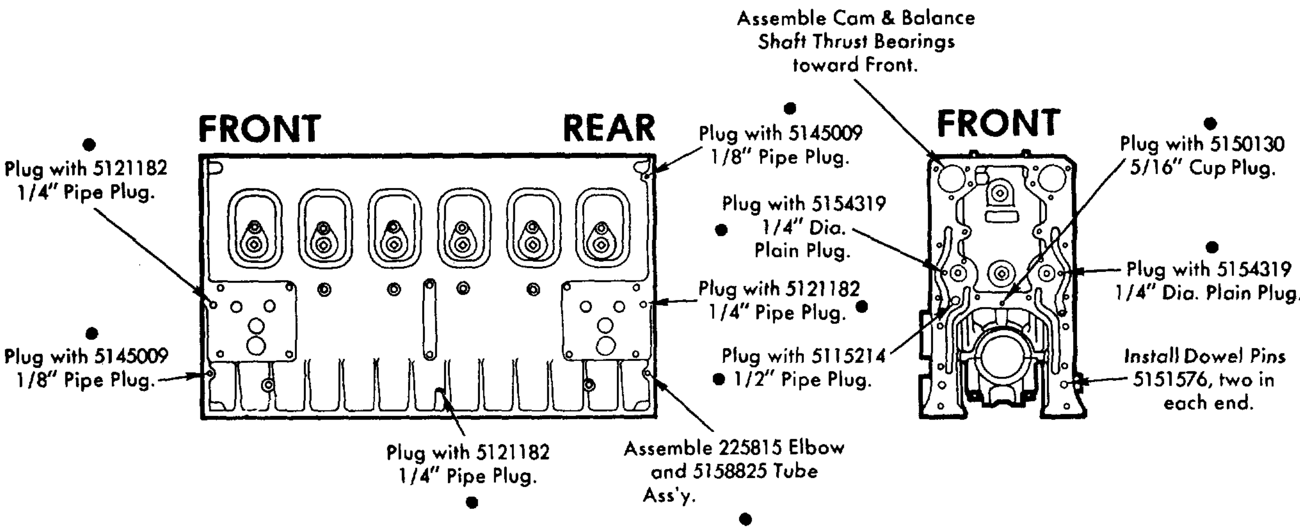
*CAUTION—Do Not Over Torque Teflon Wrapped Pipe Plugs.

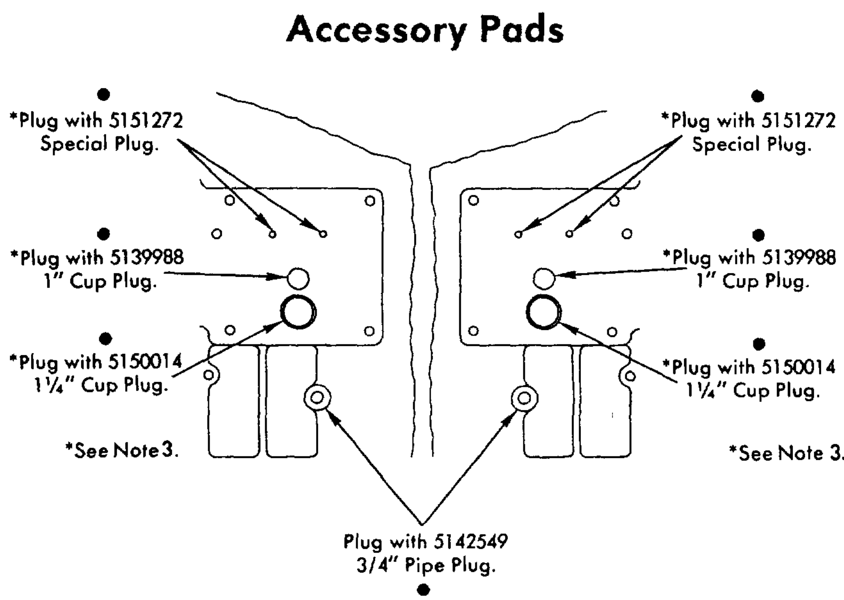
(See Note 2.)



*Not included with service block.

PLUGGING CHARTS
LC and RC ENGINES (Cont'd)





- NOTES -

(1) Apply Loctite J-26558-92 pipe sealer or equivalent with teflon

• prior to installation.

(2) one 5151272 plug when using supercharged air compressor connection.

(3) Do not install plugs when crankcase breather is to be installed on accessory pod.

SUBSECTION 11 FRONT AXLE AND STEERING

POWER STEERING PUMP

DESCRIPTION

A. GENERAL
The assembly and construction of the VT16 series pumps are illustrated in cutaway in Figure 1. The unit consists principally of a body, cover, ring, rotor, vanes, pressure plate, relief valve sub-assembly, driveshaft and reservoir. The vanes are contained in the rotor slots and follow the cam shaped contour of the ring as the rotor is driven in rotation by the driveshaft. Fluid flow is developed by the vanes carrying fluid around the ring contour.

PRINCIPLES OF OPERATION

A. GENERAL
These units depend on the vehicle engine as a source of rotary mechanical power to produce fluid flow. Inlet flow is created by a decreased pressure set up by the action of the pumping cartridge. Flow is directed through the cartridge to the pressure port and monitored by the flow control and relief valve.

B. PUMPING CARTRIDGE
The pump cartridge consists principally of a ring, rotor and vanes (see Figure 2). The rotor is driven within the ring by a driveshaft, coupled to the power source. Radial movement of the vanes, and the rotation of the rotor, cause the chamber area between vanes to increase in size at the inlet (large diameter) section of the ring. This results in a low pressure, or vacuum in the chamber. This pressure differential forces oil to flow into the inlet chamber by atmospheric pressure. Oil is then trapped between the rotating vanes and is forced, through porting in the pressure plate, to the outlet and into the system as the chamber size

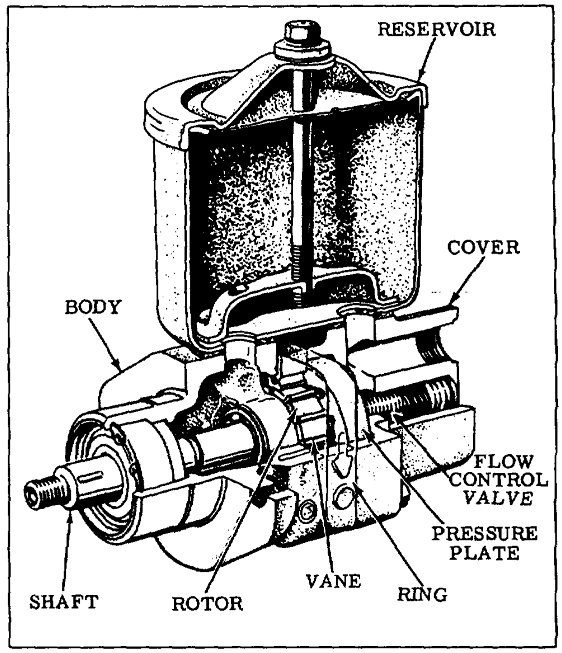


FIGURE 1

decreases at the pressure quadrants (small diameter) section of the ring. System pressure fed under the vanes assures sealing contact of the vanes against the ring during normal: operation.

C. HYDRAULIC BALANCE
The ring is shaped so that two pumping chambers are formed 180° apart. Thus, any hydraulic loads on the bearings are cancelled.

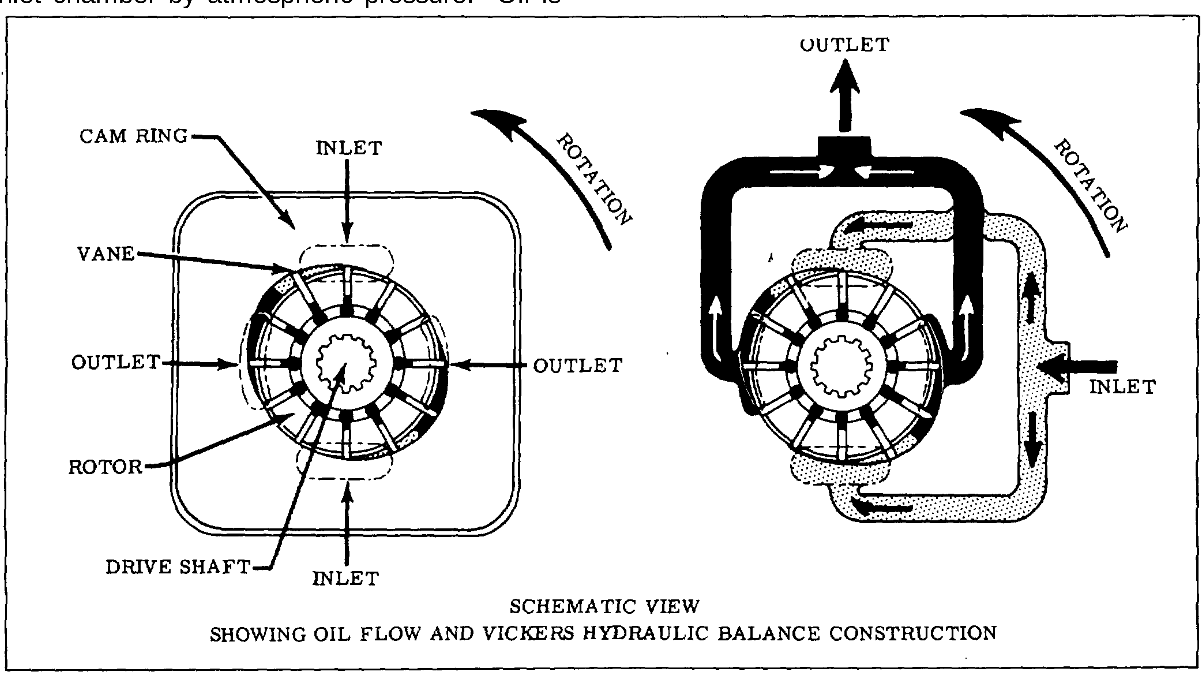


FIGURE 2

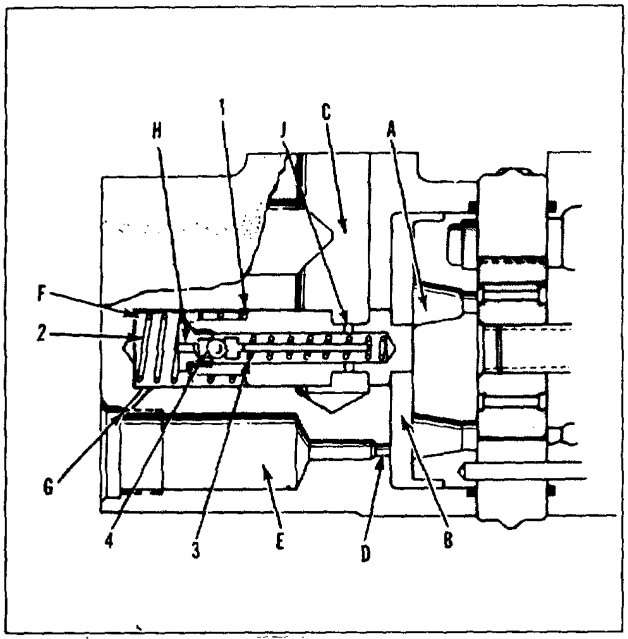


FIGURE 3

D. FLOW CONTROL AND RELIEF VALVE

1. Maximum fluid delivery and maximum system pressure are determined by the integral flow control and relief valve (Figure 3). The rate of flow depends on the sizes of the restriction, (D) in the cover. Excess oil is ported past the sliding spool (1) to the return circuit by way of passage C.

2. When all pump delivery can pass through the restriction to the load, the spool is held in the closed position by the large spring (2) and passage C is blocked from chamber B. This is the condition illustrated in Figure 4-A.

3. When pump delivery is greater than the flow rate determined by tile restriction (D), a pressure build-up in chamber B forces the spool open against the large spring force. Excess fluid is throttled past the spool to passage C and back to inlet, as shown in Figure 4-B.

4. Figure 4-C shows the condition when pressure in thesystem builds up to the relief valve setting Pressure is transmitted through sensing orifices G and H aid forces the ball (4) from its seat. Fluid flow is then from chamber B, through orifice D, passage E, orifices G, H and J to, passage C and to inlet. The pressure drop across restriction D resulting from this flow causes a differential pressure on the spool ends and the spool is shifted against the large spring, permitting the remainder of pump delivery to flow from chamber B to passage C.

5. A second function of the valve sub-assembly and #2 is to hold the pressure plate against the pump cartridge until pressure builds up in chamber B.

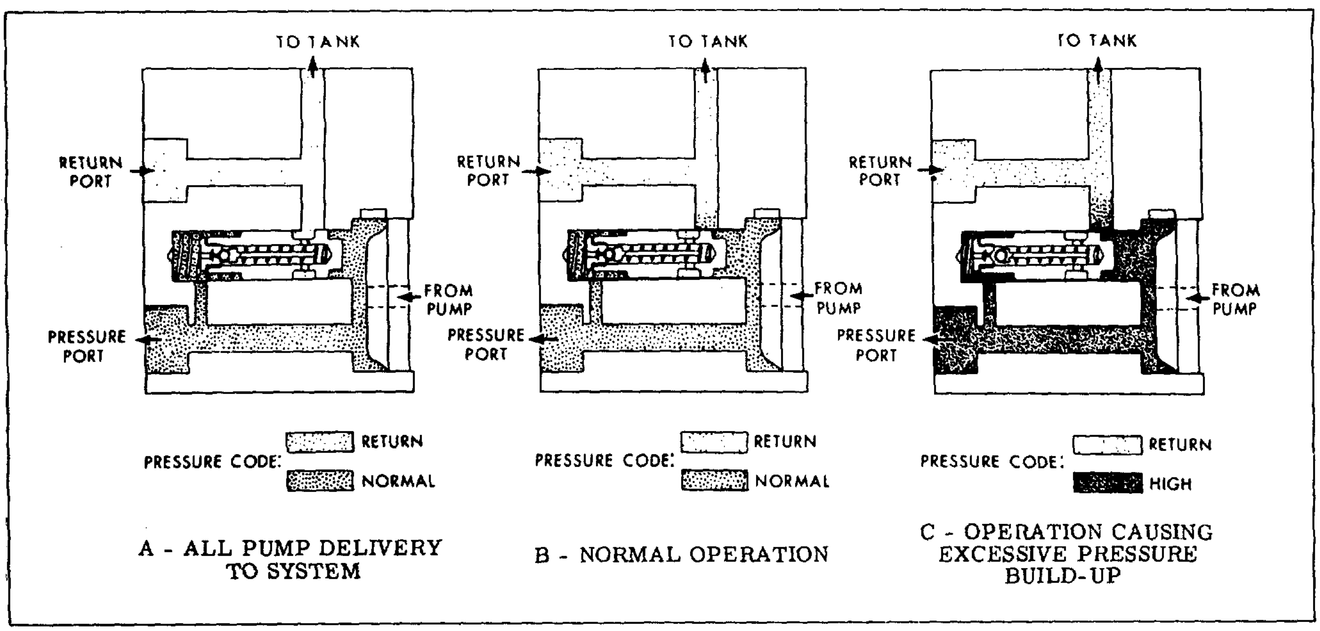


FIGURE 4

INSTALLATION AND OPERATION

1. Care must be exercised in pump mounting to insure correct alignment with the driving medium. If indirect drive is used} belts and pulleys must be properly aligned and adjusted to prevent undue side loads being imposed on the shaft bearings.

2. Pumps are manufactured for either right hand or left hand rotation. They must be driven in the direction of the arrow on the pump ring or severe damage may result.

3. Normally these pumps require no manual priming. It is essential, however, that after starting a minimum drive speed of 400 rpm be maintained until the pump picks up its prime. Failure to observe this precaution can result in scoring and possible seizure of the pump due to a lack of oil for lubrication.

4. An integral relief valve protects the hydraulic system components by limiting the maximum pressure.

5. Relief valve sub-assemblies are pre-set and tested by Vickers for given pressure settings.

6. Operation in excess of 180°F. results in increased wear of the system components and causes more rapid deterioration of the oil. The hydraulic system that is designed to maintain a temperature of 160°F. or less is desirable.

HYDRAULIC FLUID RECOMMENDATIONS

NOTE*: Do not use hydraulic brake fluid. Use only high grade hydraulic oil of the viscosities recommended in paragraph D of Hydraulic Fluid Recommendations. Do not use fire resistant fluids in Vickers' products without consulting Vickers' Mobile Division application engineering personnel. "0" rings, seals and packings which are compatible with petroleum base fluids are not compatible with synthetic type fluids.*

1. Oils used in hydraulic systems perform the dual function of lubrication and transmission of power. Oil must be selected with care and with the assistance of a reputable supplier. Use of an improper grade of oil may result in inlet vacuum conditions exceeding the recommended maximum 5 inches of mercury, and will reduce the life expectancy of the hydraulic equipment. Where vacuum exceeds 5 inches of mercury, and it is not caused by improper oil selection, the Vickers Mobile Hydraulic Division is to be consulted for recommendations.

2. Crankcase oils meeting or exceeding the "Five Engine Test Sequence" for evaluating oils for API (American Petroleum Institute) service MS (Maximum Severity) best serve the needs of mobile hydraulic systems. These engine sequence tests were adopted by the Society of Automotive Engineers, American Society for Testing Materials, and automotive engine builders. The MS classification is the key to selection of oils containing the type of compounding that will extend the operating life of the hydraulic system. Oils meeting Diesel engine requirements, DG and DS classifications, may or may not have the type of compounding desired for high performance hydraulic systems.

3. Research has developed a number of additive agents which materially improve various characteristics of oils for hydraulic systems. They may be selected for compounding with a view toward reducing wear, increasing chemical stability, inhibiting corrosion, depressing pour point and improving the anti-foam characteristics. Proper use of additive agents requires specialized knowledge, and they should be incorporated by the oil manufacturer only, as serious trouble may otherwise result.

4. Most oil companies have several brands of crankcase oils of somewhat varying formulation that will meet the API service classification of MS. The more desirable of these oils for hydraulic service will contain higher amounts of the type of compounding that avoids scuffing and wear of cam lobes and valve lifters. These oils will also be formulated to be stable under oxidative conditions and when in contact with small amounts of moisture. There should also be reasonable protection against rust to any ferrous materials submerged in the oil or covered by the oil's film.

5. Table I summarizes the oil types (viscosity and service classification) that are recommended for use with Vickers equipment. This selection is most important and should be made with considerable care.

TABLE I.

Hydraulic System Operating Range (Min. to Max.)	SAE Viscosity	API Service Classification
0° F. to 180°F.	10W	MS
15°F. to 210°F.	20-20W	MS
32°F. to 230°F.	30	MS
0°F. to 210°F.	10W-30	MS

6. These temperature ranges for each grade of oil are satisfactory if suitable procedures are followed for low temperature start-up conditions and if sustained operation is avoided at the upper temperature limits. For optimum operation, a maximum oil viscosity of 4000 SSU at the low temperature start-up condition and a minimum oil viscosity of 60 SSU for the sustained high temperature operating condition are recommended. Operation of the fluid at temperatures below 160°F. is recommended to obtain the maximum unit and fluid life.

7. Automatic Transmission Fluid, Type "A" is usually satisfactory for power steering systems or those systems operating under moderate hydraulic service.

SERVICE INSPECTION AND MAINTENANCE

A. SERVICE TOOLS
The only special service tool required is a shaft oil seal driver. The driver is used to insure that the seal is not damaged during installation. A piece of tubular round stock should be machined so that the outside diameter is 1-5/8 inches and the inside diameter is 1 inch. The tool must be at least 2-1/2 inches long and the ends must be squared.

B. INSPECTION
Periodic inspection of oil condition and pressure connections will save time consuming breakdowns and unnecessary parts replacement.

1. All hydraulic connections must be tight. A loose connection in pressure lines will allow fluid to escape. In suction and return lines, loose connections will permit air in the pump, resulting in noisy and erratic operation.

2. System filters and the reservoir should be checked for foreign particles. If contamination is found, the system should be drained.

a. The reservoir must be cleaned thoroughly before refilling. All lint particles must be removed to avoid possible clogging of system filters.

b. New oil of the proper specification, poured through a micron filter or a 200 mesh screened funnel, should be used to refill the reservoir.

C. MAINTENANCE

1. All openings in the circuit must be properly capped if a unit is removed for service. Units removed also should be capped or plugged to prevent the entry of dirt or other foreign matter.

2. These pumps require no adjustments other than maintaining correct shaft alignment.

D. LUBRICATION
Lubrication of these pumps is automatically accomplished by the hydraulic fluid.

E. TROUBLE SHOOTING
Table II lists the pump difficulties most commonly encountered and indicates the probable causes and remedies. It must be remembered that many apparent pump failures can actually be other units in the system. Improper operation is best diagnosed with adequate testing equipment and a thorough understanding of the complete hydraulic system.

F. SPARE PARTS
Only genuine parts manufactured or sold by Vickers Incorporated should be used. These are listed in parts catalog M-1370-S. Copies are available on request.

TROUBLESHOOTING

TABLE II - TROUBLE SHOOTING CHART

TROUBLE	PROBABLE CAUSE	REMEDY
PUMP NOT DELIVERING OIL	Driven in wrong direction of rotation.	Check direction of pump shaft rotation. It should rotate clockwise as viewed from the coupling end of the unit. See also reassembly instructions for pump cartridge.
	Pump drive shaft disengaged or sheared.	Remove pump. Determine damage to cartridge parts (see disassembly instructions). Replace sheared shaft and needed parts.
	Flow control valve stuck open.	Disassemble pump and wash control valve in a clean solvent. Return valve to its bore and slide it back and forth. No stickiness in movement should occur. If a gritty feeling is noted on the valve O.D. it may be polished with a crocus cloth. Avoid removal of excess material or rounding of valve edges during this operation. Do not attempt to polish the valve bore. Wash all parts before reassembly of pump. Fill system with clean oil per prescribed recommendations.

TABLE II. - TROUBLE SHOOTING CHART (CONTINUED)

TROUBLE	PROBABLE CAUSE	REMEDY
PUMP NOT DELIVERING OIL (CONTINUED)	Vane or vanes stick in rotor slots.	Disassemble pump. Examine rotor slots for dirt, grime or small metal chips. Clean rotor and vanes in a good grade solvent (mineral oil or kerosene). Reassemble parts and check for free vane movement.
	Oil viscosity too heavy to pick up prime.	Use fluid of the proper viscosity.
NOISY PUMP OPERATION	Pump intake partially blocked.	Drain system completely. Flush to clear pump passages. Flush and refill system with clean oil as per prescribed recommendations.
	Air vent for oil tank clogged or dirty strainer.	Remove filler cap and clean -air vent slot. Check strainer in tank for clogged condition. Drain, flush and add clean oil to system.
	Air being drawn into pump return connection.	Pump must receive air-free oil or pump will be noisy. Drain system. Tighten all hose connections. Clean or replace filter. Add clean oil of the proper viscosity.
	Leaking shaft seal.	Check pump shaft seal and replace if sealing lip has been damaged. Check for scoring of shaft at seal contact area. Replace faulty shaft.

OVERHAUL

A. DISASSEMBLY

CAUTION: Before removing a unit to be serviced, be sure it is not under pressure.

1. General - Use a puller to remove shaft gears or pulleys to prevent damage to the shaft and bearings.

During disassembly, pay special attention to identification of parts for proper reassembly. Refer to Figure 5 for identification of parts in the following discussion.

2. Cover End - Clamp the pump mounting flange in a vise. Be certain to use protective jaws.

a. Reservoir Remove the tank cover screw, lockwasher, washer, guide and guide gasket. Lift off the tank cover and gasket and remove the tank screws, tank, gaskets and spacers.

b. Remove the cover screws and separate the cover from the pump. Remove the control valve subassembly and spring and the cover "0" ring.

NOTE: Control valve subassemblies are preset and tested by Vickers and should not be disassembled. If any part is defective, the complete subassembly should be replaced.

c. Remove the pressure plate. Note the position of the pump ring for reassembly. Pull out the ring locating pins and remove the ring. Remove the vanes from the rotor slots and slide the rotor off the driveshaft. Remove the body "O" ring.

3. Shaft End - Remove the driveshaft key. Remove the bearing retaining snapring and gently tap the splined end of the shaft to remove the shaft and the outboard bearing. Support the outboard bearing inner race in an arbor press and press out the shaft. Remove the seal from the body with a hooked tool. Remove the inboard bearing from the shaft end of the body with a bearing puller or by tapping it out from the cover end.

B. INSPECTION, REPAIR AND REPLACEMENT

Discard all used seals and gaskets. Wash all parts in a clean mineral oil solvent and place them on a clean, lint-free surface for inspection. Soak new seals and "O" rings in hydraulic fluid prior to reassembly.

1. Cartridge, Body and Pressure Plate - Inspect all wearing surfaces for scoring. Light scoring can be removed from the body and wear plate with crocus cloth or by stoning or lapping.

Inspect the vanes for wear. Vanes must not have excessive play in the rotor slots or burred edges. Replace the vanes if they are defective. Check each rotor slot for sticky vanes or for wear. Vanes should drop in the rotor slots from their own weight when both the rotor and vanes are dry.

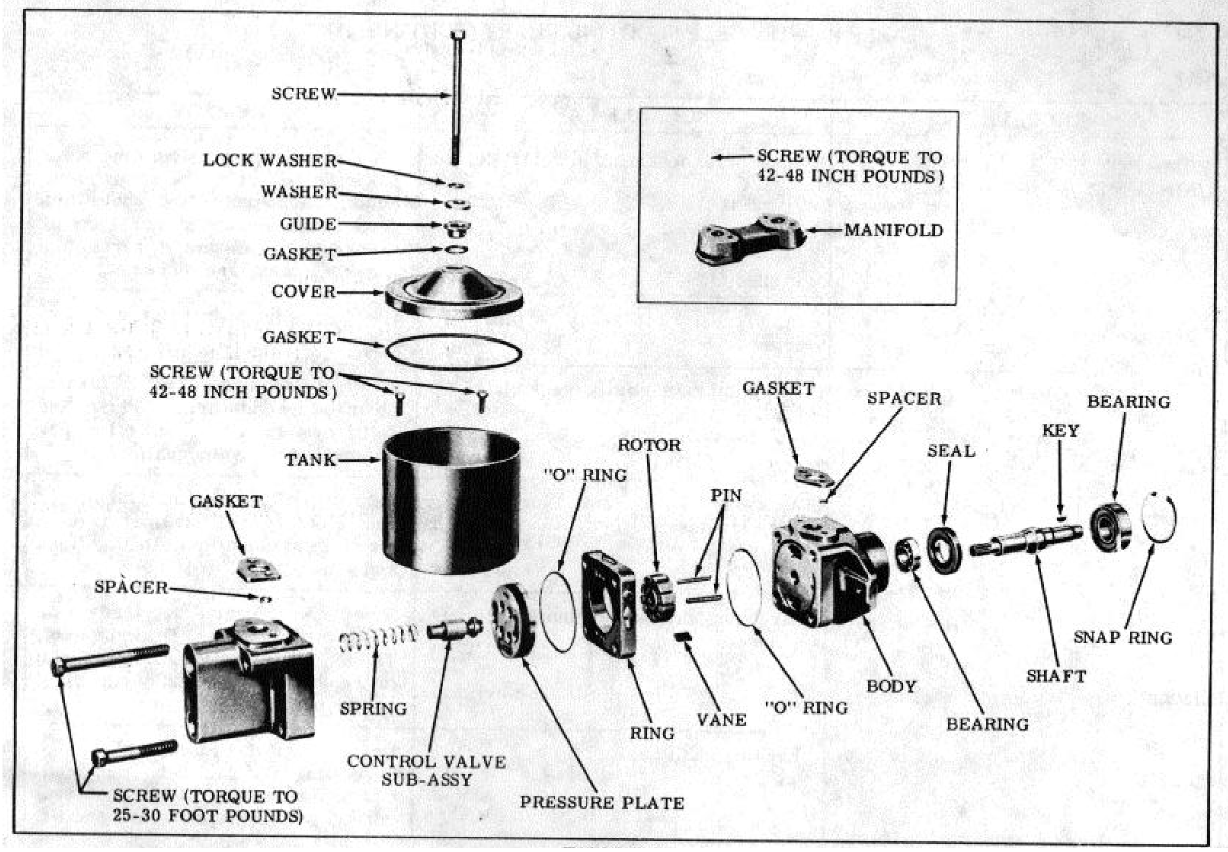


FIGURE 5

2. Control Valve Sub-Assembly - Check that the valve moves freely in its bore in the cover and check the valve and cover bore for excessive wear and scoring. Replace both the cover and valve sub-assembly if they are deeply scored.

3. Bearings - Replace the bearings if there is any roughness in their action or if any race or ball is pitted, cracked or scored.

4. Driveshaft and Shaft Seal - Always replace the seal at overhaul. Check the sealing journal on the shaft for scoring. Replace the shaft if it is worn; do not install a worn shaft with a new seal.

5. Body and Cover - Stone the mating surfaces if there are any burrs or sharp edges. Rewash the parts after stoning.

C. REASSEMBLY

1. General - Immerse all parts in clean hydraulic oil to facilitate assembly and prevent damage to seals.

2. Shaft End - Carefully seat the inboard (body) bearing in the body by pressing on the outer race. Install the outboard bearing on the shaft by supporting the inner race and pressing the shaft into it. Using the shaft seal driver. Install the shaft seal with the lip facing inward. Be sure that both bearings and the seal are properly seated. Lubricate the seal lip with petroleum jelly and slide the shaft into position. Install the snapring in the body.

3. Cover End - Support the body on blocks with the shaft end down before reassembling the pump cartridge and cover. Coat the two large "O" rings with petroleum jelly and install them in the grooves in the body and cover.

a. Place the ring against the pump body so that the cam contour is the same as at disassembly and the arrows point in the correct direction of rotation Install the rotor and insert the vanes in the rotor so that the radiused edges are against the ring cam. Position the pressure plate over the locating pins. Be sure the plate is flat against the ring.

b. Insert the spring in the cover bore and install the control valve, small land toward the cartridge. Install the cover over the pressure plate and flush against the ring. Install the cover screws and tighten them to 25-30 foot pounds torque. Turn the drive shaft through by hand to be sure it does not bind.

c. Reservoir - Place the gaskets and spacers on top of the pump and install the tank and tank screws. Torque tighten the screws to 4248 inch pounds. Plug the ports in the pump cover and fill the reservoir with clean hydraulic fluid poured through a micron filter. Turn the driveshaft several times in the proper direction of rotation to fill all the pump chambers and then refill the reservoir.

Install the tank cover gasket and cover. Assemble the bolt guide and gasket and install the guide in the cover. Assemble the lockwasher and washer on' the cover screw and install and tighten the screw.

STEERING GEAR REPLACEMENT

REMOVAL

1. Remove screws (1), steering cap (2) and nut (3).
2. Use a suitable puller and remove steering wheel (4), from splined shaft of steering column (5).
3. Label, disconnect and cap hydraulic steering lines (6), (7),(8),(9).
4. Remove U-bolt (10) from steering column bracket (11).
5. Remove four bolts, nuts, washers (12) that attach bracket (13) to firewall of vehicle. The steering column and valve can now be removed from the engine side of the firewall.

The steering gear is not repairable and if replacement is necessary, it must be replaced as a unit.

INSTALLATION

Installation is the reverse procedure.

STEERING GEAR

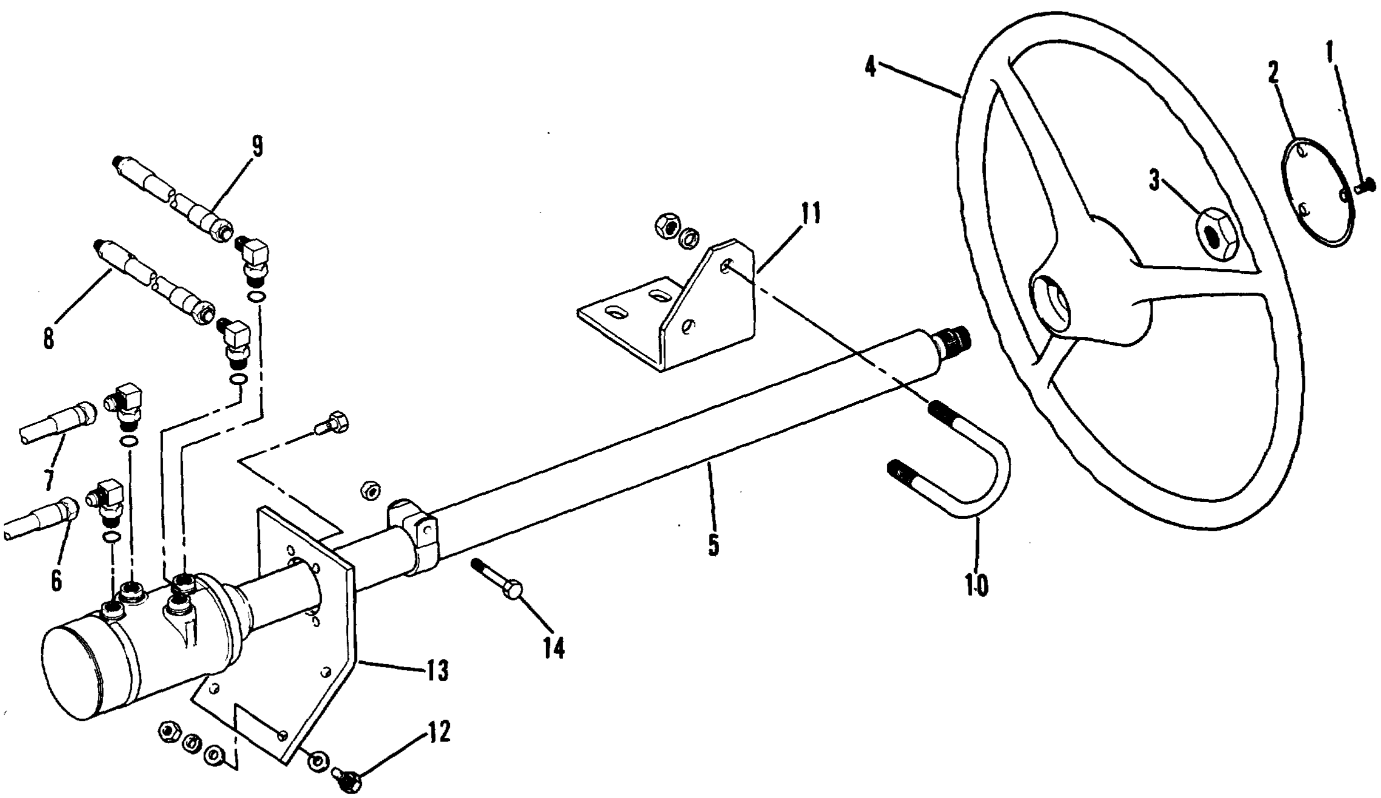
FRONT AXLE REPLACEMENT

REMOVAL

1. Place jack stands under mixer front frame behind front axle.
2. Remove both front wheels.
3. Disconnect the steering cylinder from the axle at both ends and remove with hydraulic lines attached.
4. Place lifting sling around axle.
5. Remove axle pivot pin.
6. Remove axle assembly and place in suitable area for repair.

INSTALLATION

Installation is the reverse procedure.



STEERING GEAR

FRONT AXLE REPAIR

1. Inspect pivot pin axle bushings (4), thrust washers (3) and spacer (5) for wear or looseness. Replace if necessary.

2. Inspect tie rod ends (28), (31) for excessive looseness. Replace if necessary.

3. Inspect steering knuckle pins (16) for excessive looseness. Replace bushings (14), and thrust bearings (18) if necessary.

4. Disassemble wheel bearings (45) and (40) of both wheels.

5. Inspect bearings and replace if necessary.

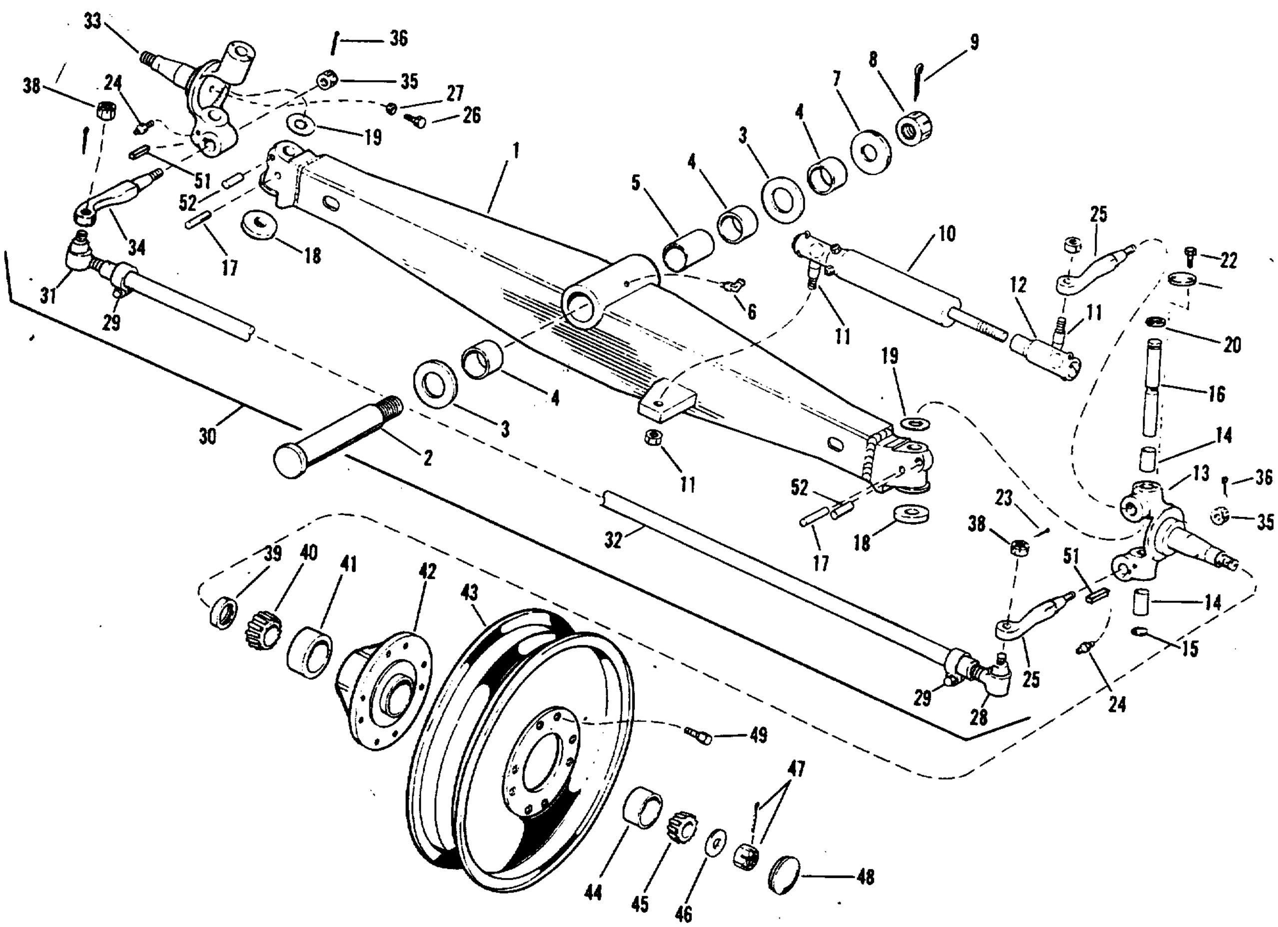
6. Pack wheel bearings with grease and install.

7. Replace seal (39).

8. Adjust wheel bearings by torqueing adjustment nut (47), to 10 ft. lbs. and then back off nut until cotter pin can be installed. Replace hub cap (48).

9. Check adjustment of wheel toe IN. Proper adjustment is +1/8" ± 1/16". If adjustment is necessary, loosen clamps (29) and turn tie rod (32) in one direction or the other to obtain the correct adjustment. Tighten clamps (29).

10. Check adjustments of wheel stops (26), steering cylinder should not bottom.



SUBSECTION 12 STEERING CYLINDER

GENERAL

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

NOTE: Handle parts with care and have them clean. Wash parts in a suitable clean solvent and blow dry with compressed air.

DISASSEMBLY

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

Remove end plate (1).

Remove retaining ring (8). To remove ring (8), push gland (9) into cylinder barrel (18) approximately 1/4", compress retaining ring (8) with a punch entered through knock out hole of cylinder barrel, and remove ring.

Pull on piston rod to remove internal parts from cylinder (18).

Remove gland (9) from piston rod, by sliding off piston end of rod.

Remove nut (17). (Hold rod by the two wrench flats near outer thread end to prevent damage to finish on rod O.D.)

Slide off piston (14) and remove piston rings (16) and seal (15).

With gland removed from rod remove sealing parts in gland by first removing retaining ring (2) then retainer washer (3), oil seal (4), spacing washer (3), leather back up washer (6), and "O" ring (7). From O.D. of gland disassemble "O" ring (11) and back up washer (10).

Check action of poppet valve (13).(if used) for leakage. If not in good condition, replace with new piston assembly.

ASSEMBLY

NOTE: Use only NEW piston rod seal components, piston rings and seal for satisfactory overhaul.

Lubricate all seals and "O" rings with light oil before assembling.

Assemble "O" ring (7) to inside of gland (9), then leather back up ring (6), steel spacing washer (5), and retaining washer (3). Assemble seal (4) with sealing lip toward inside. Assemble retainer washer (3) and secure oil seal parts with retaining ring (2).

Assemble back up ring (10) on O.D. of gland (9), then "O" ring (11). To prevent damage to rod seal (4) assemble gland assembly to the rod (12) from the piston end of the rod. Slide gland over rod toward threaded end of rod.

Assemble seal (15) in piston ring groove of piston (14) and piston rings (16) over seal.

Assemble piston (14) to end of rod (12) with nut (17). Tighten to 60-65 foot pounds torque.

Slide piston (14) into cylinder barrel (18). Push assembly into cylinder half way and slide gland (9) into cylinder taking care to not damage "O" ring (11) as it slides past retaining ring groove in end of cylinder.

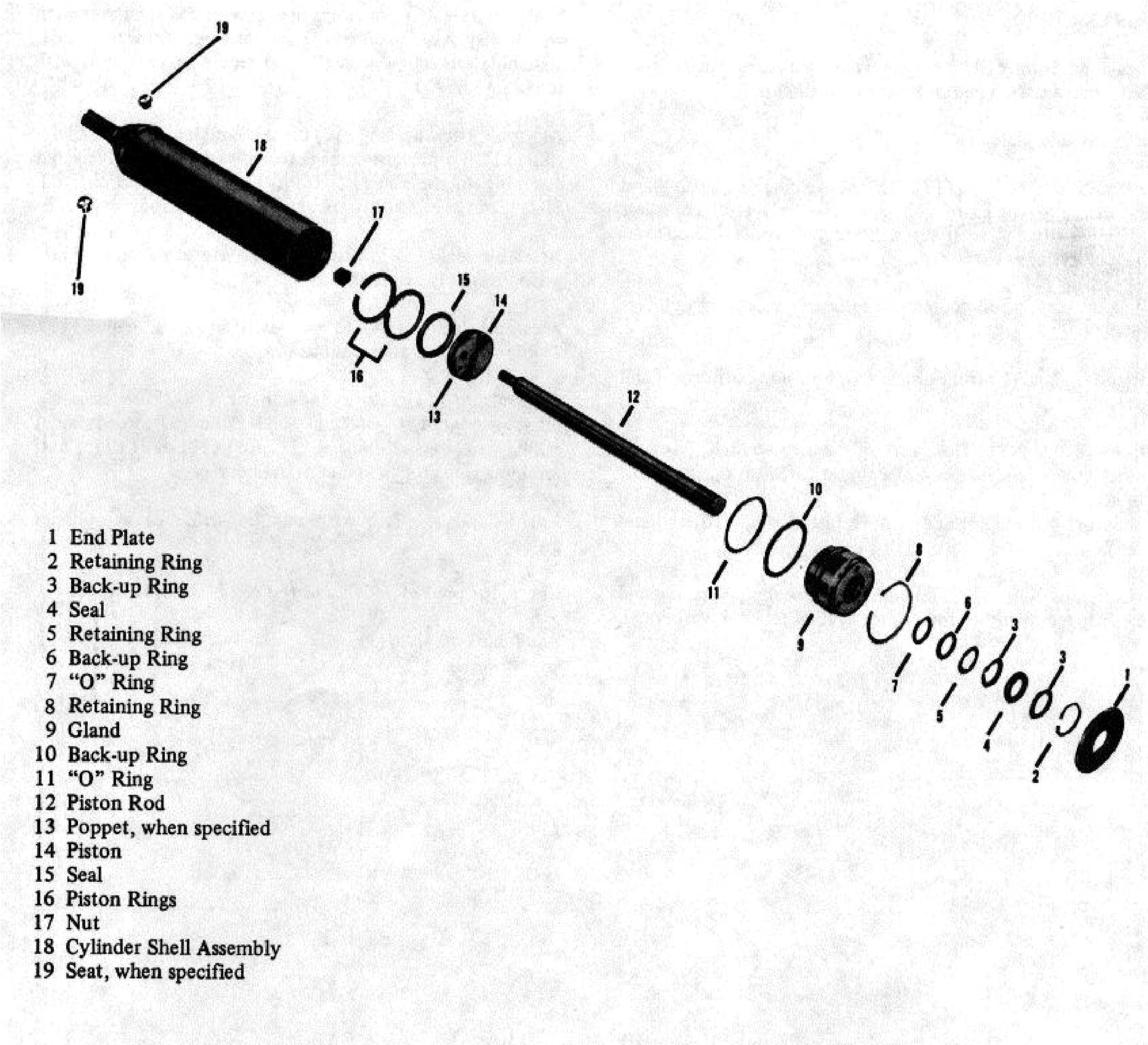
Lock gland in place with retaining ring (8) in cylinder groove.

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

Assemble end plate (1).

POWER STEERING VALVE UNIT ON STEERING COLUMN

The steering valve unit, located at the bottom of the steering column, controls the actuation of the steering cylinder secured to the front axle. The manufacturer of the steering valve does not recommend field repair. Refer to Parts Book for ordering replacement valve. When removing the old unit, plug hydraulic lines to keep dirt from entering. It is recommended an oil change be made when new unit is installed.



SUBSECTION 13 V.P.I. FLUID HANDLING SYSTEM

INTRODUCTION

The V.P.I. System operates on an electrical balance principle that integrates the fluid rate of flow with the Stabilizer travel speed indicating the degree of balance through a proportioning meter for a specified application rate.

The total system, figure 1, can be separated into four (4) basic units consisting of:

1. Meter Recording Unit
2. Travel Speed Unit
3. Application Rate Unit
4. Proportioning System Unit

Refer to this diagram when studying the component descriptions on the following pages.

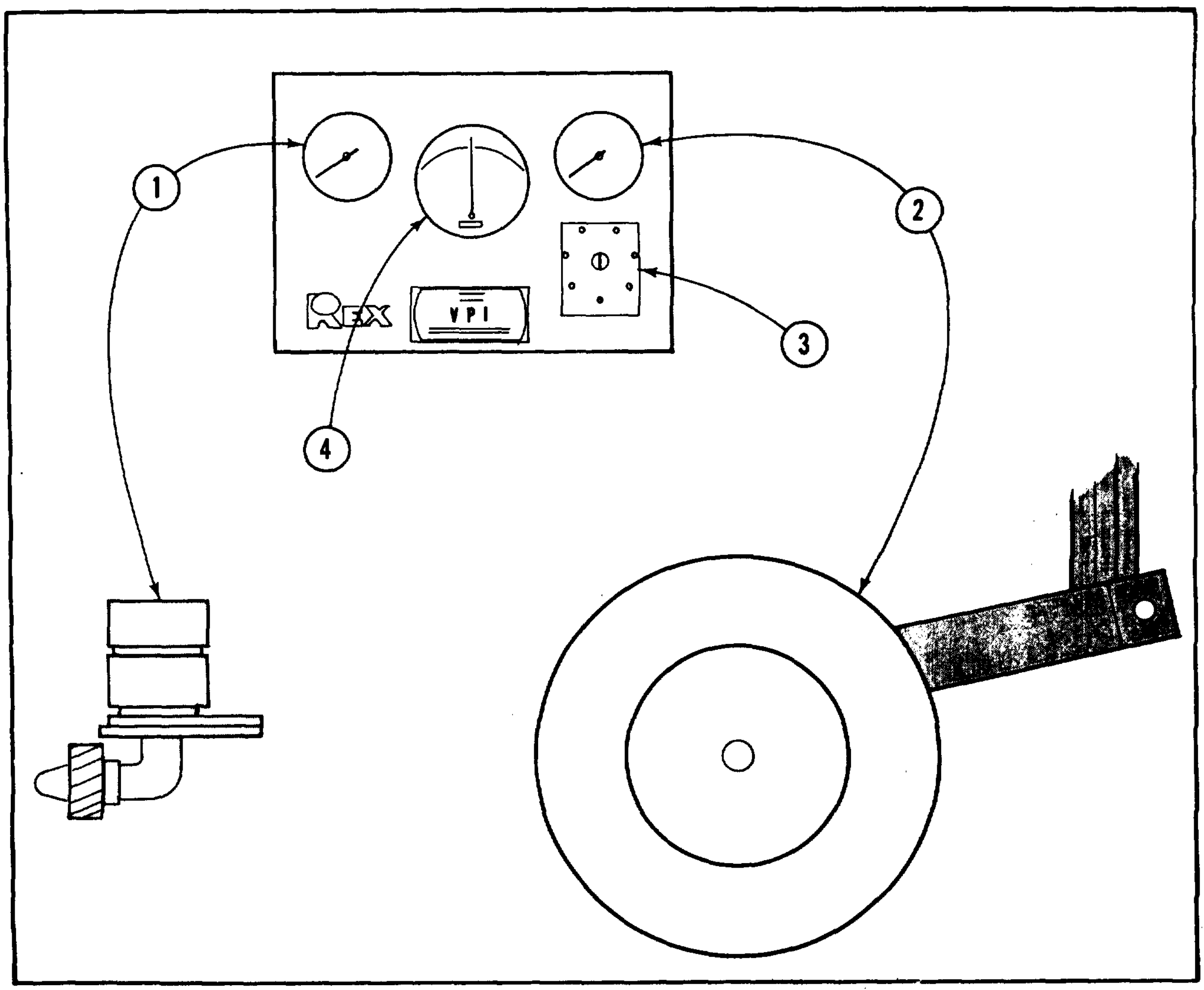


FIGURE 1

CALIBRATING THE V.P.I. SYSTEM-
METER RECORDING UNIT

The meter recording unit, figure 2, is the basic unit of the V.P.I. system and the accuracy of the total system depends largely upon the accuracy of the recording totalizer head on the meter. This is calibrated to within 2%.

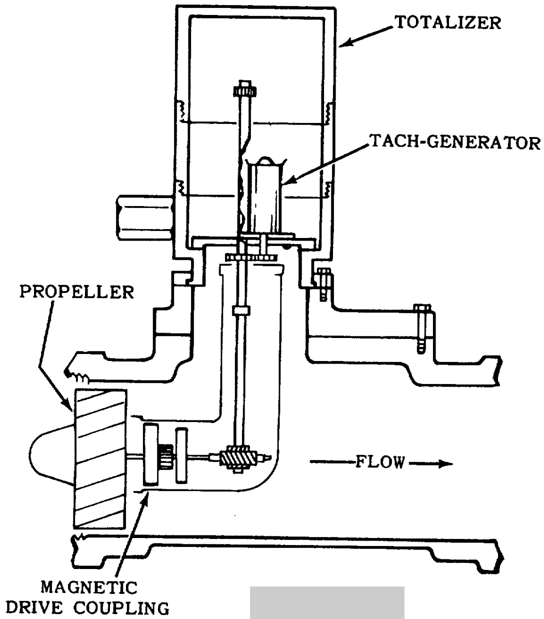


FIGURE 2

In operation, the meter propeller is rotated by the liquid flow pressure passing through the line into which the meter propeller is inserted. The propeller drives a worm gear train through a magnetic coupling then directly to the recording totalizer which records the total gallons having passed through the meter. A tach-generator connected to the basic gear train produces a voltage signal proportionate to the liquid flow which is relayed to the instrument panel where it indicates the flow in gallons per minute.

In checking out and calibrating the meter recording unit, it is best to pump a liquid through the meter, time the flow and check it against the totalizer, simultaneously checking the voltage output of the meter tach-generator. This will determine the rate of flow and corresponding voltage output under these specific conditions. The voltage will be used later to calibrate the "gallons per minute" indicator. If it is impractical to actually pump a liquid thru the system, the meter body assembly complete with the propeller may be removed from the system and the flow rate determined by the following method: Place the meter body assembly on a bench so that the propeller will rotate freely, and with the meter mounting flange in a horizontal plane. If the meter is tipped excessively, oil will be lost from the lower gear train. A Type "A" transmission fluid must be added to replace the lost oil. Direct an air hose with regulating valve so
that it will rotate the propeller at a constant low speed. This simulation of flow, timed and checked against the totalizer will provide a gallons per minute flow rate and the corresponding voltage output of the meter tachgenerator. If the air method is used for checking the meter flow rate, do not rotate the propeller too fast. A flow rate of 200-400 gallons per minute is a good rate at which to check the tach-generator voltage output.

Figures 3 and 4. With the voltage output determined for a specific flow rate, the gallons per minute indicator on the V.P.I. panel may now be calibrated. Remove the face bolts holding the V.P.I. panel in place and fold the panel down so that the terminal block is accessible. Remove the leads #3 and #8 (from the meter tachgenerator) from the terminal block. Substitute an adjustable external D.C. voltage source to terminals #3 and #8 of the same magnitude previously determined for the given flow rate. Refer figure 5.

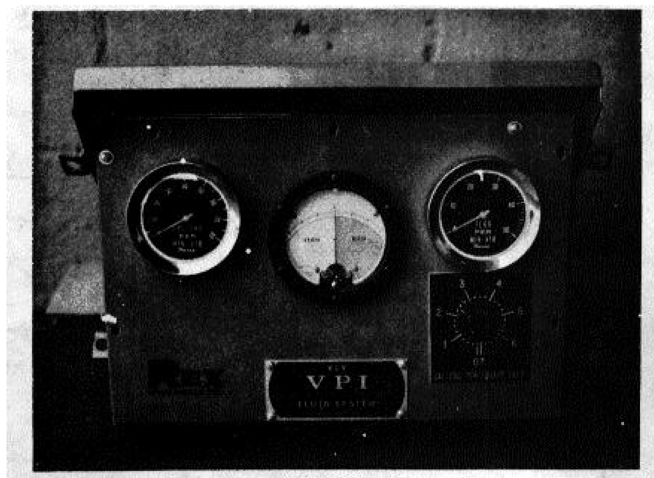


FIGURE 3

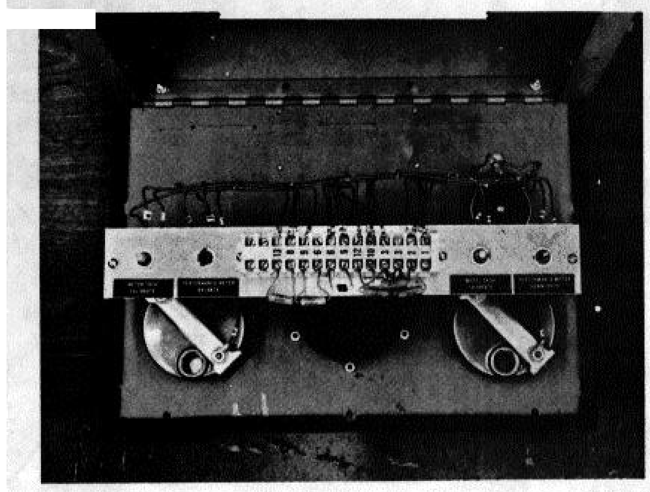


FIGURE 4

Adjust the meter tach-generator potentiometer so that the gallons per minute indicator corresponds to the same flow rate as determined by the timed totalizer measurement. The meter recording unit is now calibrated.

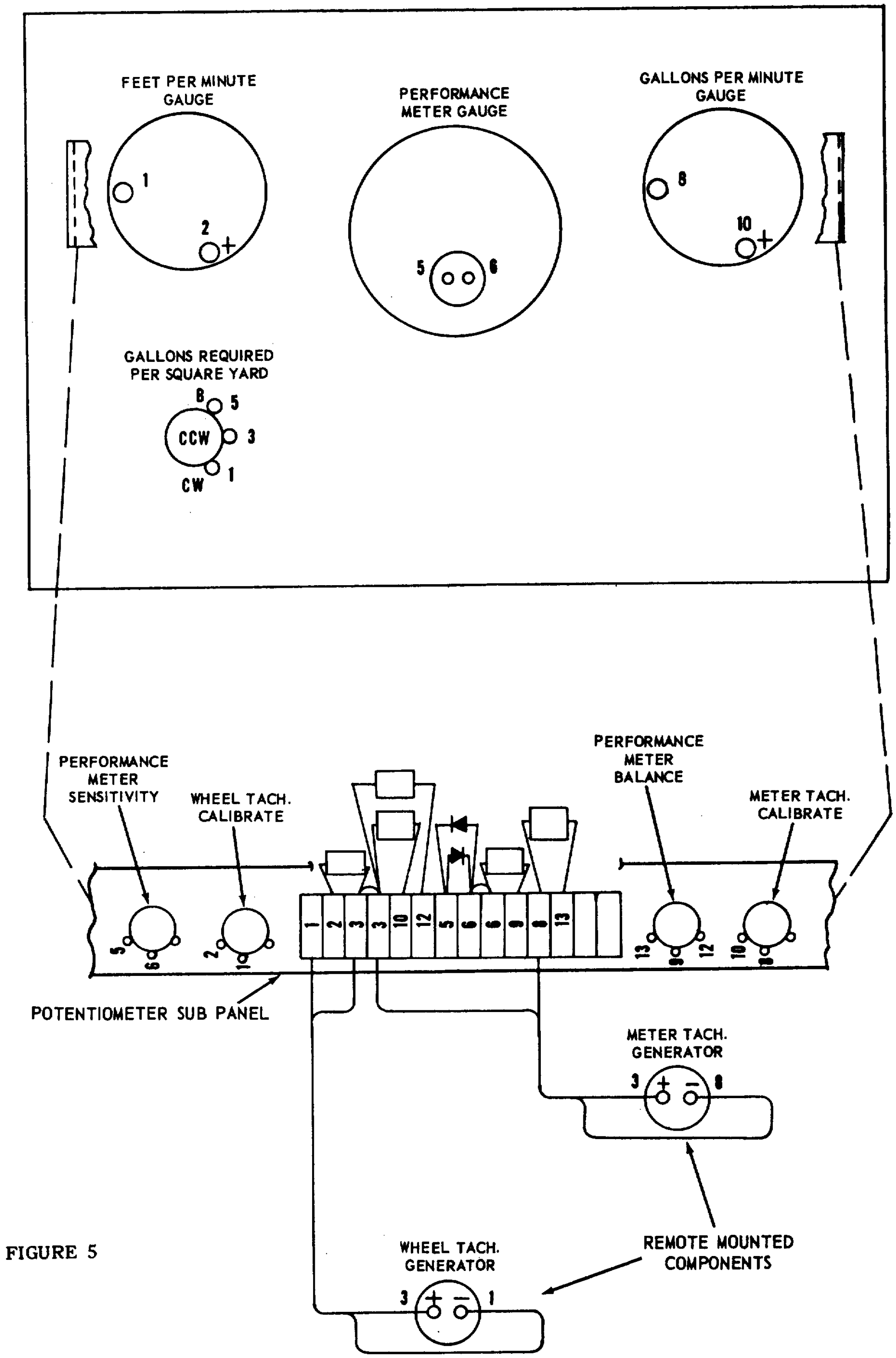


FIGURE 5

FIGURE 5

TRAVEL SPEED UNIT

The travel speed unit, figure6, consists of a pneumatic tire and wheel that is automatically lowered to the ground when the spray bar valves are opened. The wheel drives a tach-generator through an enclosed gear box which generates a voltage proportionate to the travel speed of the Pulvi-Mixer. If the tach-generator leads have been removed, check that the polarity is correct for the direction of travel in order to get an indicator reading.

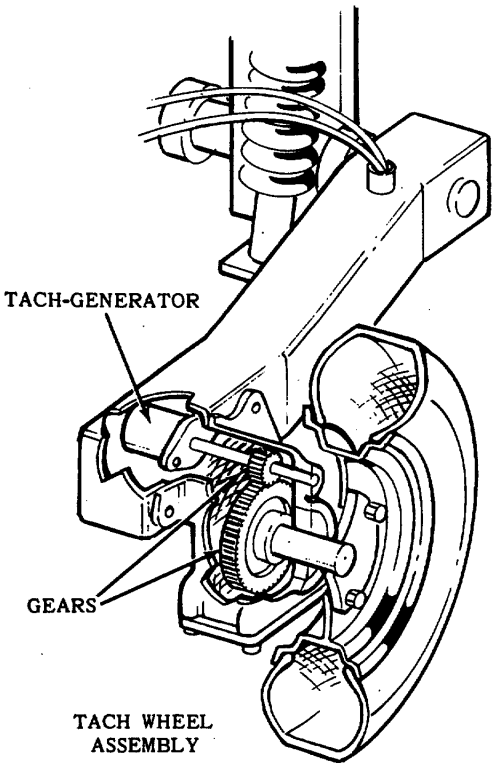


FIGURE 6

This voltage is transmitted to the travel speed indicator mounted on the V.P.I. panel. The travel speed unit is easily calibrated by measuring a suitable distance (50 ft. or 100 ft.) and timing the machine over the measured distance maintaining a constant forward speed and checking the rate against the indicator reading. With the travel speed indicator pointer at 100 f.p.m. for example, the machine should traverse this distance (100 ft.) in one minute. If it does not, adjust the tach wheel potentiometer on the back of the V.P.I. panel until the travel speed indicator reads correctly for the timed distance.

APPLICATION RATE UNIT

The application rate unit, figure 7, consists of an extremely accurate potentiometer that must be correctly adjusted in order to signal the proportioning system the proper integration of the voltage signals for overall system accuracy. This calibration is effected by removing the control knob on the front of the V.P.I. panel with a '4"' allen wrench. On the back of the V.P.I. panel, connect an ohmmeter to posts #3 and #5 on the gallons per square yard potentiometer and rotate the shaft from a high ohm setting counterclockwise until an ohmmeter reading of one (1) ohm is reached. This operation should

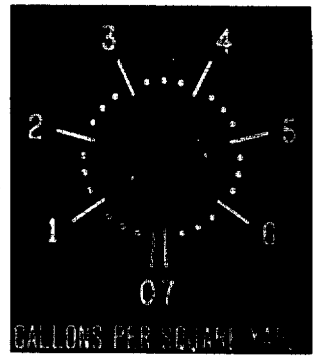


FIGURE 7

be repeated several times as there is no positive stop on this potentiometer, only a "dead band." After the one (1) ohm position has been determined, very carefully replace the knob on the shaft with the pointer directed at zero ("0") on the gallons per square yard legend plate. Tighten the socket head set screw making sure #1, that the one (1) ohm reading is repeatable with the pointer directed at zero ("0") and #2, that the locking ring, when turned clockwise holds the pointer securely at a predetermined position.

The above operation may have to be repeated as it can be quite delicate, however it is essential that it be done correctly.

PROPORTIONING SYSTEM UNIT

The proportioning system unit (performance meter) is the last indicator to be adjusted in this sequence. Before starting this adjustment procedure, check to see if the performance meter needle, figure 8, is reading zero ("0") in a rest or "no-power" position. If it is not, adjust the needle by slightly turning the adjusting screw near the bottom on the face of the meter. The adjustment is accomplished by first selecting an application rate from the application reference chart (figure 9). Select the gallons per square yard and lock the pointer with the locking ring.

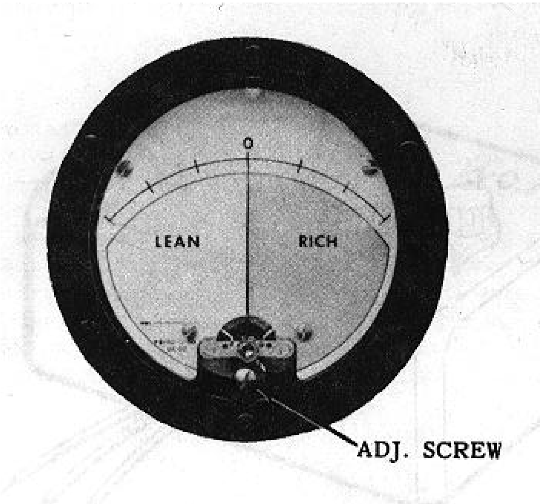


FIGURE 8

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VPI

APPLICATION REFERENCE CHART
STANDARD PULVI-MIXER (HDS-E)

GALS. PER SQUARE YARD	FLOW RATE (GPM)	APPROX. INITIAL QUADRANT SETTING EMUL. ASPHALT	APPROX. INITIAL QUADRANT SETTING WATER	TRAVEL SPEED (FPM)	GALS. PER LINEAL FOOT
2	200	4	3	140	1.43
	250	5	4	175	
3	200	4	3	94	2.14
	250	5	4	117	
	300	6	5	140	
	350	7	6	164	
	400	8	7	187	
4	200	4	3	70	2.85
	250	5	4	88	
	300	6	5	105	
	350	7	6	123	
	400	8	7	140	
	450	10	9	158	
	500	–	10	175	
5	200	4	3	56	3.57
	250	5	4	70	
	300	6	5	84	
	350	7	6	98	
	400	8	7	112	
	450	10	9	126	
	500	–	10	140	
6	250	5	4	58	4.28
	300	6	5	70	
	350	7	6	82	
	400	8	7	94	
	450	10	9	105	
	500	–	10	117	
7	300	6	5	60	5.00
	350	7	6	70	
	400	8	7	80	
	450	10	9	90	
	500	–	10	100	

FIGURE 9

On the back of the V.P.I. panel, disconnect leads #3 and #8 (from the meter) and leads #1 and #3 (from the tach wheel) at the terminal block.

Consult the application reference chart for both a gallons per minute indicator reading and a feet per minute indicator reading that will correspond to the application rate selected.

Feed in from one adjustable external voltage source to positions #3 and #8 (for the meter) and from another adjustable external voltage source to positions #1 and #3 (for the tach wheel) on the terminal block. These voltage sources should have a variable range from .5 volts D.C. to 2 volts D.C. When the proper voltages have been introduced to obtain the respective meter reading indicated on the application reference chart for the rate previously selected, the performance meter should read zero ("0") and be in a vertical position. If it does not, adjust the performance meter balance potentiometer on the back of the V.P.I. panel to a position where the performance meter does read zero ("0"). This calibration should be checked by selecting a different application rate, changing the meter readings by varying the voltages to the corresponding application reference chart readings and again check the performance meter for a zero ("0") reading. If the performance meter zero ("O") readings are not consistent, check the fixed resistors in the V.P.I. circuit.

Remove the external voltage leads from the terminal block positions #1 and #3, and #3 and #8 and re-attach the tach-generator leads to their respective positions on the terminal block. Place a drop or two of nail polish on the shafts of any of the potentiometers on the back of the V.P.I. that have been re-adjusted prior to bolting the V.P.I. panel back in its operating position.

The total V.P.I. system is now adjusted and ready for use.

SUGGESTED EXTERNAL POWER SOURCE CIRCUITRY

An external power source may be easily constructed for calibrating the V.P.I. system by following the diagram illustrated.

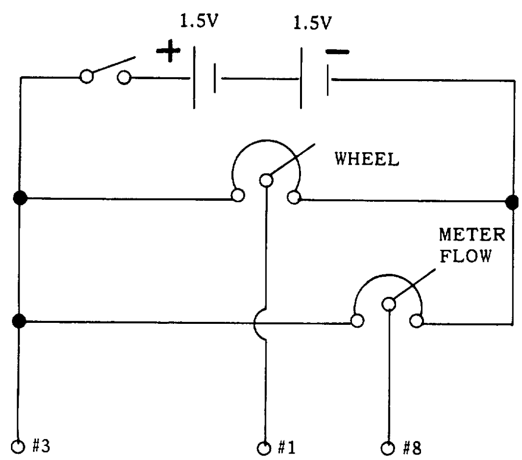


FIGURE 10

FIGURE 10

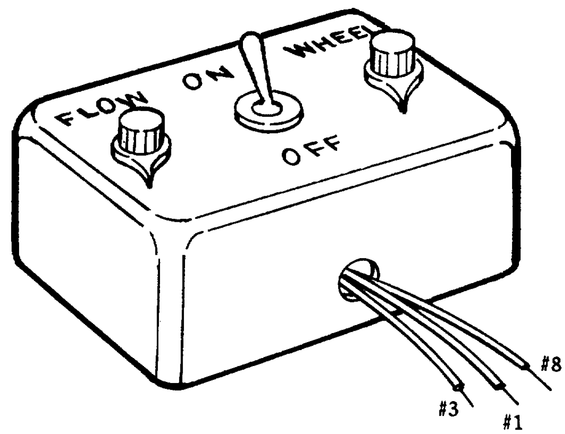


FIGURE 11

MATERIAL LIST
2 - 11/2 Volt Batteries
1 - Switch (On-Off)
2 - 50 Ohm Potentiometers
1 - Suitable Box or Container

Whenever a new fluid meter assembly is installed in the V.P.I. system, the V.P.I. panel must be recalibrated with the meter.

V.P.I. TROUBLE SHOOTING

PROBLEM	POSSIBLE CORRECTION
No flow in system.	1, 2, 3, 4, 5, 6, 7
Gallons per minute indicator not working with flow in system and meter totalize registering.	8, 9, 10, 11, 12, 13
Meter totalizer not registering with flow in system.	11, 12
Feet per minute indicator not working with tach wheel turning.	8, 9, 10, 13
Performance meter not centered with proper f.p.m. - g.p.m. indicator readings for corresponding gallons per square yard setting.	14
Rapidly varying gallons per minute indicator reading.	3, 15, 16
Rapidly varying feet per minute indicator reading.	9, 10, 17

POSSIBLE CORRECTION

1. Pump engine not running. Start engine.
2. Tank truck outlet plugged. Check outlet valve and/or strainer.
3. Suction line air leak. Tighten connections.
4. Strainer clogged. Check and clean strainer.
5. Pump not primed. Prime pump.
6. Metering valve closed. Open metering valve.
7. Tank truck going down grade or empty. Check capacity.
8. Tach-generator polarity reversed.
9. *Tach-generator not putting out voltage.
10. Loose connection or broken wire. Tighten or replace wiring.
11. Meter propeller not turning.
12. Meter propeller turning, but not the meter gear train, indicates something is binding in the meter gear train. Check for: tight bearings; stripped or loose gears; gears too tightly meshed; faulty magnetic coupling.
13. Faulty indicator if tach-generator is putting out voltage, but indicator not registering.
14. Check application rate unit calibration for one (1) ohm reading with pointer at zero ("0"). (See calibration procedure.)
15. Pulsating flow in system. (Check 3, 7, 10, 16)
16. Pump engine not running at constant speed.
17. Tach wheel bouncing, skidding, not lowered completely.

*Tach-generator voltage may vary with an oil or moisture film on the commutator and brushes. Inspect and clean thoroughly.

SUBSECTION 14 GASOLINE PUMP ENGINE

COMPONENT DESCRIPTION AND MAINTENANCE

OIL FILTER

A by-pass type oil filter is furnished on these engines. The oil filtering cartridge should be replaced after every other oil change. If operating conditions are extremely dusty, replace cartridge after every oil change.

AIR CLEANERS

The air cleaner is an essential accessory, filtering the air entering the carburetor and preventing abrasive dirt from entering the engine and wearing out valves and piston rings in a very short time.

The air cleaner must be serviced frequently, depending on the dust conditions where engine is operated. Check hose connections for leaks or breaks; replace all broken or damaged hose clamps.

Excessive smoke or loss of power are good indications the air cleaner requires attention.

The **oil bath** type air cleaner, illustrated in Fig. I is standard equipment.

OIL BATH AIR CLEANER (Fig. 1)

Service daily or twice a day; if engine is operating in very dusty conditions. ***Once each week***; in comparatively clean conditions.

Remove oil cup from bottom of air cleaner and clean thoroughly. Add fresh oil to the ***level line*** indicated on cup, using the same grade oil as used in engine crankcase.

> ***Operating the engine under dusty conditions without oil in the air cleaner or with dirty oil, may wear out cylinders, pistons, rings and bearings in a few days time, and result in costly repairs.***

Once a year; or oftener in very dusty conditions, the air cleaner should be removed from the engine and the element, which is not removable, should be washed in a solvent to clean out accumulated dust and dirt.

FIGURE 1

FUEL STRAINER (Fig. 3)

A fuel strainer is very necessary to prevent sediment, dirt and water from entering the carburetor and causing trouble or even complete stoppage of the engine. The strainer has a glass bowl and should be inspected frequently and cleaned if dirt or water are present. To remove bowl, first shut off fuel valve, then loosen the knurled nut below bowl and swing the wire bail to one side. After cleaning bowl and screen, reassemble the parts, being sure the gasket is in good condition; otherwise use a new gasket. See Fig. 3.

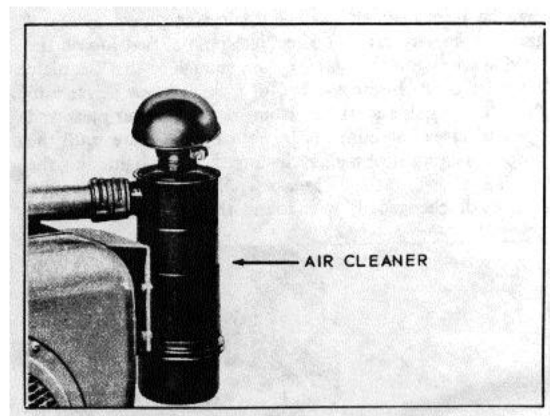


FIGURE 2

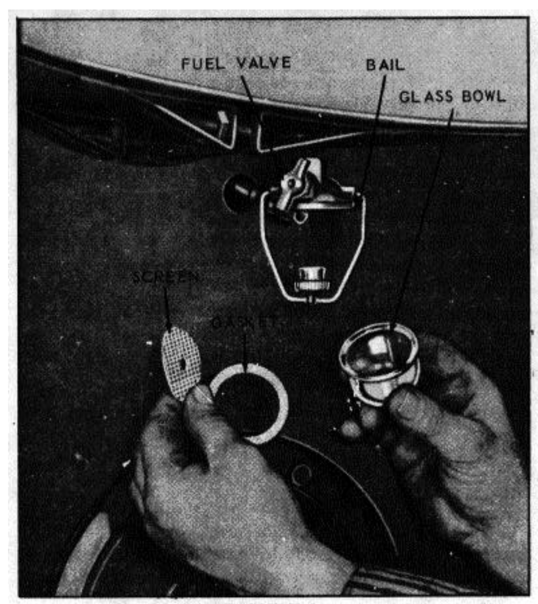


FIGURE 3

CARBURETOR ADJUSTMENT

The main metering jet in the carburetor is of the fixed type, that is, it requires no adjustment. The idle needle should be adjusted for best low speed operation, while carburetor throttle is closed by hand. For illustrations and more information, see Walbro

Carburetor; Operation, on page 14-14.

MAGNETO BREAKER POINT ADJUSTMENT

The shielded magnetos are properly adjusted before leaving factory. The breaker points on the magneto should be .015" at full separation. If the spark becomes weak after continued operation, it may be necessary to readjust these points. To do this first remove the end cover on the magneto. The crankshaft should then be rotated by pulsing the starter, (this also rotates the magneto), until the breaker points are wide open. The opening or gap should then be measured with a feeler gauge as shown in *Fig. 4* and if necessary reset. To readjust points, first loosen the **locking screws** on the **contact plate** enough so that the plate can be moved. Insert the end of a small screw driver into the **adjusting slot** at the bottom of the **contact plate** and open or close the contacts by moving the plate until the proper opening is obtained. See Fig. 5. After tightening the locking screws, recheck breaker point gap to make sure it has not changed. If it is found that the breaker points

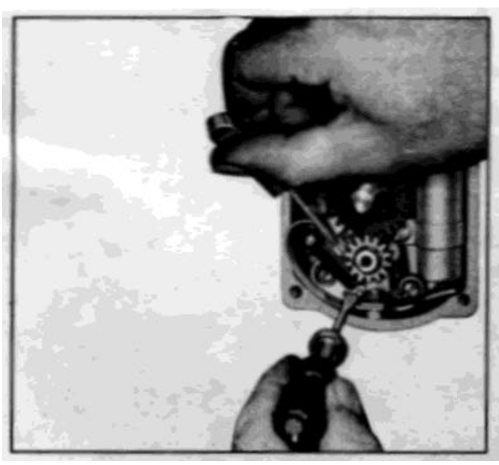
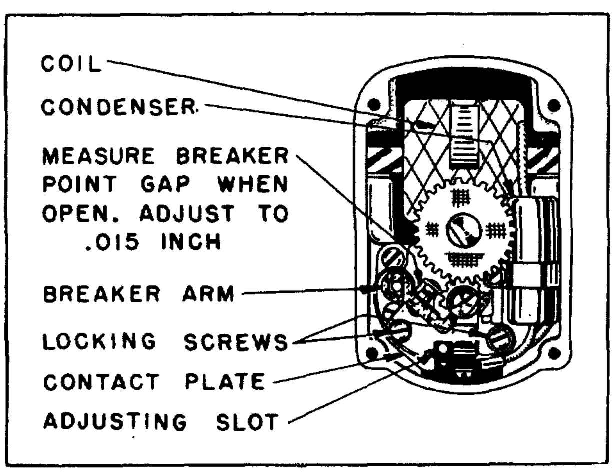


FIGURE 4



OPEN END VIEW OF FAIRBANKS-MORSE SHIELDED MAGNETO
FIGURE 5

have become rough, they should be smoothed with a breaker point file before the preceding adjustments are made. Replace magneto end cover carefully so that it will seal properly. Do not force cover screws too tightly otherwise cover may crack.

MAGNETO IGNITION SPARK

If difficulty is experienced in starting the engine or if engine misses firing, the strength of the ignition spark may be tested by disconnecting the No. 1 ignition cable from the spark plug and holding the terminal about 1/8 inch away from the air shroud or any other conveniently located metal part of the engine. Turn the engine over and watch for a strong spark discharge, which should occur during the cycle at the instant the impulse coupling on the magneto snaps. Repeat this check with each of the other ignition cables. If there is a weak spark, or none at all, check breaker point opening as mentioned in preceding paragraph under *"Magneto Breaker Point Adjustment*". If this does not remedy the trouble, it may be necessary to install a new condenser.

FIRING ORDER

The firing order of the cylinders is **1-3-4-2**, and the magneto rotates at one-half engine speed, as is the case with conventional "*in line*" engines. The intervals between the firing of the cylinders is 180°. No. 1 cylinder is the one nearest to the flywheel in the left bank of cylinders, when viewed from the flywheel end of the engine. No. 3 cylinder is the other cylinder in this bank. No. 2 cylinder is the one nearest to the flywheel in the right bank of cylinders and No. 4 is the other cylinder in this bank. The cylinders are numbered from I to 4 on the air shroud near the spark plugs. The flywheel end of the engine is designated the **front** and the power take-off end, the **rear** of the engine.

MAGNETO TIMING

The proper spark advance is 230. To check timing with a ***neon light***, the running spark advance is indicated by a 3/8 inch slotted hole in the rim of the air intake screen, 68° left of the flywheel shroud vertical centerline, ***marked VH***, or if screen is removed, time to the ***lower half*** of the 1/4 inch elongated hole on the face of flywheel shroud 230 below the centerline of No. 1 and No. 3 cylinders as illustrated in *Fig. 11*. The end of the ***'X'*** marked vane should be whitened with chalk or paint for this operation.

To Time Magneto to Engine: Remove air intake screen to expose ***timing marks*** on both flywheel and shroud. *See Magneto Timing Diagram, Fig. 6.*

Next, remove the spark plug from No. 1 cylinder and slowly turn the flywheel clockwise, at the same time holding a finger over the spark plug hole, so that the compression stroke can be determined from the air blowing out of the hole.

The flywheel is marked with the letters 'DC' near one of the air circulating vanes. This vane is further identified by an **'X'** mark cast on the end. See Fig. 6. When the air blows out of the No. 1 spark plug hole, continue turning the engine until the edge of the **marked vane** on flywheel is on line with the **mark** on the **vertical centerline** of the **shroud** as shown on Fig. 6. Leave flywheel in this position. At this point the **keyway** for mounting the flywheel is also on top. Reassemble spark plug.

Next, remove the inspection hole plug from the magneto timing opening, located in the gear cover.

Assuming that the magneto has been removed from the engine, the following procedure should be followed before remounting.

The Number 1 cylinder firing position of the magneto must be determined. Insert the ignition cable into the No. 1 tower terminal of the magneto end cap and hold the spark plug terminal at the other end, about 1/8" away from the magneto body. Turn the magneto gear in a clockwise rotation, tripping the impulse coupling, until the No. 1 terminal sparks, then hold the gear in this position. Mount the magneto to the engine, meshing the gears so that when the magneto is in place, the gear tooth marked with an **'X'** will be visible TM 5-3895-359-14&P through the **lower half** of the **inspection hole** in the gear cover, as shown in Timing Diagram, Fig. 6. Tighten the nut and capscrew for mounting the magneto to the gear cover, making sure the magneto flange gasket is in place.

The No. 1 terminal is identified on the magneto cap. The terminals follow the proper firing order of 1-3-4-2 in a clockwise direction viewing the cap end. The leads from the magneto should be connected to spark plugs of corresponding numbers.

No.1 cylinder is the cylinder nearest the fan-flywheel of the engine in the left bank and No. 3 cylinder is the other cylinder in that bank. No. 2 cylinder is across the engine from No. 1 and No. 4 is across from No. 3.

When the magneto is properly timed the impulse coupling will snap when the **'DC'** and **'X'** marked vane of the flywheel, line up with the mark on the flywheel shroud which indicate the **centerline** of the No. 1 and 3 cylinders. This can be checked by turning crankshaft over slowly by means of pulsing the starter. The impulse will also snap every 1800 of flywheel rotation thereafter.

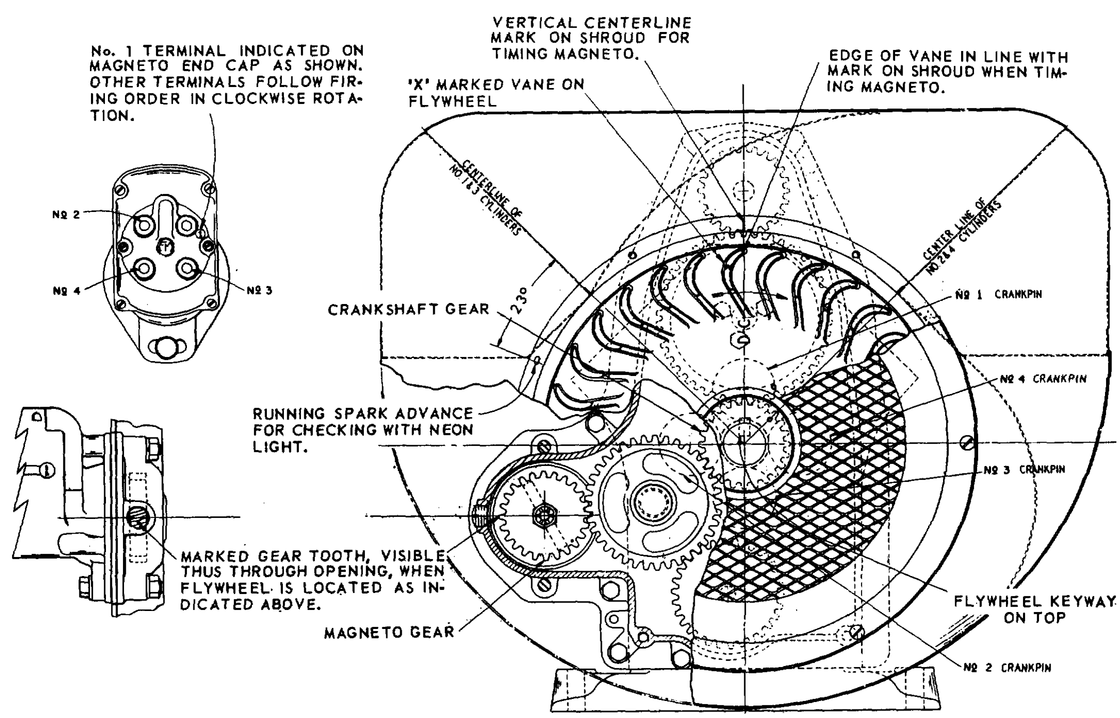


FIGURE 6. MAGNETO TIMING DIAGRAM

The electrical system which is of 12 volt negative ground polarity consists of the following circuits; starting, magneto tachometer, hour meter, oil pressure and high temperature safety. Power is furnished by the main vehicle batteries through a connecting point at the diesel engine starter terminal.

The relay has two sets of contacts; one set completes the magneto and tachometer circuit, and the other completes the engine hour meter circuit. When the ignition switch is in the OFF position, the magneto and tachometer are grounded and the engine hour meter circuit is open. When the switch is turned ON, the relay becomes energized ungrounding the magneto and tachometer and closing the circuit to the engine hour meter. The circuit to the oil pressure gage is completed directly through the ignition switch.

The high temperature safety switch will short out the ignition by grounding the magneto when the engine temperature becomes excessive.

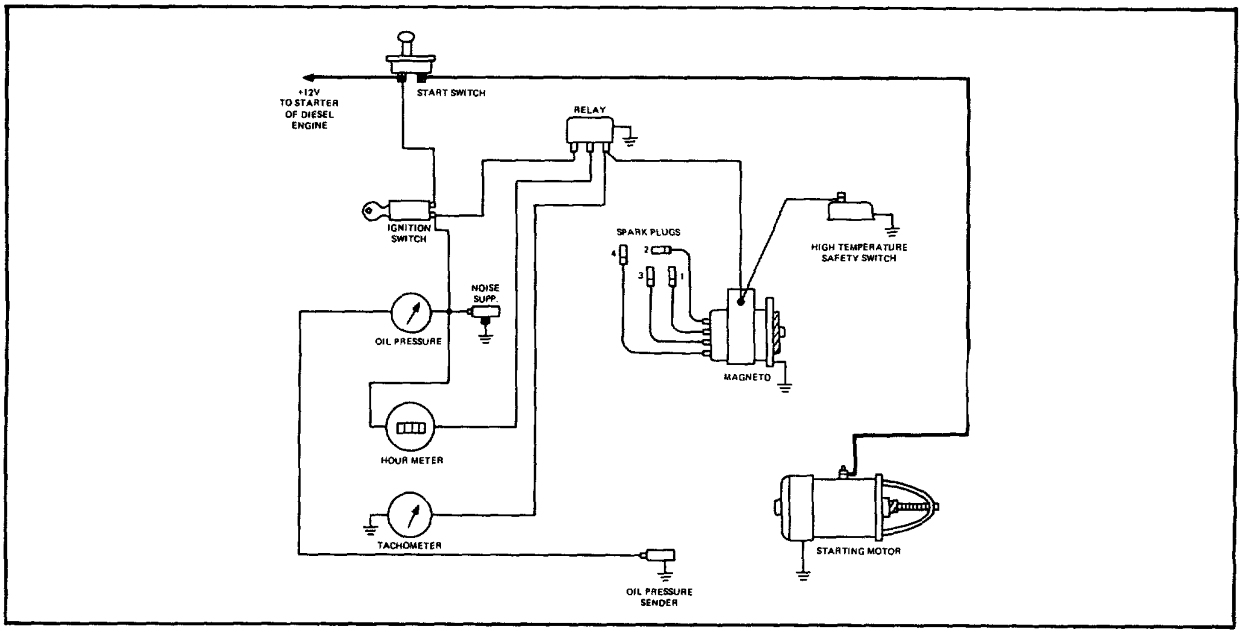


FIGURE 7. WIRING DIAGRAM

RESTORING COMPRESSION

In a new engine or one which has been out of operation for some time, oil may have drained off the cylinders so that compression will be weak, causing difficulty in starting. To remedy this condition, remove the spark plugs and pour about a fluid ounce of crankcase oil through the spark plug hole into each cylinder. Turn engine over several times with the hand crank to distribute oil over the cylinder walls. Assemble spark plugs and compression should be satisfactory.

SPARK PLUGS, Fig. 8

Incorrect gap, f6ulWd,4l , worn spark plug electrodes, will have an adverse affect on engine operation. Remove spark plugs periodically, clean, reg ap or replace if necessary. Thread size is 18 mm.

Spark plug gap 0.030 of an inch.

Replacement spark plugs must be special type YD311SI for use in shielded ignition systems. Tighten spark plugs, 25 to 30 foot pounds torque.

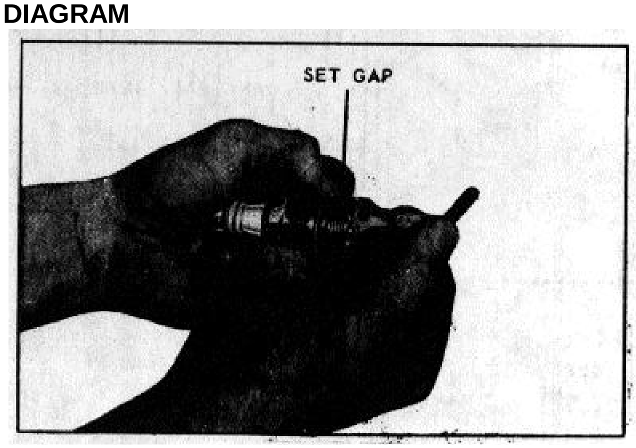


FIGURE 8

HIGH TEMPERATURE SAFETY SWITCH

As a safety precaution against overheating, engines can be equipped with a high temperature switch mounted to the cylinder head at the **No. 4** spark plug.

When cylinder head temperature becomes critically high, the safety switch will automatically stop the .engine by shorting out the ignition system. A waiting period of about 10 minutes will be required before the switch has cooled off sufficiently to re-start the engine. An overheated engine will score the cylinder walls, burn out connecting rod and crankshaft bearings, also warp pistons and valves. The cause of the overheating condition will have to be remedied before the engine is re-started. See **Engine Overheats** paragraph in Troubles, Causes and Remedies section **Service Kit** is available see parts list section.

KEEPING ENGINE CLEAN

This engine is cooled by blasts of air which must be allowed to circulate all around the cylinders and cylinder heads to properly cool the engine and thereby keep it in good running condition. **If dust, dirt or chaff is allowed to collect in the cylinder shrouding or in the V between the cylinders**, it will retard the flow of air and cause the engine to overheat. Keep flywheel screen and rotating screen clean, so as not to restrict the intake of cooling air.

1. Remove covers frequently and clean out all dust, dirt and chaff. Be sure to replace covers.

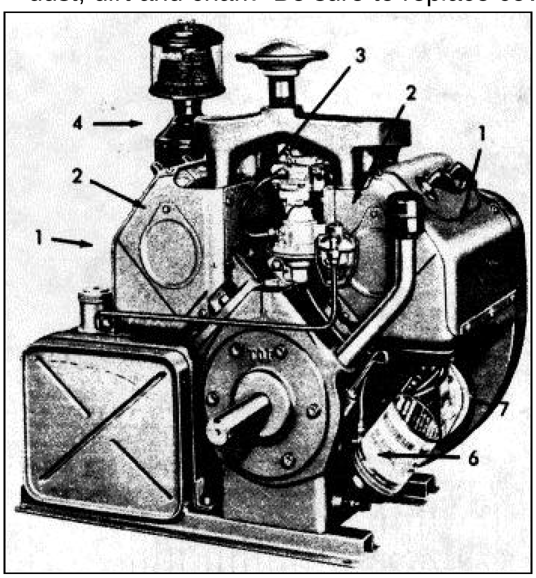


FIGURE 9 221526C

2. Open these covers frequently and clean out all dust and chaff. Be sure to close covers.
3. Keep this space between cylinders free of dust and chaff.
4. Read instructions on this air cleaner regarding its care. This is important. The entire air cleaner should be removed from the engine at least once a year, and washed in a cleaning fluid to clean out dirt gathered in the back fire trap in the top part of the air cleaner.
5. Replace the oil filter cartridge every other oil change. If operating conditions are extremely dusty replace TM 5-3895-359-14&P cartridge every oil change. Be sure that your replacement is a Wisconsin Micro-Fine filter.
6. Do not allow shrouding to become damaged or badly dented as this will retard air flow.

   Never operate engine with air shrouding removed. This will retard air cooling.

   Always keep all parts of the engine clean. This will prolong engine life, and give more satisfactory operation.

Every 4 to 8 hours, depending on dust conditions, check air cleaner and change oil. See Page 14-1.

Every 8 hours check crankcase oil level. Keep filled to full mark on oil gauge sabre, but no more.

Every 50 hours drain crankcase and refill with fresh oil.

TROUBLES CAUSES AND REMEDIES

Three prime requisites are essential to starting and maintaining satisfactory operation of gasoline engines. They are:

1. ***A proper fuel mixture in the cylinder.***
2. ***Good compression in the cylinder.***
3. ***Good spark, properly timed, to ignite the mixture.***

If all three of these conditions do not exist, the engine cannot be started. There are other factors which will contribute to hard starting; such as, too heavy a load for the engine to turn over at a low starting speed, a long exhaust pipe with high back pressure, etc. These conditions may affect the starting, but do not necessarily mean that the engine is improperly adjusted.

As a guide to locating any difficulties which might arise, the following causes are listed under the three headings: ***Fuel Mixture, Compression, and Ignition***.

In each case, the causes of trouble are given in the order in which they are most apt to occur. In many cases the remedy is apparent, and in such cases no further remedies are suggested.

STARTING DIFFICULTIES

FUEL MIXTURE

No fuel in tank or fuel shut-off valve closed.

Fuel pump diaphragm worn out, so pump does not supply carburetor with fuel.

Carburetor not choked sufficiently, especially if engine is cold.

Water, dirt, or gum in gasoline interfering with free flow of fuel to carburetor.

Poor grade or stale gasoline that will not vaporize sufficiently to form the proper fuel mixture.

Carburetor flooded, caused by too much choking especially if engine is hot.

Dirt or gum holding float needle valve in carburetor open. This condition would be indicated if fuel continues to drip from carburetor with engine standing idle. Often tapping the float chamber of the carburetor very lightly with the handle of a screw driver or similar tool will remedy this trouble. Do not strike carburetor with any metal tools, it may cause serious damage. Also if the mixture in the cylinder, due to flooding, is too rich, starting may be accomplished by continued cranking, with the carburetor choke open.

If, due to flooding, too much fuel should have enter, ed the cylinder in attempting to start the engine, the mixture will most likely be too rich to burn. In that case, the spark plugs should be removed from the cylinders and the engine then turned over several times so the rich mixture will be blown out through the spark plug holes. The choke oil the carburetor should of course be left open during this procedure. The plugs should then be replaced and starting tried again.

To test for clogged fuel line, loosen fuel line nut at carburetor slightly. If line is open, fuel should drip out at loosened nut.

COMPRESSION

If the engine has proper compression, considerable cranking resistance will be encountered. If this resistance is not encountered, compression is faulty. Following are some reasons for poor compression:

Cylinder dry due to engine having been out of use for some time. *See 'Restoring Compression '.*

Loose spark plugs or broken spark plug. In this case a hissing noise will be heard when cranking engine, due to escaping gas mixture on compression stroke,

Damaged cylinder head gasket or loose cylinder head. This will likewise cause hissing noise on compression stroke.

Valve stuck open due to carbon or gum on valve stem. To clean valve stems, see 'Valves' Valve tappets adjusted with insufficient clearance under valve stems. *See 'Valve Tappets'*.

Piston rings stuck in piston due to carbon accumulation. If rings are stuck very tight, this will necessitate removing piston and connecting rod assembly and cleaning parts. See *'Piston and Connecting Rod'*.

Scored cylinders. This will require reboring of the cylinders and fitting with new pistons and rings. If scored too severely, an entirely new cylinder block may be necessary.

IGNITION

See 'Magneto Ignition Spark' No spark may also be attributed to the following:

Ignition cable disconnected from magneto or spark plugs.

Broken ignition cables, causing short circuits.

Ignition cables wet or soaked.

Spark plug insulators broken.

Spark plugs wet or dirty.

Spark plug point gap wrong.

Condensation on spark plug electrodes.

Magneto points pitted or fused.

Magneto breaker arm sticking.

Magneto condenser leaking or grounded.

Spark time wrong. See 'Magneto Timing'

ENGINE MISSES

Spark plug gap incorrect. *See 'Spark Plugs'*.

Worn and leaking ignition cables.

Weak spark. *See 'Magneto Ignition Spark'*.

Loose connections at ignition cable.

Magneto breaker points pitted or worn.

Water in gasoline.

Poor compression. See 'Compression'

ENGINE SURGES OR GALLOPS

Carburetor flooding.

Governor spring hooked into wrong hole in lever. *See 'Governor Adjustment'* Governor rod incorrectly adjusted. *See 'Governor Adjustment'*.

ENGINE STOPS

Fuel tank empty.

Water, dirt or gum in gasoline.

Gasoline vaporized in fuel lines due to excessive heat around engine (Vapor Lock). See 'Stopping Engine'.

Vapor lock in fuel lines or carburetor due to using winter gas (too volatile) in hot weather.

Air vent hole in fuel tank cap plugged. Engine scored or stuck due to lack of oil.

Ignition troubles. *See 'Ignition'*

ENGINE OVERHEATS

Crankcase oil supply low. Replenish immediately.

Ignition spark timed wrong. See 'Magneto Timing'.

Low grade of gasoline.

Engine overloaded.

Restricted cooling air circulation.

Part of air shroud removed from engine.

Dirt between cooling fins on cylinder or head.

Engine operated in confined space where cooling air is continually recirculated, consequently becoming too hot.

Carbon in engine.

Dirty or incorrect grade of crankcase oil.

Restricted exhaust.

Engine operated while detonating due to low octane gasoline or heavy load at low speed.

ENGINE KNOCKS

Poor grade of gasoline or of low octane rating. See 'Fuel'.

Engine operating under heavy load at low speed.

Carbon or lead deposits in cylinder head.

Spark advanced too far. See 'Magneto Timing'

Loose or burnt out connecting rod bearing.

Engine overheated due to causes under previous heading.

Worn or loose piston pin.

ENGINE BACKFIRES THROUGH CARBURETOR

Water or dirt in gasoline.

Engine cold.

Poor grade of gasoline.

Sticky inlet valves. *See 'Valves'*

Overheated valves.

Spark plugs too hot. *See 'Spark Plug'*.

Hot carbon particles in engine.

DISASSEMBLY AND REASSEMBLY OF VH4D ENGINE

Engine repairs should be made only by a mechanic who has had experience in such work. When disassembling the engine, it is advisable to have several boxes available so that parts belonging to certain groups can be kept together, such as, for instance, the cylinder head screws, etc. Capscrews of various lengths are used in the engine, therefore great care must be exercised in reassembly so the right screw will be used in the various places, otherwise damage may result.

Tighten the capscrews and nuts of the manifolds, cylinder heads, gear cover, oil pan, connecting rods, cylinder blocks, main bearing plate and the spark plugs to the specified torque readings indicated in the following paragraphs of reassembly.

While the engine is partly or fully dismantled, all of the parts should be thoroughly cleaned. Remove all accumulated dirt between the fins.

If it is desired to disassemble the engine, the following order should be substantially adhered to. As disassembly progresses, the order may be altered somewhat if desired, as will be self-evident to the mechanic. Reassembly of the engine should be made in the reverse order.

TESTING REBUILT ENGINE

An engine that has been completely overhauled, such as having the cylinders rebored and fitted with new pistons, rings and valves, should go through a thorough "run-in" period, before any amount of load is applied to the engine.

The engine should be started and allowed to run for about one-half hour, at about 1200 to 1400 R.P.M. without load. The R.P.M. should then be increased to engine operating speed, still without load, for an additional three and one-half to four hours.

The proper 'running-in" of the engine will help to establish polished bearing surfaces and proper clearances between the various operating parts and thus add years of trouble free service to the life of your engine.

ACCESSORIES

The air cleaner, oil filter, magneto, electric starter and generator should be removed first.

FLYWHEEL

After the flywheel screen has been removed, drive out the pin in the crankshaft and remove the flywheel nut and washer.

The flywheel is mounted to a taper on the crankshaft.

Take a firm hold on the flywheel fins, pull outward and at the same time strike the end of the crankshaft with a babbitt hammer, see Fig. 10. The flywheel will slide off the taper of the crankshaft. Do not use a hard hammer as it may ruin the crankshaft and bearings. When reassembling the flywheel, be sure the Woodruff key is in position on the shaft and that the keyway in the flywheel is lined up accurately with the key.

AIR SHROUDING

To disassemble air shrouding, refer to Fig. 11. First remove cylinder head covers and the screws mounting the flywheel shroud to the lower cylinder shrouds and cylinder heat deflectors, then remove the screws holding the flywheel shroud to gear cover.

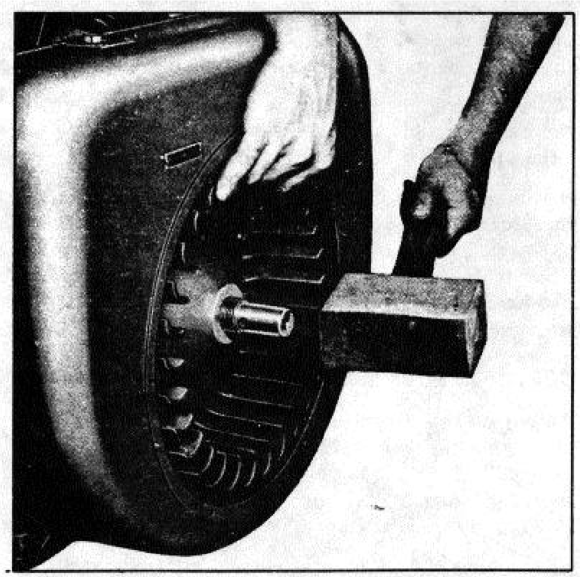


FIGURE 10 76696C

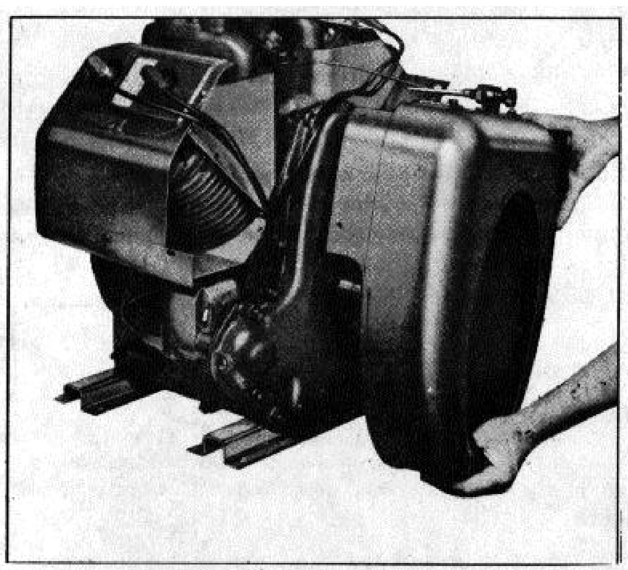


FIGURE 11 104811C

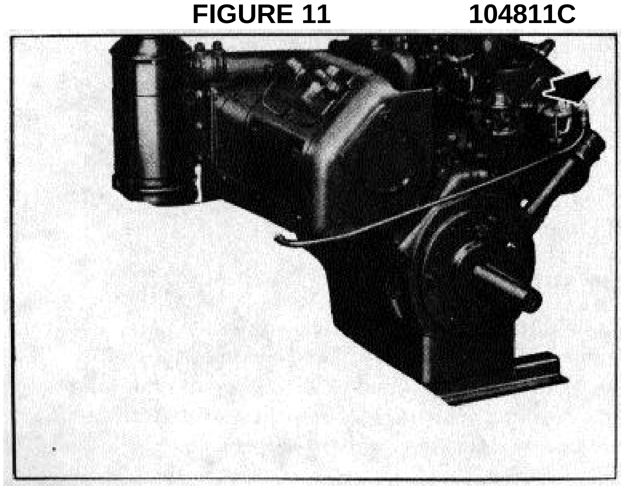


FIGURE 12 83608C

FUEL LINE

Disconnect fuel line at fuel strainer as illustrated in Fig. 3.

CARBURETOR AND MANIFOLD

The carburetor and manifold can be removed as a complete unit. In reassembly; tighten the manifold nuts to 18 ft. lbs. torque. Tightening beyond specifications may cause the flanges to break.

CYLINDER HEAD

The cylinder head must be removed if it is necessary to regrind valves, or to work on the piston, rings or connecting rods. All of the cylinder head screws are plainly in view and can be easily removed. Screws of different lengths are used but these can be properly reassembled according to the various lengths of cylinder head bosses.

In reassembly; remove all carbon and lead deposits from combustion chamber. It is recommended that new cylinder head gaskets be used as the old gaskets will be compressed and hard and may not seal properly.

Use a mixture of graphite and oil on the cylinder head screws to prevent them from rusting tight against the cylinder block. Tighten cylinder head screws to 24 **ft. lbs. torque** in the sequence shown in Fig. 13. After complete assembly and engine is run in, retorque head screws.

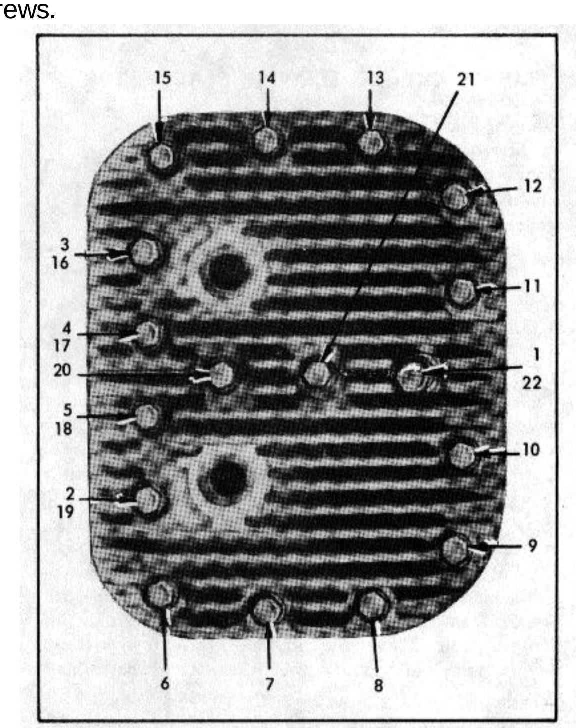


FIGURE 13

GEAR COVER

Disconnect the governor linkage and remove governor housing and gear-flyweight assembly from shaft in gear cover. Take out the ten gear cover capscrews and drive out the two dowel pins as shown in Fig. 14. The cover can then be taken off exposing the gear train as illustrated in Fig. 15.

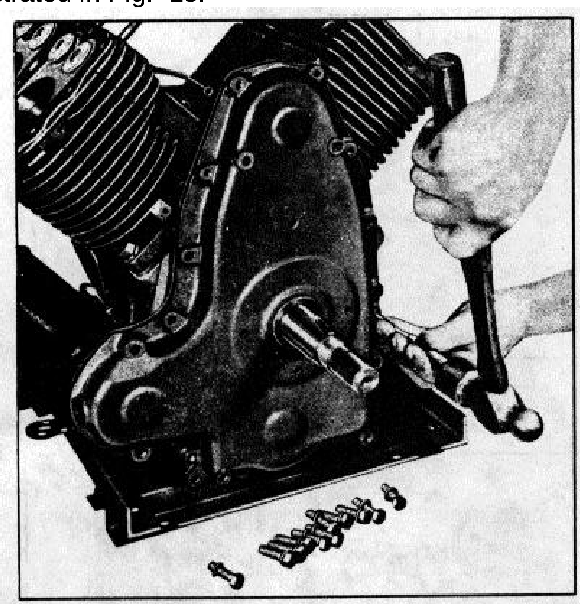


FIGURE 14 71056C

In reassembly; inspect crankshaft oil seal and replace if necessary. Be sure that oil sling is in place on crankshaft, then mount gear cover using a new flange gasket. Tap the two dowel pins in place and mount capscrews. Tighten screws 14 to 18 ft. lbs. torque.

CAMSHAFT GEAR

If it is necessary that the camshaft gear be removed, first pry oil sling off crankshaft, and remove thrust plunger and spring from end of camshaft. Take out the three capscrews and lockwashers, and remove gear from camshaft using a screw driver or similar wedge tool.

The ***camshaft gear*** has offset mounting holes to provide accurate assembly for valve timing. The gear can only be put on the correct way for matching up the timing mark with that of the crankshaft gear. See Fig. 15.

IDLER GEAR AND SHAFT

A tapped hole in the side of the crankcase contains a setscrew for locking idler shaft in place. *See Fig. 16*. Remove screw with a 5/32" Allen wrench. Disassemble shaft and gear from case by means of the 3/8"-16 tapped puller hole in end of idler shaft.

In reassembly; be sure oil groove in shaft is facing up. Drive shaft into crankcase with soft metal hammer and maintain a .003 to .004 inch clearance between idler gear and shoulder of shaft. Lock shaft in place with the Allen set screw.

OIL PAN

The engine can now be inverted so that the supports and oil pan can be removed, see Fig. 17.

In reassembly; tighten oil pan mounting screws, 6 to 9 foot pounds torque.

OIL PUMP (Fig. 18)

Remove locknut and driver gear from shaft. If gear is too tight to remove by hand, use a puller, ***hammering on end of shaft to loosen gear will damage pump***.

Take out slotted pipe plug from bottom of crankcase.
By means of a 5/32 inch Allen wrench, remove lockscrew from pipe plughole. Withdraw oil pump from inside crankcase. If pump fits too tight to remove by hand, tap front of pump housing (not shaft), with hammer and brass rod.

PISTONS and CONNECTING RODS (Figs. 19, 20, 23),

By means of a 1/2" socket wrench, loosen and remove the hex locknuts from connecting rod bolts. Then, by tapping the ends of the bolts lightly, the connecting rod cap will break free from the bolts.

Scrape off all carbon deposits that might interfere with removal of pistons from upper end of cylinder. Turn

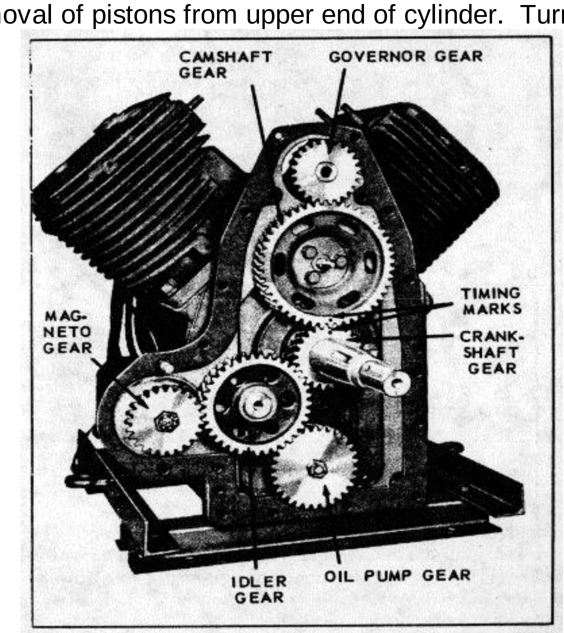


FIGURE 15 104716C-1

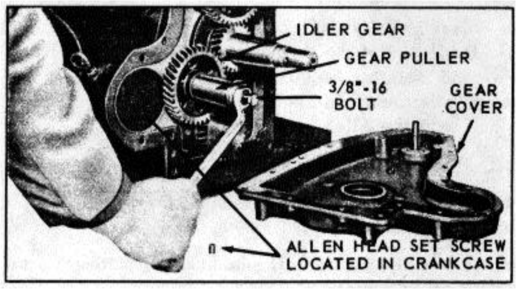


FIGURE 16 70166C

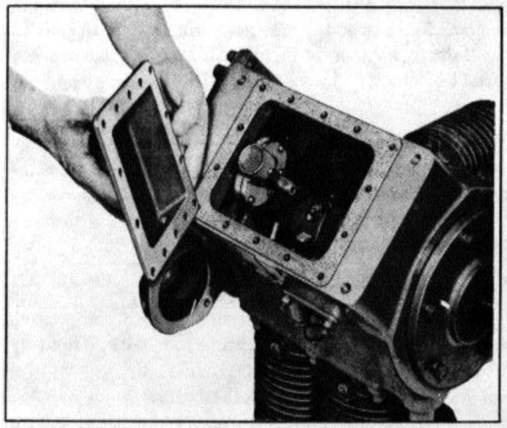


FIGURE 17 104721C

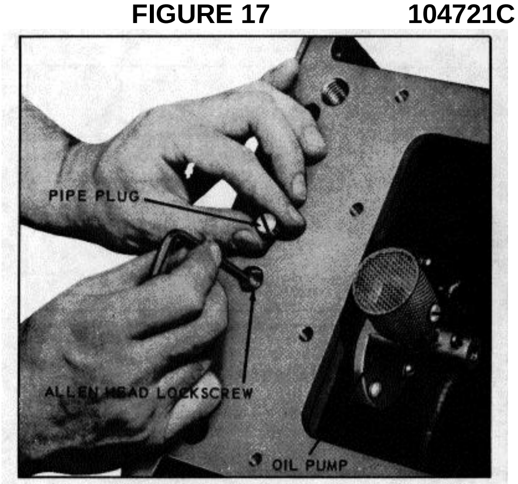


FIGURE 18 180178C

crankshaft until piston is at top, then push connecting rod and piston assembly upward and out thru top of cylinder. Be careful not to mar the crank pin by allowing the rod bolts to strike or scrape across it. Place caps on rods immediately so that they will not be mismatched in reassembly.

NOTE

Care should be taken in reassembly to mount bearings properly. The cap should be assembled to the rod so that the locating lug of both bearing halves are on the same side as illustrated in *Fig. 19*. Refer to chart, *Fig. 23*, for clearance between bearing and crank pin.

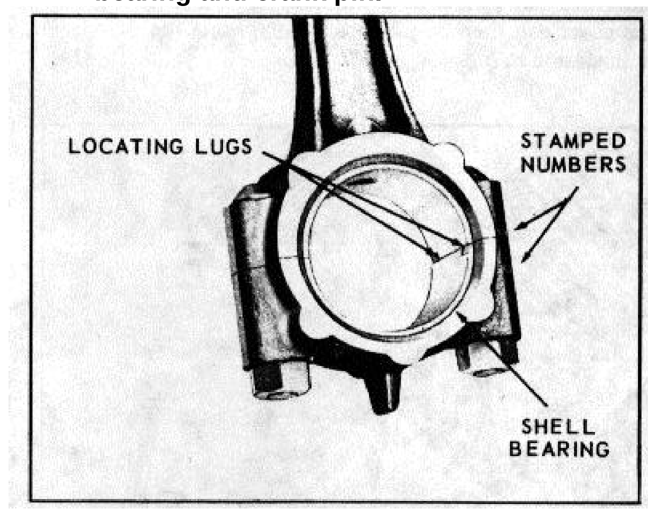


FIGURE 19 316307C

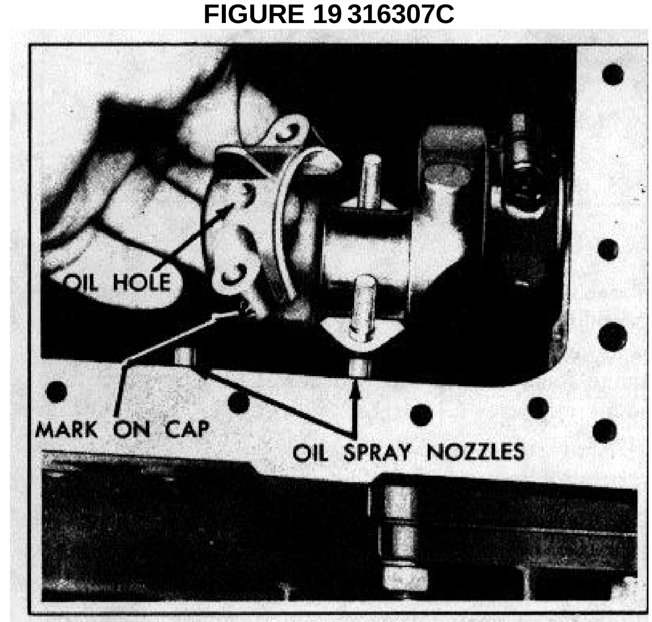


FIGURE 20 104819C

The piston skirt is **cam-ground** to an elliptical contour. Clearance between the piston and cylinder must be measured at the center of the thrust face at the bottom of the piston skirt. Refer to Chart, *Fig. 23*, for proper clearance. The thrust faces on the piston skirt are 900 from the axis of the piston pin hole, with the wide section of the piston skirt toward the maximum thrust side, or opposite the crankshaft rotation.

In reassembly; be sure piston and connecting rod assemblies are put back into the same bore from which they were removed. Use a suitable ring compressor and stagger the piston ring gaps 900 apart around the piston. Oil the pistons, rings, wrist pins, rod bearings and cylinder walls before assembly.

NOTE

> **Identical numbers are stamped on the side of the rod with its corresponding cap. These numbers must be on the same side of the connecting rod when mounted in engine. Be sure that oil hole in connecting rod cap is facing toward the oil spray nozzle, as illustrated in Fig. 20. Install new nuts on connecting rod bolts and torque 22 to 28 foot pounds.**

PISTON RINGS (Fig's. 21, 22, 23)

If a ring expander tool is not available, install rings by placing the open end of ring on piston first, as shown in Fig. 21. Spread ring only far enough to slip over piston and into correct groove, being careful not to distort ring. Install bottom ring first and work toward the head of the piston, installing top ring last.

The word ***'TOP'*** on compression and scraper rings indicates direction of ring placement on piston.

The outer diameter of the compression ring is ***chrome plated***. Mount scraper ring with scraper edge down, otherwise oil pumping and excessive oil consumption will result. Refer to *Fig. 22* for the correct placement of piston rings.

CYLINDER BLOCKS

Clean all dirt and foreign deposits from between the cylinder fins and manifold ports.

The cylinder blocks do not have to be removed unless the cylinder bore is scored, out-of-round, or worn oversize more than 0.005 inch. In this event, the block will have to be removed, rebored and fitted with oversize pistons and rings.

In Reassembly; tighten the cylinder block mounting nuts, ***40*** to ***50 foot pounds torque***.

VALVES and SEAT INSERTS (Fig. 24)

Remove valve tappet inspection plate and compress valve springs with a standard automotive type valve lifter as illustrated. Insert a rag in the opening at the bottom of valve chamber so the retaining locks do not fall into engine crankcase. Remove retaining locks, seats, springs, valves and clean these, as well as the ports and guides, of all carbon and gum deposits. Tag each valve so that in reassembly they will be mounted

FIGURE 21 **71152C**

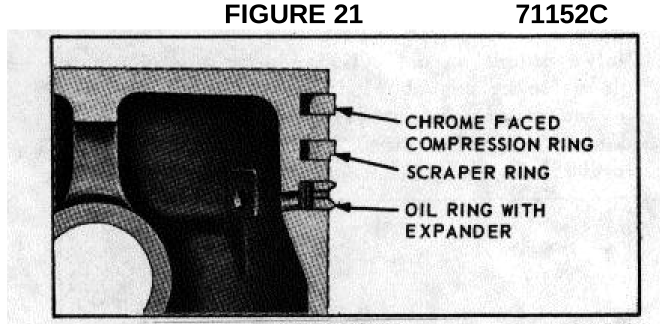


FIGURE 22 **285335C**

PISTON TO CYLINDER AT PISTON SKIRT THRUST FACE		.003 to .004"
PISTON RING GAP		.010 to .020"
PISTON RING SIDE CLEARANCE IN GROOVES	TOP RING	.002 to .004"
	SCRAPER RING	.002 to .004"
	OIL RING	.001 to .003"
PISTON PIN TO CONNECTING ROD BUSHING		.0004 to .0012"
PISTON PIN TO PISTON		.0000 to .0008" tight
CONNECTING ROD TO CRANK PIN – SIDE CLEARANCE		.009 to .016"
CONNECTING ROD SHELL BEARING TO CRANK PIN DIA. (VERTICAL)		.0012 to .0033"
CONNECTING ROD BABBITT BEARING TO CRANK PIN		.0007 to .0020"

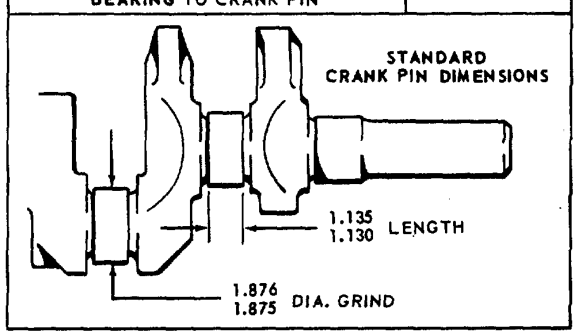


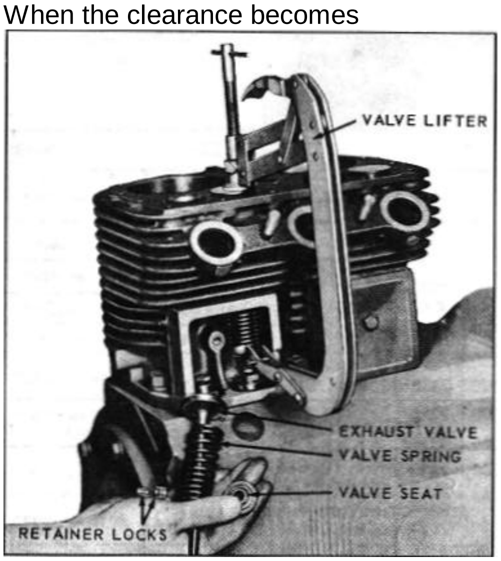
FIGURE 23. PISTON, RING, AND ROD CLEARANCES CHART

in the same guide they were removed from. Replace valves that are burned or pitted.

The inlet and exhaust valve ***seat inserts*** can be removed, when replacement becomes necessary, by means of Wisconsin Motor DF-66-A insert puller.

Before grinding valves, inspect valve guides for possible replacement. Refer to Valve Guide paragraph. The valve face is ground at 45 0to the vertical center line of the valve stem and the valve seat insert should also be ground at a 450 angle. ***After*** grinding, lap valves in place until a uniform ring will show entirely around the face of the valve. Clean valves and wash block thoroughly with a hot solution of soap and water. Wipe cylinder walls with clean lint free rags and light engine oil, especially if cylinders were rebored and honed.

Valve guides in the cylinder block are easily replaceable by use of Wisconsin ***DF-72 driver tool***. In reassembly; mount guides with inside chamfer down. The valve stem has a clearance of .003 to .005' in the guide. When the clearance becomes



180188C .007",

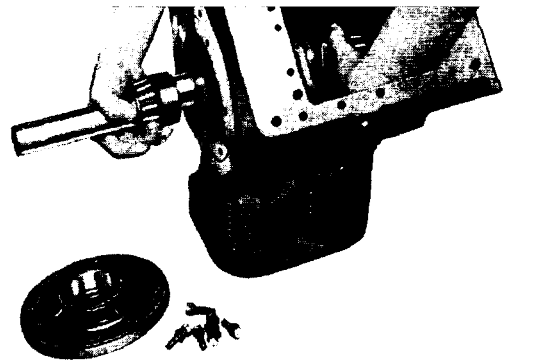
FIGURE 24

the guides should be driven out and replaced with new guides.

These engines that have ***Stellite*** exhaust valves and inserts are designated as Model ***VH4D*** and are equipped with **positive** type **exhaust valve rotators**. The action of the rotocap, which rotates the valve slightly each time the valve opens, helps prevent sticky valve and will impart a wiping action between the valve face and valve seat, thereby preventing the build-up of foreign deposits. Valve rotation will also avoid prolonged exposure of any one sector of the valve face to a local hot spot on the seat which will result in lower and more uniform valve face-seat temperatures.

CRANKSHAFT

To remove the crankshaft, first remove the six capscrews in the main bearing plate at the take-off end of the engine. This plate can then be pried off, and crankshaft removed from that end of crankcase. See Fig. 25. Be sure to keep shims and gaskets in place as these are necessary to give the proper end play to



71075C

FIGURE 25

the tapered roller main bearings on the crankshaft. This ***end play*** should be ***.002 to .004*** inch when engine is cold. There is practically no wear in these bearings so that no readjustment is necessary after proper assembly.

When reassembling crankshaft, the timing marks on the crankshaft gear and the camshaft gear must be matched as shown in Fig. 15, otherwise engine will not operate properly, or if timing is off considerably, engine will not run at all.

The mounting holes for the main bearing plate are off-set in such a manner that it can only be mounted in the correct position. Tighten main bearing plate capscrews, 25 to 30 foot pounds torque.

CAMSHAFT

The camshaft must be withdrawn from the flywheel end of the engine as shown in Fig. 26. When reassembling, be sure the spring and plunger are in place in the end of the camshaft, as they hold the camshaft in position endwise.

VALVE TAPPETS

The valve tappets are taken out after the camshaft is removed. In reassembly, the tappets must of course be inserted in proper position in crankcase, before the camshaft is assembled.

After the cylinder blocks have been assembled to the crankcase, adjust the valve tappets as shown in Fig. 27. With the tappets in their lowest positions, engine cold, the clearance should be .008 inch for the inlet and .016 inch for the exhaust, with or without Stellite valves.

GOVERNOR OPERATION

The centrifugal flyball governor rotates on a stationary pin driven into the upper part of the timing gear

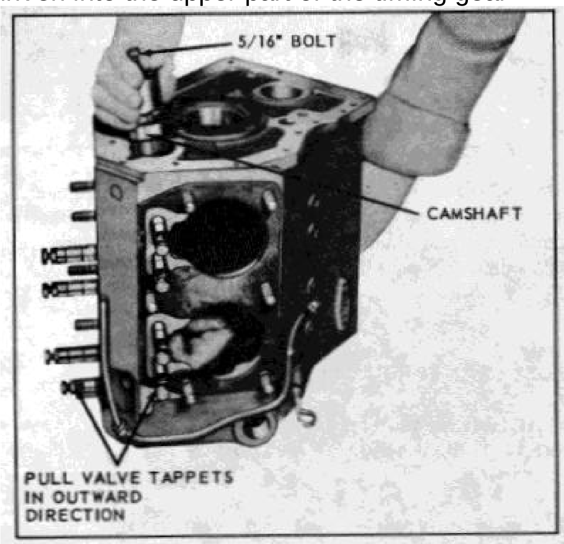


FIGURE 26 104726C-A

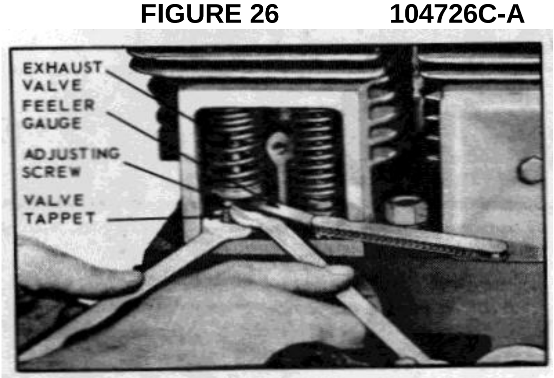


FIGURE 27 180186C

cover, and the governor is driven off the camshaft gear at crankshaft speed.

Flyweights are hinged to lugs on the drive gear. Hardened pins on the flyweights bear against the flanged sliding sleeve, moving it back and forth as the flyweights move in or out. The motion of the sleeve is transmitted through a ball thrust bearing to the governor lever, which in turn is connected to the carburetor throttle lever. A spring connected to the governor lever tends to hold the governor flyweights to their inner position, also to hold the carburetor throttle open. As the engine speed increases, the centrifugal force in the flyweights acts against the spring and closes the throttle to a point where the engine speed will be maintained practically constant under varying load conditions. This speed can be varied to suit conditions by adjusting the governor spring tension to suit.

Fig. 8. Checking Rack and Plunger for Free Movement with J 22396

GOVERNOR ADJUSTMENT

The governor rod connection to the carburetor must be very carefully adjusted for length, otherwise the governor will not function properly and cause the engine to surge badly. With the engine at rest, the governor spring will keep the flyweights in, and the control rod must be of such length as to hold the carburetor throttle wide open at that point. The accuracy of this adjustment can be tested by disconnecting the control rod from the governor lever, and then pushing the rod toward the carburetor as far as it will go. This will open the throttle wide. The governor lever should then be moved as far as possible in the same direction, all of this being done with the rod disconnected from the lever. Holding both parts in the above position, the rod should be screwed into the swivel block on the carburetor, until the bent end of the rod will register with the hole in the lever, then, screw the rod in two more turns. Insert the rod into the hole in the governor lever and assemble cotter pin. With the governor lever pushed toward the carburetor as far as it will go, there should be about a 1/16 inch clearance between the throttle lever and the stop pin on the carburetor. The clearance will cause the lever to bounce back from the stop pin, rather than jam against the pin, when a load is suddenly applied to an idling engine. This will eliminate excessive wear on the threads in the carburetor throttle swivel block.

	STANDARD Vertical Mounted Carburetor	
LOAD R.P.M.	NO LOAD R.P.M.	HOLE NO.
1400	1525	4
1500	1650	5
1600	1725	5
1700	1850	6
1800	1950	7
1900	2025	7
2000	2150	8
2100	2225	8
2200	2350	9
2300	2425	9
2400	2550	10
2500	2625	10
2600	2750	11
2700	2850	12
2800	2925	12

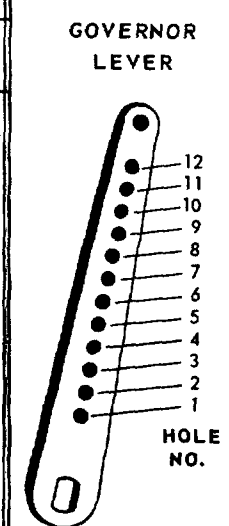


FIGURE 28

The governor lever is furnished with 12 holes, as shown in Fig. 28, for attaching the governor spring. It is very important that the spring is hooked into the proper hole to suit the speed at which the engine is to be operated. The Governor Lever Chart, Fig. 28, shows the **full load** and **no load** speeds of the engine and the hole corresponding thereto. Note that the **full load** speed is less than the **no load** speed and this must be taken into consideration when readjusting the governor. The pump engine operates at a full load speed of 2500 R.P.M. and a no load speed of 2650 R.P.M. The spring should be hooked in hole 10 of the governor lever and the spring tension adjusted by means of the adjusting screw to run 2650 R.P.M. at no load. When load is applied the engine will run at approximately 2500 R.P.M.

A tachometer or revolution counter should be used against the crankshaft to check speed while adjusting the governor spring tension. Tightening the adjusting screw locknut will give higher speeds, while loosening the locknut will lower the spring tension and reduce the R.P.M.

WALBRO CARBURETOR

OPERATION, Fig. 29

Fuel is pumped through the gas lines from the tank to **Inlet fitting (1)**, through inlet needle **Valve seat (2)** and into the fuel bowl. As the level in fuel bowl increases, the **Float (3)** rises, shutting off the fuel supply by forcing needle valve into **Valve seat (2)**. As fuel is being consumed, the float drops and allows additional fuel to enter the bowl through the valve seat. Internal **Air vent (7)** provides clean air to balance atmospheric pressure in fuel bowl.

WHEN STARTING; the **Choke valve (5)** is closed and the **Throttle valve (10)** is wide open causing an abnormally high suction. This high vacuum demand draws fuel and air from both idle and main systems for ease in cold starts.

Fuel from the bowl enters the **Main metering jet (4)**. then up through **Main nozzle (9)** where it combines with air from **Nozzle well air-vent (6)**. This mixture passes thru **Venturi (8)** and blends with fuel/air mixture **from Air vent (15)** and **Idle holes (11)** and **(12)** to provide a highly volatile rich mixture for starting.

AT IDLE SPEEDS; the **Throttle valve (10)** remains closed, exposing only the **Idle hole (11)** from which a fuel/air mixture is drawn. Air volume is closed off up to the idle hole by the throttle valve as the **Choke valve (5)** is now open. The **Idle adjusting needle (14)** regulates the amount of fuel/air mixture to **the Idle hole (11),** from **Idle air vent (15)** and **Idle fuel channel (16),** to meet various engine operating conditions.

AT HIGH SPEED, or full throttle operation; gradual acceleration is obtained when the **Throttle valve (10)** is partially opened allowing additional fuel/air mixture from the **Idle hole (11)** and **Part throttle hole (12)** to enter the engine combustion chamber, causing the engine to run faster. As the throttle valve opening is increased and the engine demands a greater fuel/air volume, the **Nozzle (9)** begins to satisfy this requirement beyond the idle hole and part throttle hole capacities.

After the acceleration assist from the idle system; at full throttle the complete idle circuit is reversed, as air only, in place of the fuel/air mixture, is drawn through the **Idle holes (11), (12), and Channel (16), to Nozzle (9),** where it is blended with fuel drawn from float chamber thru **Jet (4).**

TROUBLE CAUSES AND REMEDIES Dirt is the major cause of field service carburetor problems.

An adequate Fuel Filter must be used between the tank and carburetor, and should be serviced frequently. Service Air Filter daily Keep carburetor and linkage free of dirt.

FUEL LEAKS FROM CARBURETOR Float level set too high: Remove bowl, invert carburetor and set float. See Fig. 30 and Float Setting Instructions, page 14-15.

Dirt under inlet needle valve: Remove inlet valve, clean seat by rinsing in mild solvent or clean fuel, and blow off with compressed air.

Bowl vent plugged: Remove bowl and blow clean with compressed air.

Collapsed float, caused by blowing assembled carburetor with compressed air: Replace float.

Carburetor gummed from storage float stuck: Remove fuel bowl and clean.

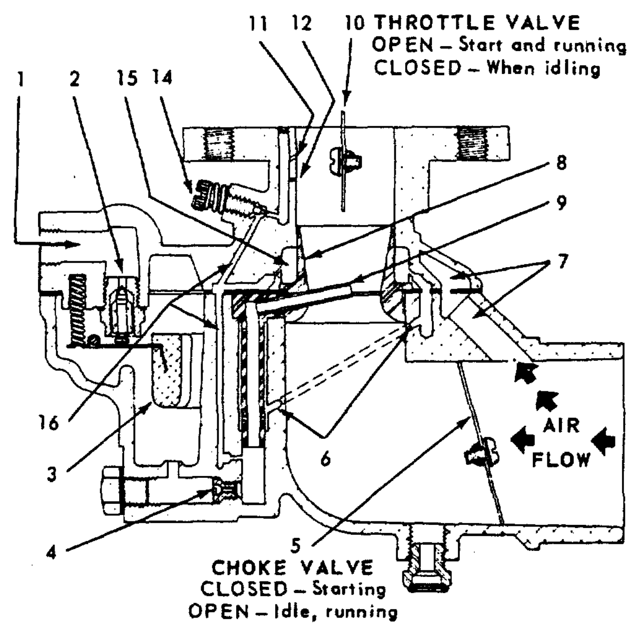


FIGURE 29

ENGINE SMOKES AND RUNS RICH

Dirty air filter: Clean per instructions.

Improper adjustment: Set Idle Needle 1 ± 1/8 turns open from seat. Refer to Adjustment Instruction, page 14-15.

Bowl to body gasket leaks: Tighten securely, or replace.

Air vent in carburetor plugged: Remove fuel bowl and idle needle. Clean air and idle channels thoroughly with compressed air.

ENGINE RUNS LEAN Improper adjustment: Set Idle Needle 1 ± 1/8 turns open from seat. Refer to Adjustment Instructions, page 14-15.

Idle holes plugged. Dirt in fuel delivery channels: Remove fuel bowl and idle needle. Clean thoroughly with compressed air.

Low fuel level: See Fig. 30 and Float Setting Instructions, page 14-15.

Fuel filter plugged: Remove and clean.

ENGINE STARTS HARD Improper adjustment: Set Idle Needle 1 ± 1/8 turns open from seat. Refer to Adjustment Instructions, page 14-15.

No fuel in carburetor: Check carburetor drain plug. Clean tank, filter and carburetor. Check fuel lines for obstructions, and test fuel pump.

Choke valve not closing: Check linkage for proper travel.

GOVERNOR SURGE Governor sticking: Check linkage for binding.

Throttle shaft and valve binding: Remove and replace.

shaft if worn. Clean carburetor body and reassemble throttle shaft.

DISASSEMBLY Before disassembling: Clean outside of carburetor from all foreign material.

IMPORTANT: When cleaning a completely assembled carburetor **do not** blow with compressed air, you may collapse the float.

For a complete disassembly, follow the sequence of part reference numbers in the carburetor exploded view, Fig. 31. **Nozzle** Ref. 9, Fig. 29 **is not removable**.

IMPORTANT: Before removing Throttle and Choke levers, note their position and location. Optional mounting is available and may differ from exploded view illustration.

CLEANING Wash all parts in a mild solvent or fuel. Blow air through orifices (holes) and channels in throttle body and fuel bowl. Do not probe with any sharp tools which might damage small metering holes.

REASSEMBLY Replace all worn or damaged parts use all new gaskets.

Note; Body Gasket (18) is put on before float is assembled, and round opening in gasket fits into groove of Venturi (11).

Be sure that Notch in Venturi is **facing toward float needle valve** this is clearance for Main nozzle in throttle body.

Assemble Throttle Valve (8) and Choke Valve (25) with part numbers **facing to the outside**, when valves are in the closed position.

IMPORTANT: Be careful in tightening brass screws and fittings, so as not to strip threads and screw driver slots.

Tighten firmly but not excessively.

Valve Seat (16) 40 to 50 inch pounds torque Main Jet (22) 50 to 60 inch pounds torque **FLOAT SETTING, Fig. 30** With fuel bowl removed and float assembly in place, turn throttle body upside down so that float assembly is on top.

Check float height with a depth gauge. Setting should be **1.010 inch ± .020** above bowl gasket. If necessary, bend float arm (at float), to obtain correct height.

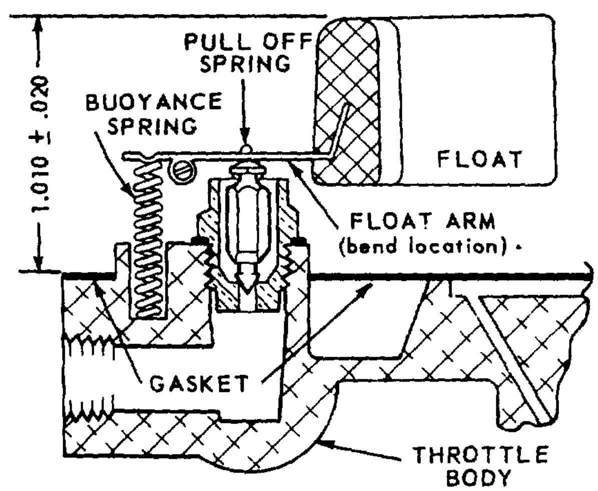


FIGURE 30. FLOAT SETTING

ADJUSTMENTS, Fig. 29 Turn **Idle speed screw (5)**, Fig. 31, in until throttle valve is slightly open. With engine warmed up and running, turn adjusting screw in or out as required to obtain desired low idle speed (1000 to 1200 r.p.m.).

The **Idle adjusting needle (14)** should be seated lightly (clockwise), then backed out 1 ± 1/8 turns as a preliminary setting. With engine warmed up and running at about 1200 R.P.M., fine tune idle mixture for smooth steady running.

The **Main Metering Jet (4)**, for high speed operation is fixed (not adjustable), as standard equipment.

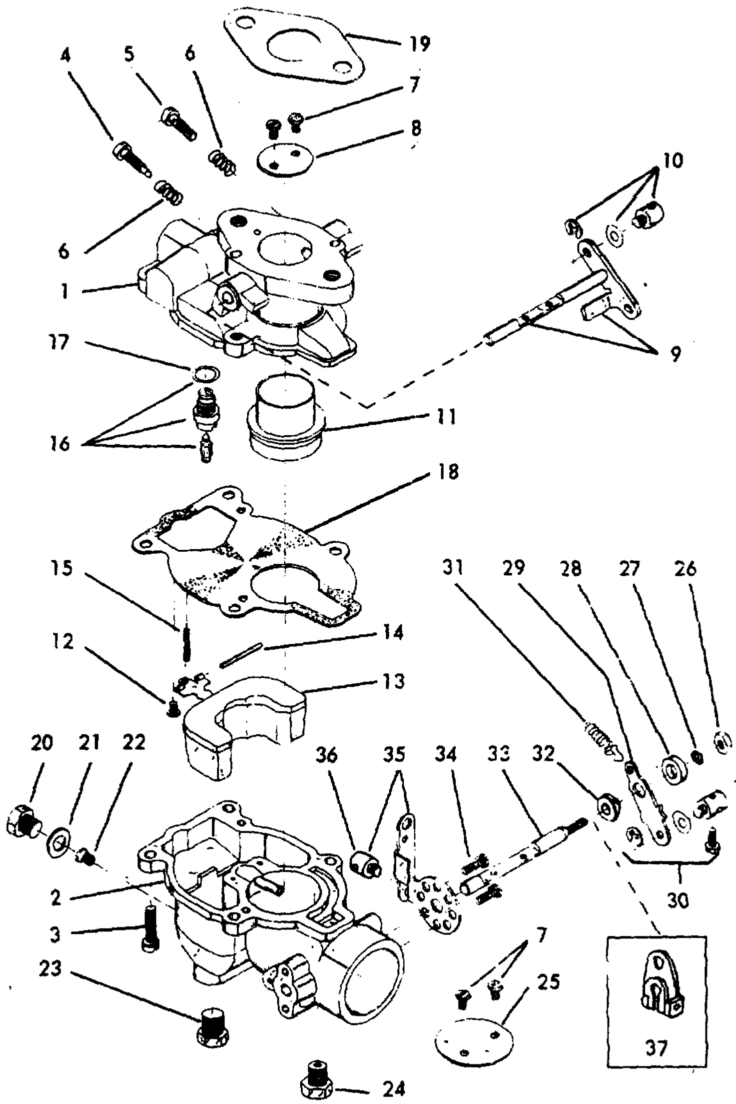
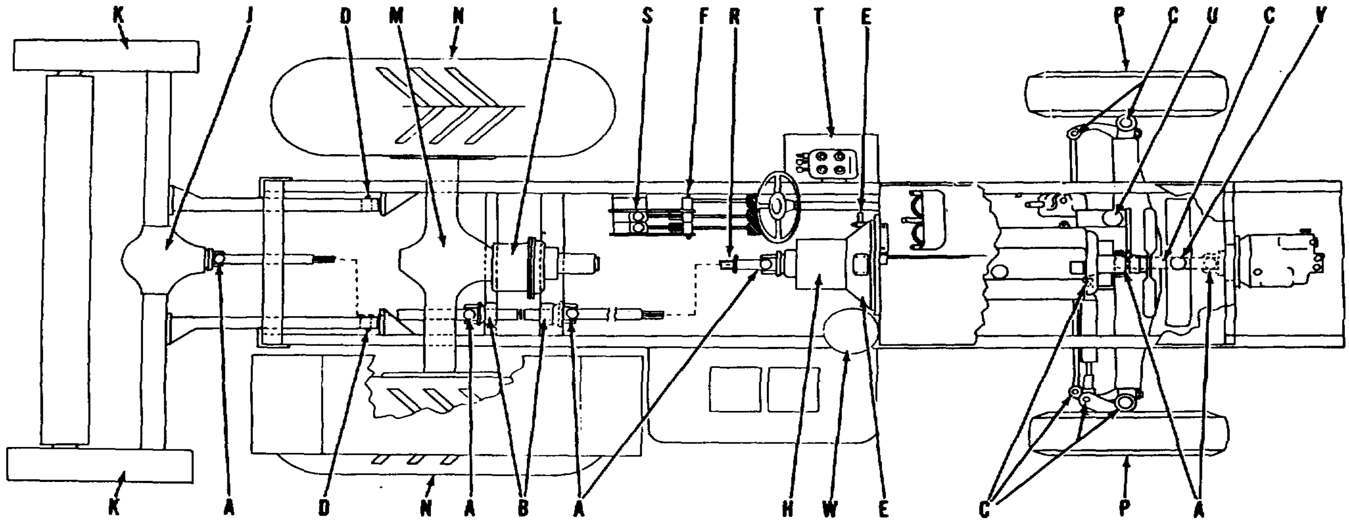


FIGURE 31. EXPLODED VIEW
Instructions and Service Parts Illustration

SUBSECTION 15 LUBRICATION CHARTS



LUBRICATION CHART 1 - GENERAL

REF.	DESCRIPTION AND NUMBER OF LUB. POINTS	LUBRICANT	SERVICE, CAPACITIES AND REMARKS
A	UNIVERSAL JOINTS (6)	MOBIL TEMP. #1(OR EQUIVALENT)	WEEKLY. FITTINGS. PRESSURE GUN.
B	PILLOW BLOCK BEARINGS (2)	MOBIL TEMP. #1(OR EQUIVALENT)	WEEKLY. FITTINGS. HAND GUN.
C	CENTER AXLE PIVOT (1) STEERING KNUCKLES (4), ARMS (2) STEERING RAM LINKAGE (2)	MULTI-PURPOSE	WEEKLY. FITTINGS. PRESSURE GUN.
D	ROTOR ARM BEARINGS (2)	MULTI-PURPOSE	WEEKLY. FITTINGS. PRESSURE GUN.
E	CLUTCH RELEASE BEARING (1) SHAFT (2)	MULTI-PURPOSE	WEEKLY. FITTINGS. PRESSURE GUN.
F	BRAKE AND CLUTCH PEDAL (1)	MULTI-PURPOSE	WEEKLY. FITTINGS. PRESSURE GUN.
H	UR-163, 2-SPEED ROTOR DRIVE TRANS. (1)	HD80-90below30° F HD140 above 30°F	CHECK LEVEL DAILY. SERVICE EVERY 500 HOURS. DRAIN, FLUSH AND REFILL TO LEVEL PLUG. CAPACITY: 4 QTS.
J	END DRIVE DIFFERENTIAL CASE (1)	HD80-90 below30°F HD140 above 30°F	CHECK LEVEL DAILY. SERVICE EVERY 500 HOURS. DRAIN, FLUSH AND REFILL TO LEVEL PLUG. CAPACITY: 4 1/2 QTS.
K	END DRIVE CHAIN CASE (2)	HD80-90 below30°F HD140 above30°F	CHECK LEVEL DAILY. SERVICE EVERY 500 HOURS. DRAIN, FLUSH AND REFILL TO LEVEL PLUG.
L	NOSE BOX ON REAR AXLE DIFFERENTIAL (1)	HD80-90below30°F HD140 above30°F	CHECK LEVEL DAILY. SERVICE EVERY 500 HOURS. DRAIN, FLUSH AND REFILL TO LEVEL PLUG. CAPACITY: 4 QTS.
M	REAR AXLE DIFFERENTIAL (1)	HD80-90below30 F HD140 above30°F	CHECK LEVEL DAILY. SERVICE EVERY 500 HOURS. DRAIN, FLUSH AND REFILL TO LEVEL PLUG. CAPACITY: 6 QTS.
N	HUB AND DRUM ASSY. (WHEEL ENDS (2))	HD80-90below300F HD140 above30°F	CHECK LEVEL DAILY. SERVICE EVERY 500 HOURS. TURN HUB AND DRUM ASSY. SO FILL PLUG IS ON TOP. DRAIN, FLUSH AND REFILL TO LEVEL PLUG. CAPACITY: 3 QTS.
P	FRONT WHEEL BEARING (2)	*N.L.G.I. GRADE 2 WHEEL BEARING GREASE	SERVICE EVERY 2000 RUNNING HOURS. DISASSEMBLE, CLEAN AND REPACK THOROUGHLY
R	SHEAR COUPLING (1) SER. NO. HK-866 AND UP	MULTI-PURPOSE	DISASSEMBLE COUPLING, CLEAN AND REPACK YEARLY.
S	BRAKE CYLINDERS (2)	HYDRAULIC BRAKE FLUID	CHECK WEEKLY. SERVICE EVERY 500 HOURS. DRAIN, FLUSH AND REFILL SYSTEM. CAPACITY: 1 PINT

LUBRICATION CHART 1 - GENERAL (Continued)

T	HYDRAULIC OIL RESERVOIR (1)	* SEE BELOW	CHECK OIL LEVEL DAILY. DRAIN, FLUSH AND REFILL SYSTEM EVERY 2000 RUNNING HOURS, INCLUDING OIL FILTER. CAPACITY: 10t GALS. APPROX. POUR OIL THRU A 75 MICRON FILTER OR 2000 MESH SCREEN. PERIODICALLY CLEAN FILTER ELEMENT WITH SOLVENT AND BLOW AIR DRY. MAINTAIN TANK BREATHER CAP CLEAN.
U	POWER STEERING PUMP RESERVOIR (1)	SAME AS (T)	CHECK OIL LEVEL DAILY. SERVICE EVERY 500 RUNNING HOURS. DRAIN, FLUSH AND REFILL RESERVOIR TO LEVEL. CAPACITY: 3 PINTS. POUR OIL THRU A 75 MICRON FILTER OR 200 MESH SCREEN.
V	ENGINE COOLING SYSTEM	WATER-FREE OF MINERALS WITH RUST INHIBITOR ADDED. ANTI-FREEZE WHEN REQUIRED.	CHECK DAILY. FILL AS REQUIRED. CAPACITY: 34 GALS. APPROX. IT IS RECOMMENDED NOT TO USE AN ANTI-FREEZE CONTAINING A LEAK PREVENTA-TIVE ADDITIVE.
W	ENGINE AIR CLEANER (DRY TYPE)	—	CHECK AND EMPTY BOWL DAILY. CLEAN ELEMENT PERIODICALLY. CHANGE ELEMENT AS REQUIRED.
X	FUEL TANK (NOT SHOWN)		DIESEL FUEL OIL FILL AS REQUIRED. CAPACITY: 80 GALS. NO. 2D
	ENGINE	—	REFER TO ENGINE MANUAL

TIRES: FRONT: STANDARD 30 P.S.I.; OPTIONAL 30 P.S.I.
REAR: STANDARD 18 P.S.I.; OPTIONAL 16 P.S.I.

* N.L.G.I. NATIONAL LUBRICATING GREASE INSTITUTE.

** HYDRAULIC OIL PROPERTIES

FLUID TYPE	TYPICAL VISCOSITY SUS			VISCOSITY INDEX	POUR POINT °F	OPERATING RANGE(TYPICAL °F.)
	0°F	100°F	210°F			
ANTI-WEAR HYDRAULIC OIL	7,000	200	50	132	-30	0 - 200°F
TYPE "F"	3,200	212	57.2	208	-40	-15 - 200°F
HYDRAULIC TRANS. OIL	12,000	233	49	100 MIN.	-35	0 - 200°F
†PYDRAUL 312	100,000	312	51	77	-10	50-200°F

†FIRE RESISTANT FLUID

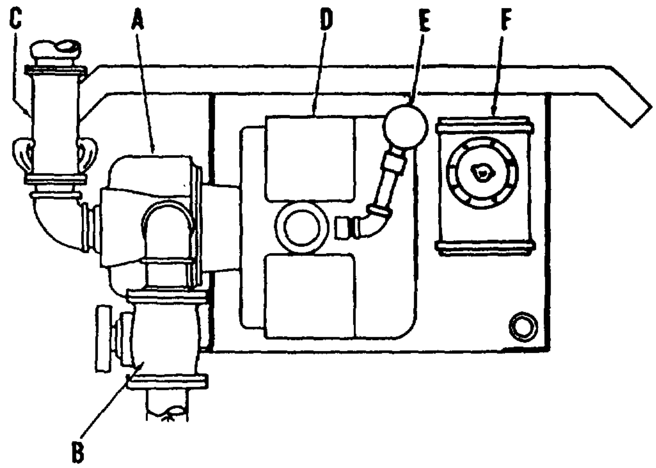
THE ABOVE LISTING MAY BE PRESENTED TO YOUR OIL COMPANY AS A GUIDELINE FOR SELECTING THEIR BRAND OF OIL FALLING IN THE CATEGORY OF THE RECOMMENDED FLUIDS FOR USE WITH SUNDSTRAND COMPONENTS.

BELOW ARE LISTED A FEW HYDRAULIC FLUIDS THAT HAVE BEEN TESTED AND APPROVED BY THE SUNDSTRAND HYDRO-TRANSMISSIDN CORP.

SOURCE	FLUID DESIGNATION
MOBIL OIL CO.	MOBILFLUID #300
AMERICAN OIL CO.	RYCON #21
AMERICAN OIL CO.	LF-5179
VISCOSITY OIL	L-2135
SHELL OIL CO.	DONAX T-7
SHELL OIL CO.	TELLUS T-27

IF IT IS NECESSARY TO ADD OR REFILL IN THE FIELD AND THE ABOVE FLUID CANNOT BE OBTAINED, IT IS RECOMMENDED THAT AUTOMATIC TRANSMISSION FLUID TYPE A, SUFFIX A BE USED.

THE ABOVE OILS HAVE BEEN TESTED AND APPROVED BY THE SUNDSTRAND HYDRO-TRANSMISSION CORP., HOWEVER, A NUMBER OF ACCEPTABLE FLUIDS ARE ON THE MARKET THAT ARE COMPATIBLE. IF FLUIDS OTHER THAN LISTED ABOVE ARE GOING TO BE USED, THE USER SHOULD TAKE APPROPRIATE STEPS, INCLUDING TESTING, TO INSURE THE COMPATIBILITY OF THE OIL. CONTACT YOUR LOCAL OIL SUPPLIER.



LUBRICATION CHART 2 - EMULSION HANDLING SYSTEM

Ref.	Description	Lubricant	Service and Remarks
A	Centrifugal Pump 4"	Liquid in Pump Body	Do not operate pump without liquid in the pump body, as operating pump dry will result in damage to the rotary seal.
B	Nordstrom Metering Valve	Sealent #421 in stick. Grade and Size "D"	Weekly or more often as deemed necessary.
C	Pump Strainer	—	Disassemble and clean periodically with fuel oil or solvent. Solids passing thru the strainer could cause damage to the meter.
D	Engine Crankcase	Consult Engine Manual	Check daily. Consult engine manual for oil and changes.
E	Engine Air Cleaner	—	Check daily. Clean bowl frequently. Consult Engine Manual.
F	Fuel Tank	—	13 gallons capacity.

SECTION 3 PARTS

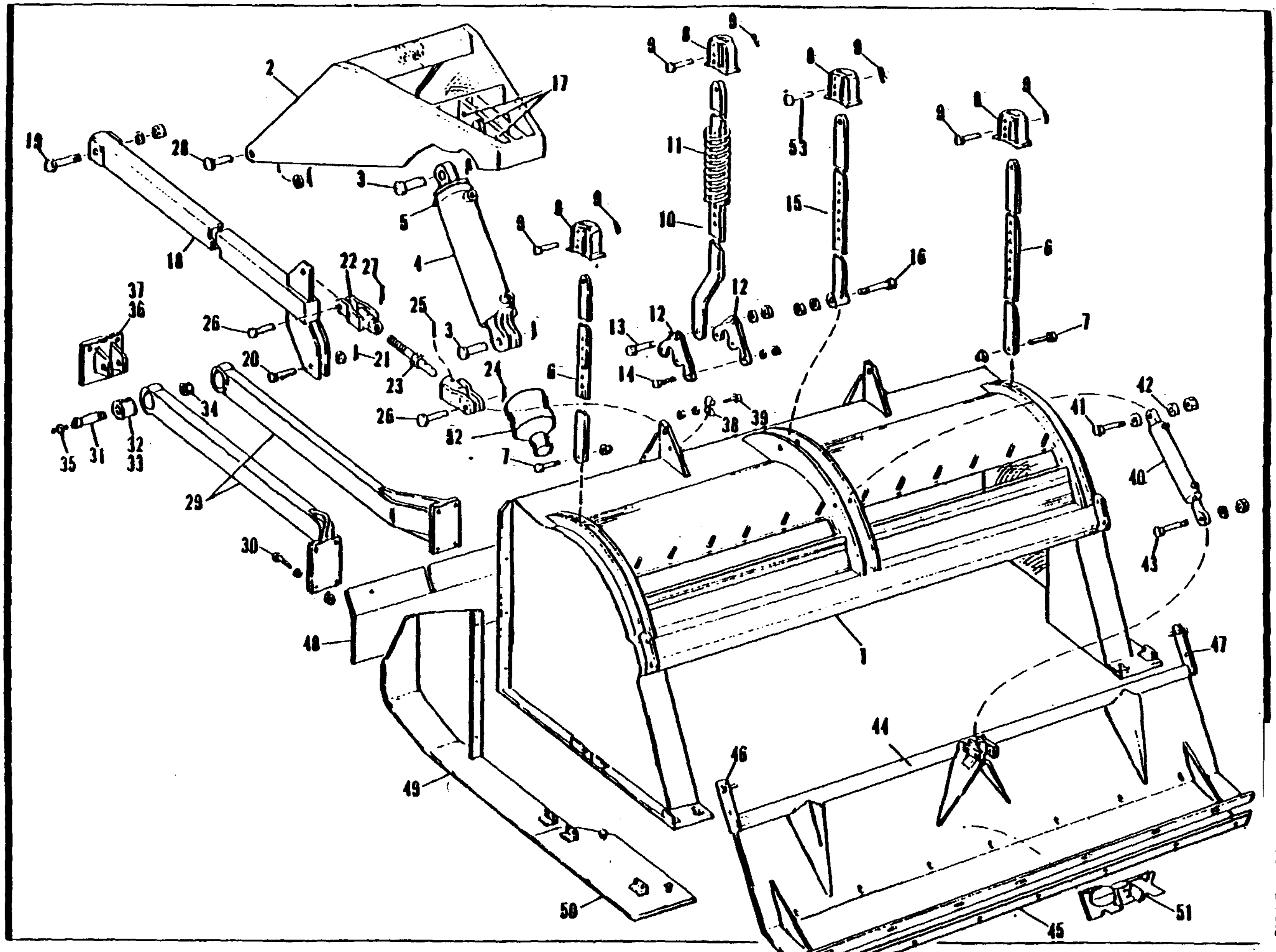
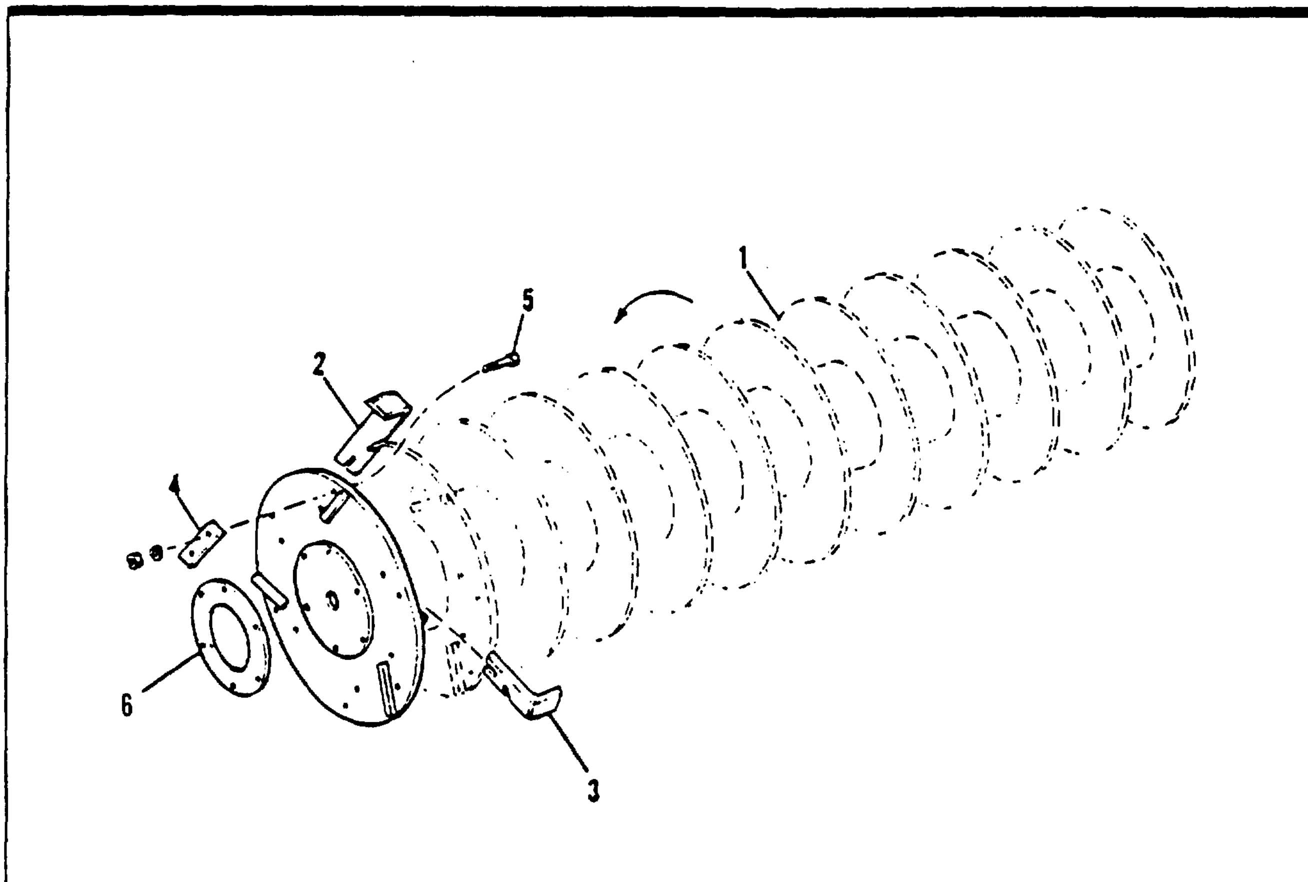


FIG. 1. ROTOR HOOD, TAILBOARD, LIFT ARMS, HOOD ARMS, JACK AXLE ARMR AND SKIS

ROTOR HOOD-CRANE-TAILBOARD-LIFT ARMS
HOOD ARMS-JACK AXLE ARMS & SKIS
REX SELF-PROPELLED PULVI MIXERS

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	502-6160-80	Rotor Hood	1	29	502-4290-80	Jackaxle Arm (R.H. & L.H.)	2
2	502-5615-8	Crane	1		298-131-93	H.T. Zinc Plated Cap Screw ¾ x 2 ¼"	8
	102-6216-1	Drilled Pin	3	30	298-2061-11	Flanged Lock Nut-Cad. Plated ¾”	8
3	398-13000-35	Cotter Pin 3/16 x 2 ¼”	3	31	102-1562-1	Special Boll	2
4	102-4283-1	Lilt Cylinder for Crane 5" x 12'		32	298-5001-a	Bushing	2
		(See Separate Illustration)	1	33	298-5550-68	Rubber Joint	2
	102-6215-1	Shroud for Lift Cylinder	1	34	298-2029-71	Lock Nut 1 ¼ " NF	2
5	298-9025-86	Clamp for Shroud	1	35	398-8000-11	Grease Filling # 1613B	2
6	502-4939-80	Rotor Depth Bar	2	36	502-2053-80	Bracket for Arm	2
	398-2002-619	Cap Screw 5/8 x 3" U.N.C.	2		298-125-93	Zinc Plated Cap Screw 5/8 x 2"	6
7	298-2014-71	Sell Locking Nut 5/8"' U.N.C.	2	37	298-2066-71	Flanged Lock Nut-Cad. Plated 5/8"	6
8	402-593-2	Cap for Bar	4	38	298-121-47	Hose Clip	4
	102-1551-2	Pin	4	39		Cap Screw 5-16" x 2'½" U.N.C.	
9	298-78-47	Spring Lock for Pin	4			w/L.W. & Nut	4
10	102-2723-1	Rotor Lift Bar	1	40	102-2786-1	Hyd. Cyl. -Tailboard (See Sep. Illus.)	1
11	102-2727-1	Rotor Lift Spring	1	41	……….	Cap Screw ¾ “ x 5” U.N.C. w/Nut	1
12	402-592-2	Rotor Lilt Bracket	2	42	102-6214-1	Spacer	2
	398-2004-70	Cap Screw ¾ x 3 ¾ “ Ht-HC-	1		……….	Cap Screw ¾ “ x 3 ½ “ U.N.C.	1
13	298-2035-71	Stop Nut ¾ " U.N.C.	1	43	298-2016-71	Lock Nut ¾ “ U.N.C.	1
14	398-2003-83	Cap Screw ½ x 2 ¾" HT-HC-		44	502-5596-80	Tailboard	1
		(U.N.F.)	3		102-4225-1	Wear Plate -Tailboard	1
15	502-2090-80	Hood Lift Bar	1	45	398-2001-10	Cap Screw 3/8 x 1" U.N.C. with Nut	7
16	……….	Cap Screw ¾ x 4 ¾ “ with L.W. & Nut	1		398-2001-76	Machine Screw-Flat Head 3/8 x 1”	
	398-2002-31	Cap Screw ½ x 2½ “ U.N.C.				U.N.C. with Nut	11
17		with Nut	3		502-2050-80	Pivot Pin (L.H.)	1
	102-1559-1	Spacer	3	46	……….	Cap Screw ¾ “ x 2" U.N.C.	
18	502-3836-80	Rotor Hood Arm	1			w/L.W. & Nut	2
	398-21003-40	Cap Screw 1" x 5" U.N.C.	2		502-2050-81	Pivot Pin (R.H.)	1
19	398-20000-82	Cut Washer 1"	4	47	398-2002-98	Cap Screw ¾ “x 2” U.N.C.	
20	502-2052-80	Pin-Arm to Hood	2			w/L.W. & Nut	2
21	……….	Cotter Pin 3/16” x 1 ½ “	2		102-2945-1	Baffle for Hood	1
22	502-8055-80	Adjusting Screw & Clevis	2	41	398-2001-76	Cap Screw 3/8" x 1" U.N.C. w/Nut	8
23	398-11000-58	Jam Nut 1" U.N.C.	2		502-3834-81	Front Ski (L.H.) (As Illus.)	1
24	502-8054-80	Adjusting Clevis	2	49	502-3834-80	Front Ski (R.H.) (Opposite)	1
25	298-6016-34	Roll Pin 5/16 x 1 3/8”	2		502-1842-81	Rear Ski (L.H.) (As Illus.)	1
26	502-2051-80	Pin for Yoke	4	50	502-1842-80	Rear Ski (R.H.) (Opposite)	1
27	398-3000-22	Cotter Pin 3/16” x 1 ¼ “	4		402-1540-1	REX Nameplate	1
	502-2052-82	Pivot Pin	2	51	……….	Nut 5/16” w/L.W. Cad. Plated	2
28	398-20000-82	Cut Washer 1”	2	52	102-9940-1	Extension-Crane Cylinder	1
	398-3000-23	Cotter Pin 3*16” x 1 ½ “	2	53	102-1551-3	Pivot Pin	1



**ROTOR ASSEMBLY WITH SOLID TUBE
AND BEYEL EDGE TINES
REX ASSEMBLY NO. 602.2720, COMPLETE**

Item No.	Part Number	Description	No. Req'd
1	502-5918-80	Rotor Tub	1
2	402-1591-1	Tine (LH.) 31/2" Standard	42
3	402-1591-2	Tine (R.H.) 31/2" Standard	42
4	102-1484-1	Tine Clamp	84
	398-2004-69	Cap Screw 1/2" x 2" H.C.H.T. S.C. (U.N.F.)	168
5	298-6-71	Nut H" thick (U.N.F.)	168
	298-5-97	Lock Washer H" Heavy	168
6	102-3880-1	Rotor Shim (Not Included in above Assy. - Us* as Required)	4

FIG. 2. ROTOR ASSEMBLY

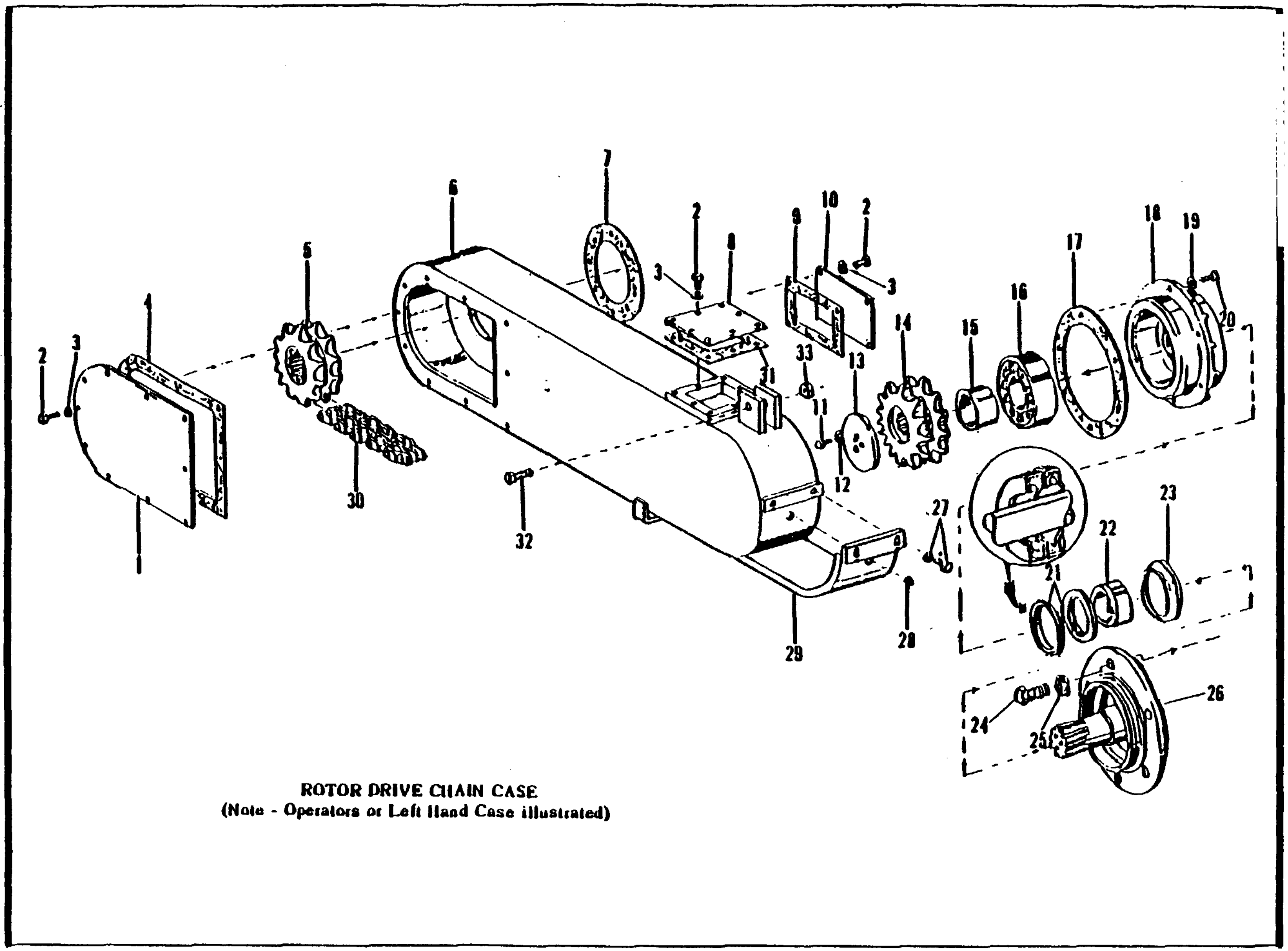


FIG. 3. ROTOR DRIVE CHAIN CASE (LEFT AND RIGHT REQUIRED)

ROTOR DRIVE CHAIN CASE
(TWO REQUIRED)
NOTE: LEFT HAND CASE ILLUSTRATED TO MATCH ILLUSTRATION OF: HOOD, CRANE, ROTOR LIFT BARS AND ROTOR ADJUSTMENTS.
SELF-PROPELLED PULVI MIXER

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	502-2032-80	Cover - Sprocket Chain Case	2	17	102-1475-1	Gasket	2
2	398-2001-72	Cop Screw 3/8" U.N.F. x 1/4" 19.	30	18	402-2582.2	Bearing Housing	2
3	398-20000-37	Lock Washer 3/8"	30	19	398-20000-39	Lock Washer 1/2"	12
4	102-2731-1	Cover Gasket	2	20	398-2003-75	Cop Screw H.C.-H.T. 1/2" U.N.F. x 11/4"	12
5	102-2735-1	Drive Sprocket (1ST)	2	21	298-3070-68	Oil Seal (C.R. 136177)	4
	{ 502-5535-80	Chain Case (As Illustrated) (L.H.)	1	22	102-6820-1	Spacer	2
6	502-5535-81	Chain Case (Opposite of Illustration)		23	102-6818-1	Spacer	I
		(R.H.)	1	24	398-2005-64	Nyloc Cap Screw 5/8" x 1 1/4" H.C.-H.T.	
7	102-1474-1	Gasket - Chain Case to Jackaxle	2			(U.N.C.)	12
8	102-1490-1	Top Cover - Chain Case	2	25	398-20000-41	Lock Washer 5/8"	12
9	102-1489-1	Gasket - Inspection Cover	2	26	502-5757-80	Rotor End Shaft	2
10	102-1491-1	Inspection Cover	2	27	398-2002-16	Cap Screw 1/2" U.N.C. x 1" w/L.W.	4
11	298-23-93	Sell-Locking Cap Screw	6	28	398-14005-23	Pipe Plug 1/2"	2
12	398-20000-37	Lock Washer 3/8"	6	29	102-4252-1	Wear Plate - Chain Case	2
13	102-6816-1	Lock Plate	2	30	100-2-60	Drive Chain 1100-2 Rex Chabelco x 60	
14	102-4356-1	Driven Sprocket (1ST)	2			Pitches long - Riveted	2
15	102-6819-1	Spacer	2	31	102-1473-1	Gasket - Top Cover	2
16	298-226-2	Bearing (S.K.F. Spherical Roller	32			Cop Screw 5/8" x 21/4"	2
		#22216C)	2	33	298-201471	Sell-Lock Nut 5/8" N.C.	2

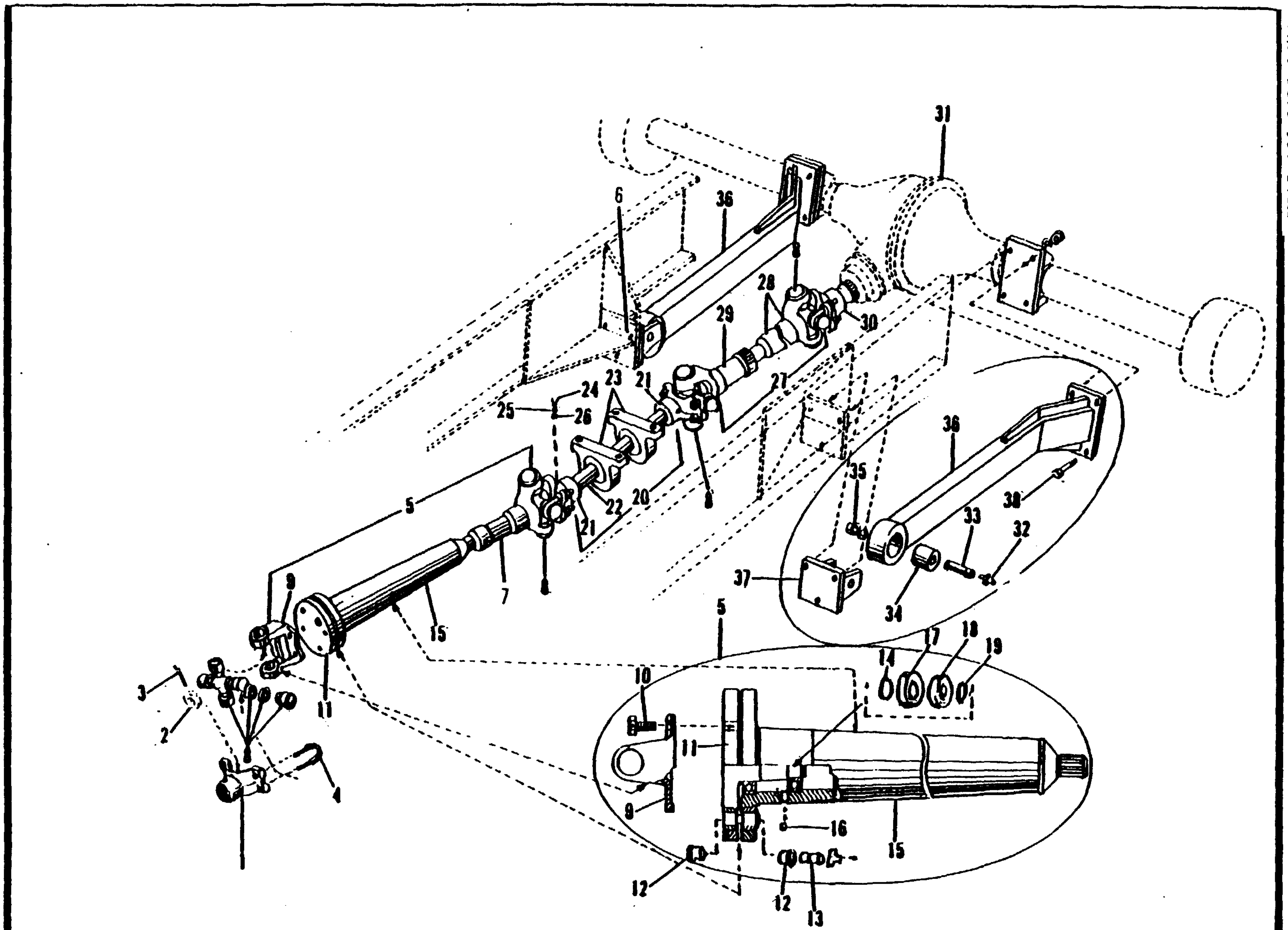


FIG. 4. ROTOR DRIVE LINE

ROTOR DRIVELINES
TRANSMISSION TO ROTOR DRIVE AXLE-
ROTOR DRIVE AXLE SUPPORT ARMS

Item No.	Part Number	Description	No. Req'd
1	298-6072-91	End Yoke - 2 Speed Transmission End	1
2	102-7286-1	Nut (End Yoke to Transmission) . - Reference Only -	1
3	398-3000-18	Cotter Pin 1/8 x 2" (Reference Only)	1
4	102-8737-1	"U" Boll Assembly -(Dana #3-94-28X - U Bolt, Nut & Washer)	8
5	602-7421-1	Shear Coupling & Driveline - (as Illustrated) - Consists of Items 7 thru 19	1
	398-2002-59	Cap Screw 5/8" x 2"	6
6	298-2014-71	Nut, Lock 5/8"- N.C.	6
7	102-8734-1	Slip Yoke Assembly (Dana #3-3-1601X	1
8	102-8735-1	Bearing Kit - Includes I set of Journal (Cross) Bearings and Snap Ring	4
9	298-6070-91	Flange Yoke (Dana #3-2-479)	1
	102-8739-1	Drilled Cap Screw	4
10		Soft Iron Wire # 16 Ga. x 9" Ig.	2
11	402-1721-2	Coupling Half- Male	1
12	102-102741	Bushing	2
13	102-8740-1	Shear Pin	1
14	102-8736-1	Spacer	1
15	502-4671-80	Tube Assembly	1
16	298-51-93	Set Screw	2
17	298-292-2	Bearing	1
18	298-268-2	Bearing	1
19	298-8519-34	Retaining Ring	
20	602-7423-2	Drive Shaft Assembly - Intermediate Consists of Items 21 thru 26	
21	102-30053-1	End Yoke	2
22	102-30054-1	Shaft	1
23	298-182-2	Bearing - Pillow Block	2
24	398-2007-2	HC - HT. Cap Screw 5/16" x 3 ¼"	2
25	398-20000-64	Lock Washer 5/16""	2
26	298-2033-71	Lock Nut 5/16"	2
27	602-7422-1	Universal Joint Assembly - Lower. Consists of Items 28, 29 and 2 of Item 8	1
28	5024670-80	Tube	1
29	102-8734-1	Slip Yoke	1
30	298-6071-91	End Yoke	1
31	502-4288-80	Rotor Drive Jackaxle Assembly- See Separate Illustration	1
32	398-8000-11	Grease Fitting #1613B	2
33	102-1562-1	Special Bolt	2
	298-5001-8	Bushing .	2
34	298-55568	Rubber Joint	2
35	298-2029-71	Nut - Lock 1 ¼" NF.	2
36	502-4290-80	Arm - Jackaxle	2
37	502-2053-80	Bracket	2
	398-2003-00	Cap Screw 3/4 x 2 1/4"	8
38	298-2035-71	Slop Nut ¾"	8
	398-2002-59	Cap Screw 5/8" x 2"	6

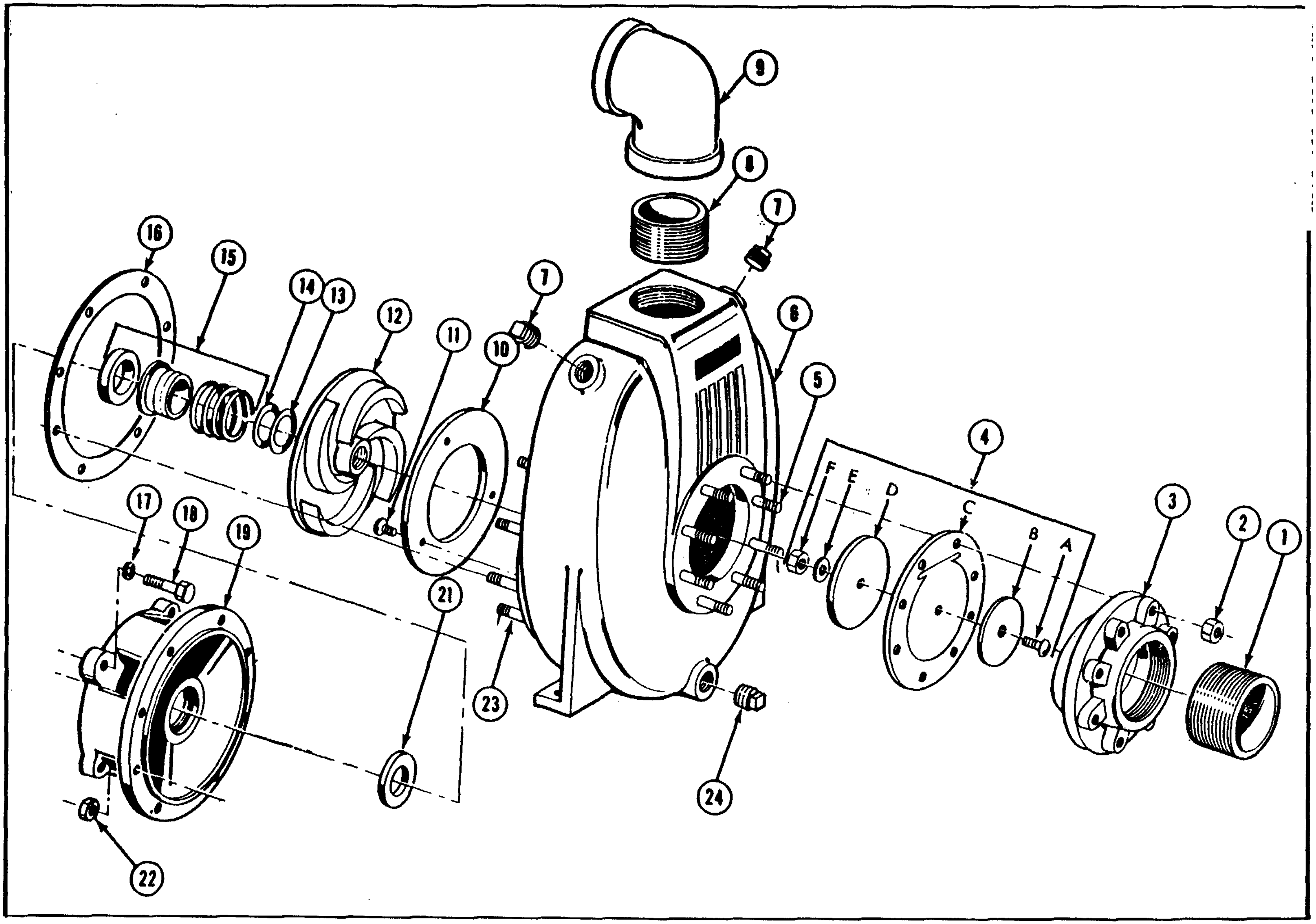
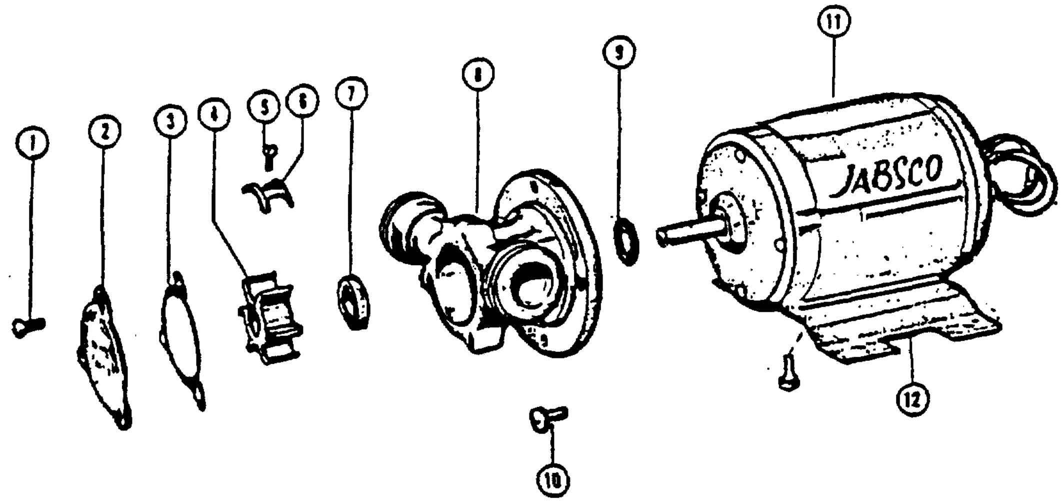


FIG. 5. EMULSION PUMP ASSEMBLY PEABODY - BARNES MODELS: 30CCG, 30CCG-1, 30CCG-2

EMULSION PUMP ASSEMBLY
PEABODY - BARNES

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	3587	Suction Nipple	1	11	28936	Machine Screw	1
2	2505	Hex Nut	8	12	31266	Impeller	1
3	1485	Suction Flange	1	13	1348	Shim	1
4	1493	Check Valve Assembly	1	14	1349	Shim	2
4A	24418	Cap Screw	1	15	19146	Shaft Seal	1
4B	1487	Weight, Small	1	16	3188	Gasket	2
4C	1486	Gasket	1	17	3189	Gasket	1
4D	1488	Weight, Large	1	18	2606	Lockwasher	4
4E	22333	Lockwasher	1	19	2253	Cap Screw	4
4F	24419	Hex Nut	1	20	11846	Coupling Head (Not Shown)	1
5	2453	Stud	8	21	5163	Slinger	1
6	31263	Body	1	22	28173	Hex Nut	8
7	3208	Pipe Plug	2	23	2439	Stud	8
8	3240	Nipple	1	24	3207	Pipe Plug	1
9	3412	Elbow	1	25	1998	Strainer (Not Shown)	1
10	31105	Wear Plate	1	26	27041	Mounting Base (Not Shown)	1



WATER PUMP
JABSCO - "MINI-PUPPY" 48860
12 VOLT D.C.
REX PART NO. 102-6440-1

Item No.	Part Number	Description	No. Req'd
1	1026440-11	Screw (*SP1002-09)	3
2	1026440-12	End Cover - Mod. 8860 (*8865)	1
3	102-6440-13	Gasket (*7828)	1
4	102-6440-14	Impeller (*1414-37)	1
5	102-6440-15	Screw - Cam (*SP1002-01)	1
6	102-6440-16	Cam (*8089)	1
7	102-6440-17	Seal (*SP3000-10)	1
8	102-6440-18	Body (*7824)	1
9	102-6440-19	Slinger (*6342)	1
10	1026440-20	Screw (Body to Motor) (*SP8019-02)	2
11	102-6440-21	Motor - Mod. 8860 (*SP8012-02)	1
	102-6440-22	Service Kit - Consists of Impeller, Seal, Gasket and 31 End Cover Screws (*8860-SK92)	1

*Part numbers are Jabsco - Costa Mesa, California part numbers.

FIG. 6. PUMP FOR WASH-DOWN SYSTEM

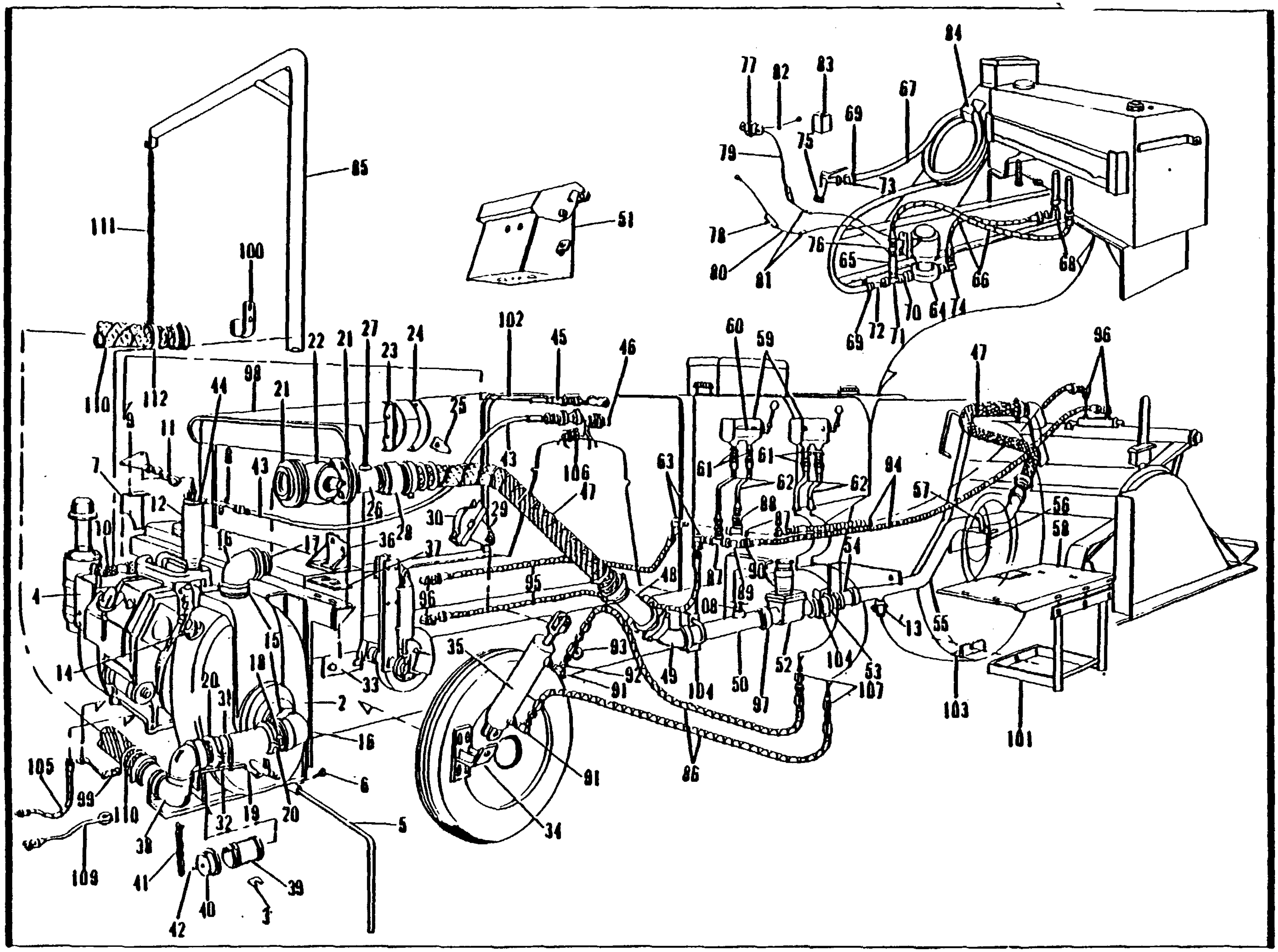


FIG. 7. EMULSION HANDLING UNIT PIPING, CONTROLS HYDRAULIC LINES AND FITTINGS

EMULSION HANDLING UNIT PIPING - CONTROLS - HYDRAULIC LINES & FITTINGS

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	502-6349-80	Pump Frame	1		102-3918-1	Indicator Plate	1
2	102-9459-1	Pump and Engine Assembly-		24	1298-5000-34	Rivet	2
		Barnes Mfg. Co. # 30CCG with		25	102-615-1	Pointer - Valve Lever	1
		Model VH4D Wisconsin Engine		26	502-2939-80	Special Nipple	1
		-see separate parts books	1	27	398-14005-76	Pipe Plug ¾"	1
3	102-8553-1	Pump Shim	8	28	398-14000-78	Coupling- 4"	1
	102-30297-1	Bracket - Air Cleaner	1	29	502-2942-80	Valve Lever	1
4	398-2001-79	Cap Screw -3/8 x 1 ¼"	8		102-3897-1	Cap for Valve Lever	1
	298-2012-71	Lock Nut 3/8"	8	30	398-2003-8	Cap Screw ¾" x 3 ½"	2
5	102-1526-1	Guide Rod	1		298-2035-71	Locknut ¾"	2
6	398-99004-51	Thumb Screw 5/16 x 1"'	1	31	298-1006-4	"U" Bolt - Strainer Support	1
7	102-30323-1	Bracket - Throttle	1		298-2010-71	Locknut " N.C.	2
8	298-146-47	Cable Clamp	1	32	102-30451-1	Support - Strainer (Bracket)	1
9	102-1531-1	Bell Crank	1		502-6152-80	Fuel Tank	1
10	102-3395-1	Rubber Elbow	1	33	398-2002-16	Capscrew ½ x 1	4
11		Safety Chain 1 x 3" long	1		298-2010-71	Lock Nut ½"	4
	102-1424-2	Muffler	1	34	502-2941-80	Bracket - Cylinder Valve	1
	398-14000-31	Reducing Bushing 1 ½ x 1 ¼"		35	102-2786-1	Cylinder - Hydraulic - Emulsion	
12		Muffler to Manifold & to Clap	2			Control Valve - see separate	
	398-14006-77	Close Nipple 1 ¼"	1			Illustration	1
13	298-2089-1	Bronze Cock 1'	1	36	502-4685-80	Support for Valve	1
14	502-211-80	Plug "T" Handle	I	37	102-8773-1	Shim - Valve Mounting	3
15	398-14004-99	Pipe Nipple 4x4" T.B.E.	2	38	102-8570-1.	Swivel Joint - (Style 40 Single	
16	398-14001-25	Pipe Elbow 4" x 90°	2			swivel with two elbows)	1
17	398-14009-31	Pipe Nipple 4x5"	I	39	102-8803-1	Nipple 4 x 6" T.B.E. - faced for	
18	102-9598-1	Special Grooved Nipple - T.O.E.	2			gasket	1
19	102-9595-1	Strainer with 4" Mesh Screen	I	40	102-8576-1	Intake Cover	1
20	102-9596-1	Coupling- (2 halves will gasket)	2	41	398-51016-50	Sash Chain #50 x 2 ft. long	1
	298-7518-86	Flange -4"	2	42	398-3000-27	Cotter Pin ¼" x 1 ½"'	2
	298-2518-68	Gasket	2	43	102-8642-2	Throttle Cable - Vernier Control	
21	398-2002-69	Cap Screw 5/8" x 3"	16			-30 Series x 120" long with '	
	398-20000-41	Lock Washer 5/8","	16			10-32NF3 Thread End and	
	398-11000-23	Hex Nut 5/8"	16			A45477 Boot	1
22	102-8558-1	Valve - 4" - Flanged-		44	298-120-47	Ball Joint #10 (Special)	1
		Nordstrom # 143	1	45	102-7957-5	Choke Control Cable with "T"	
23	502-4610-80	Indicator - Valve Lever	1			Handle- 120' long	1

EMULSION HANDLING UNIT PIPING -
CONTROLS - HYDRAULIC LINES & FITTINGS
(Continued)

Item No.	Part Number	Description	No. Req'd
46	298-6062-17	Starter Switch (Wells #A 412)	1
47	102-30063-1	Hose Assembly - 4" x 60" long 1 side Female, 1 side Male	2
48	102-8794-1	Nipple 4" x 9" TOE- one end faced for gasket	
49	102-8562-1	Joint - 4" x 45° elbow (Acroquip Corp. Marman Divn. #6645-4)	1
50	502-214-80	Nipple - 4" - Special	1
51	102-8577-1	Instrument Panel Assembly with Feel per Min., gallons per Min., and Visual performance instruments	1
	502-6158-80	Console - Instruments	1
52	602-1466-1	Meter and Register Assembly (Badger) - service parts for unit not available - Return to factory for service	1
53	102-8547-1	Nipple - T.O.E. 4" x 6 ¾"	1
54	102-8561-1	Straight Joint - Aeroquiip Corp., Marman Divn. #6600-4-650	1
55	502-4591-80	Pipe Assembly	1
56	502-8061-80	Support - Pipe	1
57	298-1010-4	"U' Bolt	1
58	502-4631-80	Running Board -(L. H.)	1
59	102-6301-1	Single Section Gresen CP4-4 spool section only - (for service parts see items 1 thru 32 as listed for 102-6208-1 Valve Assy.) these sections are added to 102-6208-1 Valve Assy. to control spray bar, fifth wheel, and valve control cylinders	2
60	298-162-47	Stud - 4 Spool Valve Assembly	3
61	298-8037-86	Half Union SAE 45° ½" tube x ½" N.P.T. (Imperial Eastman Corp. #648-F!	4
62	50(2-2086-81	Hydraulic Tube - 1 ft. 4½" long will flared tube nuts	4
63	291-057-8116	Adapter Filling 90° Male, 3/8" NPTF (Anchor 6MA-6UFS)	2

Item No.	Part Number	Description	No. Req'd
64	102-6440-1	Pump - Wash Down, System - (Jabsco Pump Co. Model 8860) -See separate Illustration	
	398-2001-46	Capscrew ¼" x 1"	4
	398-20000-36	Lock Washer ¼"	4
	398-11000-17	Hex Nut ¼"	4
65	102-8640-1	Nipple with orifice	
66	502-1343-94	Hose Assembly with i&" Male fittings - 1 ft. 6" long	2
67	2556-10	Hose - 24 ft. long - (Wash off system)	1
68	298-2070-62	Union- 90° Adapter A Male NPT x H" female NPT (Anchor 8MA-6UFS)	1
69	X7820	Hose Clamp	2
70	398-14002-27	Close Nipple 3/8"	1
71	398-14005-21	Pipe Tee 3/8"	1
72	398-14009-30	Pipe Nipple 3/8" x 2" T.O.E.	1
73	298-8125-86	Male Hose Coupling - 5/8" Garden Hose Thread- Serrated Shank - Cast Brass	1
74	298-8057-86	Fitting - Adapter Union - 90° Male - 3/8" N.P.T.F. (Anchor 6MA-6UFS)	1
75	298-49-98	Lever Spray Nozzle	1
76	398-14000-49	Pipe Coupling 3/8"	1
77	298-6176-17	Switch - Wash Off Pump - (Cole Hersee Co. #EX: 1735 with 83357 key)	I
78	502-222-80	Fuse, Container and Terminal Assembly	1
	298-11040-17	Fuse-20 Amp	1
79	502-2987-82	Wire Assembly - consisting of: wire, connector and bullet terminal	1
80	502-2987-83	Wire Assembly Consisting of wire, connector and bullet terminal	
81	298-26086-17	Wire Connector	2
	298-26085-17	Bullet Terminal	2

(Continued)

Item No.	Part Number	Description	No. Req'd
82	502-208-80	Wire Assembly - consisting of: wire and connectors	1
83	102-8802-1	Shield - Switch	1
84	203683	Holder - Wash off Hose - Weldment	1
85	502-4595-80	Boom - Suction Hose	1
86	102-3985-1	Hose Assembly - ¼ - 18 Male pipe fittings both ends x 120" long	2
87	298-17005-86	Pipe Tee - 3/8" (Imperial Eastman 25VJ-06)	2
88	298-8014-86	Male Adapter ¾ - 16 SAE, 3/8 - 16 NPT. (Aeroquip 2000-6-8B)	2
89	298-2069-62	Union - 45° Adapter 3/8" Male NPT x 3/8" Female NPT (Anchor 6MAX-6UFS)	1
90	298-2064-62	Union - Adapter - 3/8" Male N.P.T. x 3/8" Female N.P.T. (Anchor 6M-6UFS)	1
91	298-2095-62	Union Adapter 90° 9/16 18 Male "O" Ring x ¼ NPSM Female (Imperial Eastman 60UB-06X04)	2
92	298-2174-62	Straight Adapter ¼" Male NPTF x ¼" Male NPSM (Anchor 4M-4MS)	1
93	298-101-53	Needle Valve ¼" NPTF (Auto Ponents # ¼ N20B)	1
94	102-2700-9	Hose - Spray Bar	2
95	102-2700-7	Hose - Fifth Wheel	2
96	298-2052-62	Union - 90° angle Adapter ¼" Male NPT x 3/8" Female NPT (Anchor 4MA-6UFS)	4

Item No.	Part Number	Description	No. Req'd
	398-4000-70	Loom - ¾ x 30 ft.	1
	398-95002-93	Wire 14 ga. x 19 ft.	1
97	298-85-17	Terminal	2
	502-2983-80	Cable Assembly	1
98	102-4654-1	Hood Top	1
99	298-26044-17	Ground Strap - Engine to Frame	1
100	102-8805-1	Hanger - Hose	1
101	502-4686-80	Ladder Step	1
102	502-3868-82	Firewall	1
103	102-8813-1	Bracket - Ladder	1
	102-8934-1	Support Angle	3
104	298-1010-4	"U" bolt	3
	102-8491-2	Fuel Hose ¼" I.D. x 66"	1
105	298-8004-86	Swivel Fitting (Aeroquip No. 4797-4B)	2
106	298-6176-17	Ignition Switch	1
107	298-9041-86	Adapter Coupling - Female - SAE 45° ½" O.D. tube (3/4 - 16 Male Thd.) x ¼" Female NPT. (Imperial Eastman #646F	2
108	502-212-80	"T" Handle Pipe Plug 1 ¼" N.P.T.	1
	102-30345-1	Battery Cable 175" long	1
109	102-30345-3	Batter Cable 50" long	1
110	102-30549-1	Suction Hose	1
	398-99006-90	No. 2 Twist Chain - 7 ft. long	1
111	X7604	Cold Shut 3/16"	2
112	102-8799-1	Support clamp	1

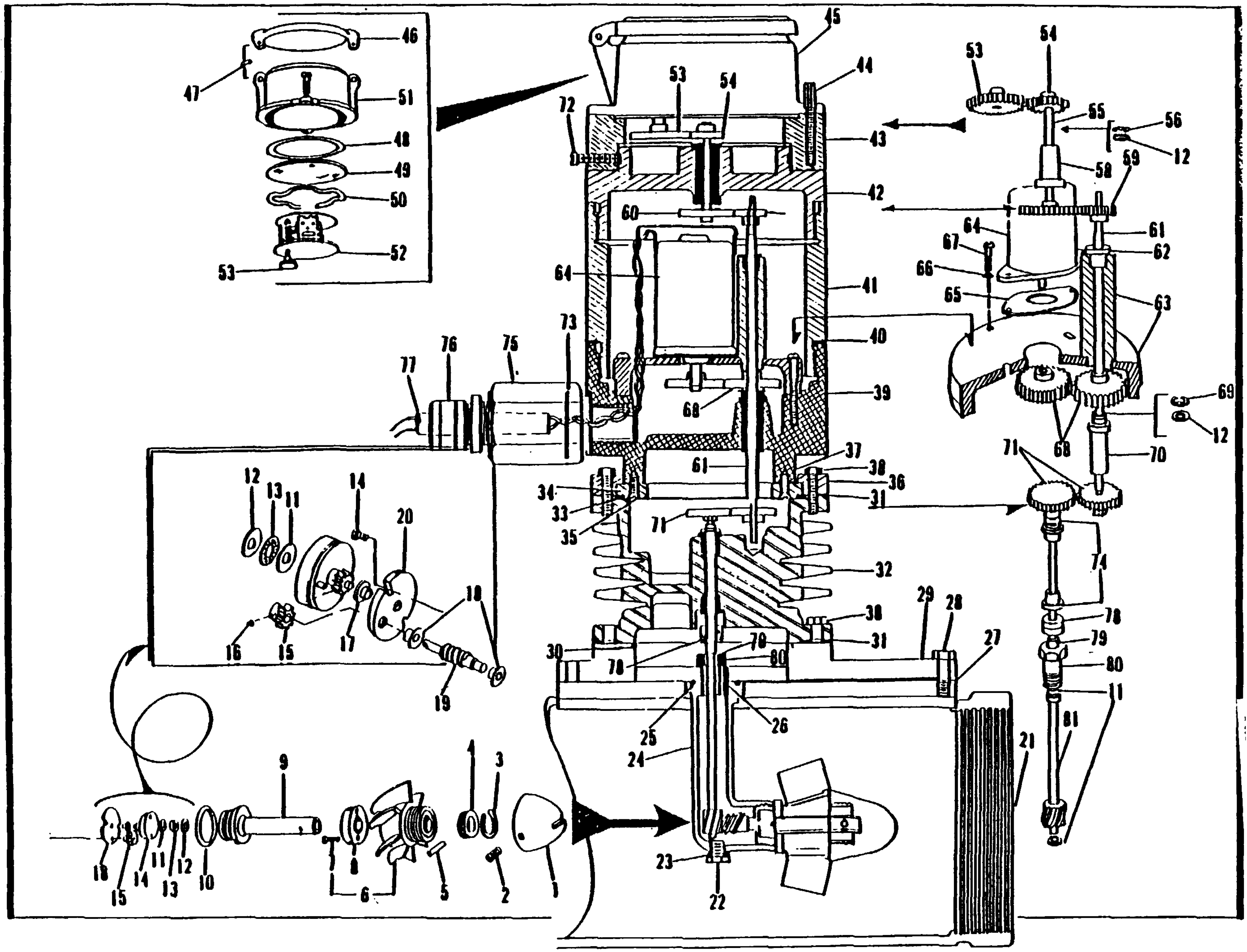


FIG. 8. FLOW METER

FLOW METER AND TACHOMETER GENERATOR ASSY.
4' MODEL 4MLFT- SGH

Item No.	Part Number	Description	No. Req'd
1	102-3933-41	Propeller Hub & Bearing Assembly (*'31310-1)	1
2	102-3933-42	Set Screw ('32097-9)	1
3	102-3933-40	Spring ('31435)	1
4	102-3933-38	Hub. Shaft Retainer (031433)	1
5	102-3933-39	Pin (*31434)	1
6	102-3933-35	Propeller Assembly with Magnets and Bushings	
7		(*31360-1)	1
8	102-3933-36	Screw (*31820-3)	2
9	102-3933-37	Magnet (*26534)	1
	102-3933-34	Propeller Shaft and Cover Assembly	
10		(*31320-1)	1
11	**102-3933-33	Seal Ring ('22559-13)	1
12	102-3933-16	Ball Race ('22581-1)	3
13	**298-27-97	Ball Race (*22581) (Thrust Washer)	3
14	**102-3933-23	Thrust Bearing (*24836)	1
15	**102-3933-31	Magnet & Pinion Assembly (*26530)	1
	**102-3933-29	Gear - 4" - (*26526)	1
16	**102-3933-30	Set Screw (*21451)	1
17	**102-3933-24	Bushing (*26950)	3
18	**102-3933-26	Plate & Bushing Assy. (*30940-1)	1
19	**102-3933-25	Worm (*31276)	1
	**102-3933-27	Shoulder Screw (*24315-1)	-
20	**102-3(933-28	Screw (*55045-170)	-
21	102-3933-44	Meter Tube and Liner Assy. (*2570 1-1)	1
22	102-3933-22	Gear Box Plug (*31184)	1
23	102-3'933-21	Seal Ring ('22559-17)	1

Item No.	Part Number	Description	No. Req'd
24	102-3933-20	Gear Box ('26549-1) 4v Meter Only	1
25	102-3933-19	Seal Ring (o22559-14)	1
26	102-3933-18	Roll Pin (*22858-6)	1
27	102-3933-43	Meter Head Gasket (*25678)	1
	102-3933-14	Meter Head Bolt 1 ¼" lg.	
28		(*55025-062)	10
	102-3933-15	Meter Head Shoulder Bolt ('*26346)	2
29		Meter Head Assy. - Reference Only Not Sold Separately	1
30	102-3933-13	Adapter Seal Ring ('22559-18)	2
31	102-8771-1	Gasket	2
32	102-3933-45	Finned Adapter and Shaft Assembly (*'34455-100)	1
33	102-3933-67	Tetra Seal ({22559-1800)	1
34	102-3933-68	Pilot Ring (*31569)	1
35	102-3933-69	Flat Head Brass Screw 10-32 x 3/8 (*55079-22200)	4
36	102-3933-58	Adapter Ring (*31303-200)	1
37	102-3933-70	Gasket (*32862)	1
38	102-3933-57	Hex Head Bolt (*31355)	1
39	102-3933-50	Transmitter Housing ('31570)	1
40	102-8926-1	Gasket for Sleeve	1
41	102-4613-1	Sleeve	1
42	102-3933-71	Housing -Top (*26974)	1
43	102-3933-72	Adapter Ring (*26972)	1
44	102-3933-73	Seal Screw ('22713-100)	2
45	102-3933-74	Register Hood Assembly (*25694-00200) (Includes 46 thru 51)	1

FLOW METER AND TACHOMETER GENERATOR ASSY.
4' MODEL 4MLFT- SGH

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
46	102-3933-54	Register Hood Cover ('*25697)	1	63	102-4612-1	Base Plate	1
47	102-3933-55	Register Hood Cover Pin ('*23630-1)	1	(Cont d.)	102-3898-1	Shaft Bearing Housing (Sleeve)	1
48	102-3933-56	Register Glass Gasket ('22559-11)	1	64	102-8532-1	Tachometer Generator; 6 Volt at	
49	102-3933-59	Register Hood Glass ('*22448-4)	1			1000 RPM, (Zero Max. Model n2)	1
50	102-3933-60	Register Glass Retainer (*1013)	1	65	102-8927-1	Gasket- Generator	1
51	102-3933-61	Register Hood Only ('*25695)	1	66		Lock Washer #5	2
52	102-3933-62	Register & Dial Assembly ('32017)	1	67		Round Head Machine Screw	
53	102-3933-64	Gear & Screw Assy. -.992" O.D.				#5-40 x 1"	2
		55T (*23758-5500)		68	298-1011-91	Gear, 48T (Pic Design Corp. 02-48)	2
			1	69	298-8013-34	Retaining Ring--"E" Style for 3/14	
54	102-3933-66	Gear and Screw Assy. - .529" O.D.				Dia. Shaft (Truarc No. X5133-18	1
		28T (*23669-2800)	1	70	102-8563-1	Bushing	1
55	102-3933-75	Spindle Drive--Upper (*33287)	1	71	102-3933-81	Gear Assembly 24T (*25719-2400)	2
56	....	"E" Ring (*22570-00)	1	72	102-3933-73	Screw - Seal (022713-100)	3
57	....	Not Used	-	73	102-3933-83	Separator -Lead Wire (*24217)	1
58	102-3933-76	Bushing (033288)	1	74	....	Spindle Shall & Bushings - Not Sold	
59	102-3933-66	Gear & Screw Assy. ('23669-2800)				Separately, Sold Only as Item 32	
		.529" O.1., 28T	1			Finned Adapter Assembly	-
60	102-3933-64	Gear & Screw Assy. (*23758-5500)		75	298-13140-17	Adapter (*26990)	1
		.992- O.D., 55T	1	76	298-48-17	Cord Grip ½ in thd. (Pyle - Nat'l.	
61	102-3899-1	Shaft	1			No. DB-338)	1
62	298-5010-8	Bearing Sleeve (Pic Design Corp. B11-5) 1		77	502-2983-80	Cable Assy.	1
63	....	Base Plate for Tach. Generator and		78	102-3933-84	Coupling Half (*33570)	2
		Sleeve for Drive Shaft Assembled		79	102-3933-11	Bushing (*22880-22)	1
		Consisting of:	1	80	102-3933-12	Shoulder Bolt ('26552)	1
					102-3933-17	Vertical Shaft Assy. (4" Meter Only)	
				81		(*31183-1)	1

*Badger Meter, Inc. Flow Products Divn., 4545 West Brown Deer Road - Milwaukee, Wisconsin 53223 part numbers.

*Parts In upper exaggerated Illustration turned In opposite to assembly sequence to facilitate identification.

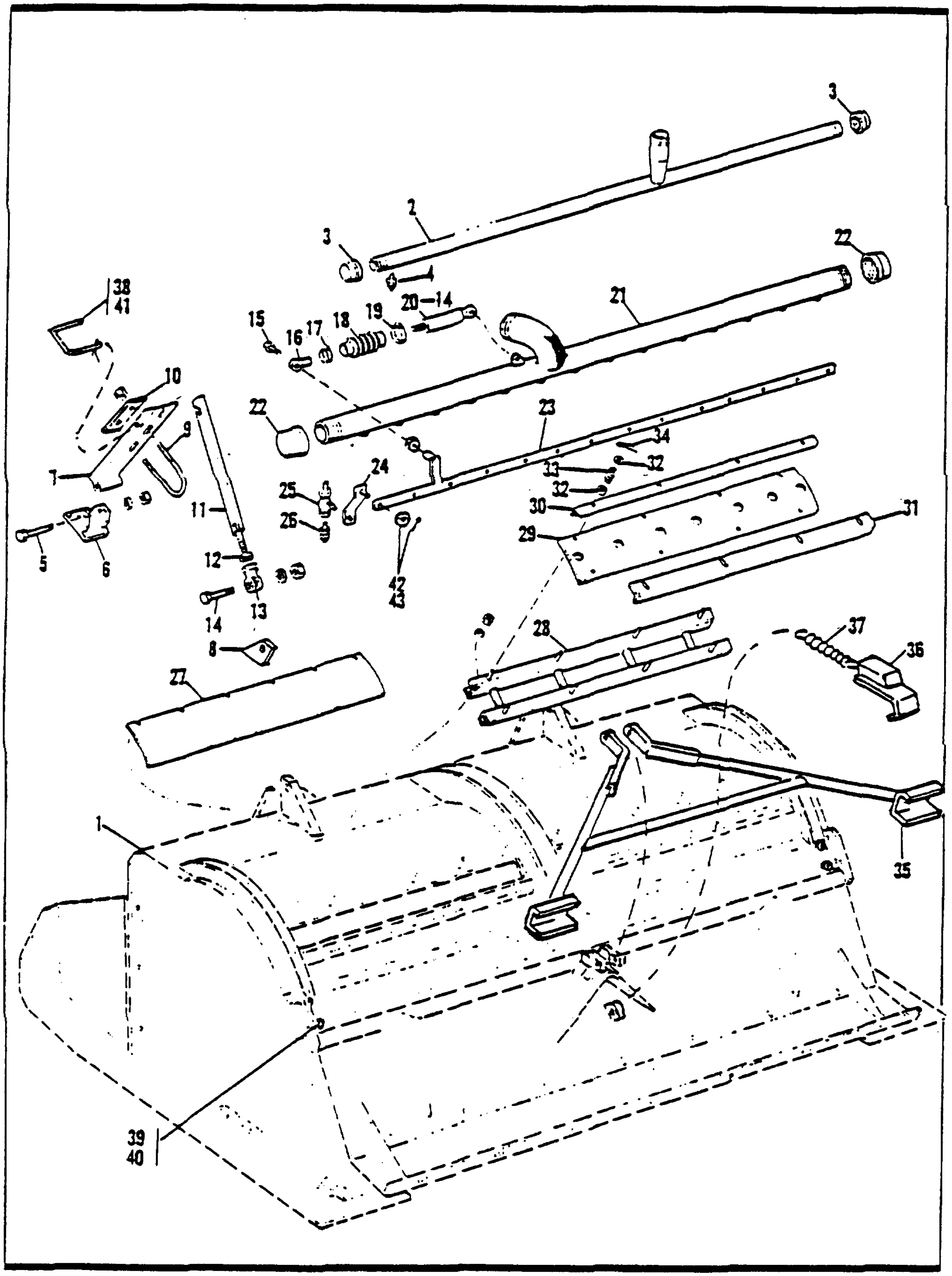


FIG. 9. WATER AND ASPHALT SPRAY BARS AND ROTOR HOOD COVERS

WATER AND ASPHALT SPRAY BARS
AND ROTOR HOOD COVERS
REX SELF PROPELLED PULVI MIXERS

Item No.	Part Number	Description	No. Req'd
1	- - - - - - -	Rotor Hood (For Reference Only) (See Sep. Illus.)	1
2	502-4606-80	Water Spray Bar - Used on Machines equipped with optional water & Asphalt Emulsion System	1
3	- - - - - - -	Pipe Cap 2”	2
4	298-19015-86	Spray Nozzle ½" Spraying Systems Co. No. U80200	12
5	398-2003-13	Cap Screw 14 x 5"	2
	298-2035-71	Stop Nut 3/4	2
6	502-2951-80	Adjusting Bracket for Spray Bar	2
7	502-8008-80	Support for Spray Bar	2
8	102-8769-1	Bracket - Adjusting Bar (Weldment)	2
9	298-1011-4	U-Bolt 3 ½” between legs, 5" long throat, 1 5/8” long threads, ½” -13 N.C. w/L.W. & Nut	2
10	102-8611-1	Bar	2
11	502-8050-80	Adjusting Bar	2
12	398-95000-34	Jam Nut ½" U.N.F.	2
13	X6399	Yoke End “A" U.N.F.	2
14	298-287-47	Clevis Pin	2
15	398-2000-6	Cap Screw 3/4 x 1 ¾” U.N.F. with Nut & L.W.	1
16	298-272-2	Rod End - Female - Spherco ¾” bore x ¾” U.N.F. (Sealmaster #FR-12)	1
17	298-9005-86	Hose Clamp , 1 5/16" to 2¼" Wittek Mfg. co. #28H	1
18	102-7819-1	Boot - Hyd Cyl.	1
19	298-9018-86	Hose Clamp 1 5/16” x 2 ¼”	1
20	102-7818-1	Hydraulic Cylinder (See Sep. Illus.)	1
21	502-4597-80	Asphalt Spray Bar	1
22	- - - - - - -	Pipe Cap 3"	2
23	502-8044-80	Connecting Link	1
24	502-2953-80	Valve Lever	14
25	298-2089-1	Bronze Cock 125# - 1” Male to 1” Female Pipe Crane #266 - Used for Water, Emulsion or Water and Asphalt Spray	28
26	298-19029-86	Spray Nozzle 34 #HU-80400-- (Standard for HDS-E Option)	14
	- - - - - - -	Reducing Bushing 1" x 44" (HDS-E)	14
27	102-4617-1	Cover - Rotor Hood - Used only when no spray bar is used	2
28	502-6161-80	Cover Adapter - Rotor Hood	2
29	102-3908-1	Rubber Cover-- Rotor Hood	2
30	102-3910-1	Pressure Angle	2
31	102-3909-1	Pressure Plate	2
32	- - - - - - -	Cut Washer 3/8”	32
33	102-6138-1	Spring	16
34	298-2017-1	Lock Nut 3/8” N.C. or 1/8” x 1” Cotter	16
35	502-6209-80	Jack - Spray Bar	1
36	502-8484-80	Handle (Hook)	1
37	202340	Spring	1
38	102-8826-1	Hook- Spray Bar	2
39	- - - - - - -	Cap Screw ½ x 1 ¼” w/C.W.	4
40	298-2010-71	Cone Lock Nut ½”	4
41	398-3000-8	Cotter Pin 3/32 x 1 1/4	2
42	- - - - - - -	Cut Washer 3/8”	14
43	298-6028-34	Pin	2

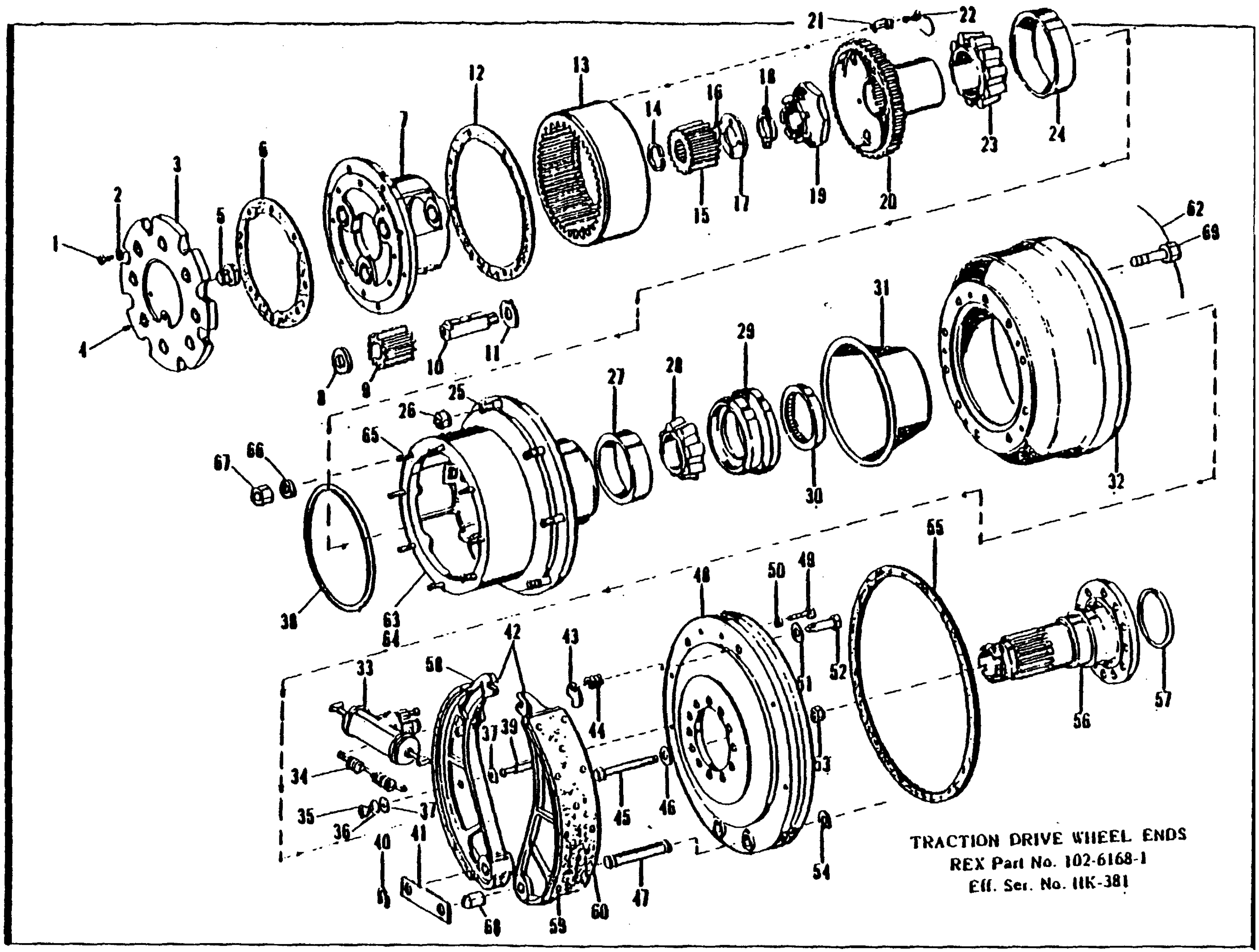


FIG. 10. TRACTION DRIVE WHEEL ENDS AND BRAKES

TRACTION DRIVE WHEEL ENDS
INCLUDED IN AXLE ASSEMBLY 102-6168-1
ROCKWELL MODEL TA-279-HXI
EFFECTIVE HK-381

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	102-7572-21	Cap Screw - Planetary Spider Cover		29	102-7572-52	Retainer (*1805.W-361)	2
		(*S-279-1)	16	30	102-7572-53	Oil Seal (Hub Bearing) (*A1805.X-362)	2
2	102-7572-22	Lock Washer (*WA-17)	16	31	102-7572-54	Oil Slinger (*3905-D-56)	2
3	102-7572-23	Cover - Planetary Spider Gear		32	102-7572-55	Broke Drum (*3819-T-436)	2
		(*3855 Y-207)	2	33	102-7572-56	Wheel Cylinder Assy.(*A1-3261-W-49)	2
4	102-7572-24	Plug - Oil Level (*P-24)	2	34	102-7572-57	Spring - Blade Shoe Return	
5	102-7572-25	Thrust Button (*1898-B-626)		2		(*2258-T-124)	2
6	102-7572-26	Gasket (*2808-Z-884)	2	35	102-7572-58	"C" Washer - Guide Pin (*1229-H-216)	8
7	102-7572-27	Spider - Planetary Gear (*3897-U-1425)	2	36	102-7572-59	Spring Washer - Guide Pin	
8	102-7572-29	Washer (Planetary Pinion Outer Thrust)				(*1229-Q-225)	8
		(*1829-H-716)	6	37	102-7572-60	Washer - Guide Pin (*1229-J-218)	16
9	102-7572-28	Planetary Pinion (16T) (*3891-M-975)	6	38	102-8095.34	"O" Ring - Planet Gear to Hub	
10	102-7572-30	Shaft (Planetary Pinion) (*3880-4953)	6			(*S-X-589)	1
11	102-7572-31	Washer (Planetary Pinion Inner Thrust)		39	102-7572-62	Guide Pin (*1846-V-282)	8
		(*1829-S-877)	6	40	102-7572-63	"C" Washer - Brake Shoe Anchor Pin	
12	102-7572-32	Gasket (Spider to Hub) (*2808-A-885)	2			(*1229-M-221)	4
	102-7572-33	Planetary Ring Gear (*3892-C 1589)	2	41	102-7572-64	Link - Brake Shoe Anchor Pin	
3	102-9047-50	Sleeve (*1874-B-106)	2			(*1845-J-36)	2
14	102-7572-34	Snap Ring - Sun Gear Retainer	42		102-7572-65	Brake Shoe Assy.(*A153222-T-124)	4
		(* 1854-D-212)	2	43	102-7572-66	Brake Shoe Adjustment Com(* 2297-U-99)	4
15	102-7572-35	Planetary Sun Gear (20T) (*3891-L-974)	2	44	102-7572-67	Spring - Broke Adjustment Cam	
16	102-7572-36	Pin (Sun Gear Washer) (*1846-Y-259)	4			(*2258-S-123)	4
17	102-7572-37	Sun Gear Washer (*1829-14-715)	2	45	102-7572-68	Bolt - Spindle to Housing (*10-X-668)	24
18	102-7572-38	Lock Hub (Bearing Hut) (*1898-H-762)	4	46	102-7572-69	Washer (*1829-K-765)	24
19	102-7572-39	Hut (Hub Bearing) (*1827-V-230)	2	47	102-7572-70	Broke Anchor Pin (*1859-E-83)	4
20	102-7572-40	Huh (Ring Gear) (*3897 S 1345)	2	48	102-7572-71	Broke Spider (*3911.-V-.334)	2
	102-7572-41	Lock (Planetary Ring Gear) (*1820-J-62)	8	49	102-7572-72	Cop Screw - Brake Wheel Cylinder to	
22	102-7572-42	Cap Screw (*S-256-D)	16			Spider (*S.269-1)	4
	102-7572-43	Lock Wire (*LW-166)	8	50	398-20000-37	Lock Washer 3/8"	4
23	102-7572-44	Cone - Bearing (Outer Hub) (*48190)	2	51	102-7572-73	Washer - Adjustment Cam Pin	
24	102-7572-45	Bearing Cup (*48120)	2			(* 1229-K-219)	4
25	102-7572-47	Wheel Stud (*20X-.262)	24	52	102-7572-74	Pin (Broke Shoe Aid.Cam) (*2297-S-97)	4
26	102-7572-46	Wheel Nut (*1199-H-112)	24	53	102-7572-75	Nut (Spindle to Housing) (*1827-8-236)	24
27	X6228	Bearing Cup (Hub) (*493)	2	54	102-7572-76	Snap Ring (*1854-Z-286)	4
28	102-7572-51	Bearing Cone (Hub Inner) (*497)	2	55	102-7572-77	Felt Seal (*5-X-583)	2

TRACTION DRIVE WHEEL EHDS
INCLUDED IN AXLE ASSEMBLY 12-6168-1
ROCKWELL MODEL TA-279-HXI
EFFECTIVE HK-381 (Continued)

Item No.	Part Number	Description	No. Req'd
56	102-7572-78	Spindle (Wheel Bearing) (3897-P-1602)	2
57	102-7572-79	Seal-spindle to Housing (*5-X-504)	2
58	102-7572-80	Stop Pin)Location Shown - Not Illus.) (*1246-F-84)	4
59	102-7572-81	Rivet (*RV-388)	64
60	102-7572-82	Lining (*2740-A-937)	4
61	502-5618-80	Wheel (15.00 x 34 Tire) (Not Illus.)	2
	298-6015-68	Tire 18.4 x 34/15.00 x 34 Traction 6 Ply (Not Illus.)	1
	298-6017-68	Tube 18.4 c 34/15.00 x (Not Illus.)	1
62	102-7873-10	Lock Wire (*LW-1650)	2
63	102-7572-48	Hub w/ Brg. Cups (*A322-F-214)	2
64	102-7572-49	Oil Drain Plug (Not Illus.) (*1850-T-98)	2
65	102-9047-49	Stud-Spider to Hub (*4X797)	24
66	----	Lock Washer (*N-18-1)	24
67	----	Nut (*N-18-1)	24
68	102-7572-86	Bushing - Brake Shoe (*1225-P-94)	4
69	102-7873-19	Cap Screw - Brake Drum to Hub (*10-X-659)	20

*Rockwell Standard Corporation part numbers.
Contact Transmissions & Axle Division, Oshkosh, Wisconsin.

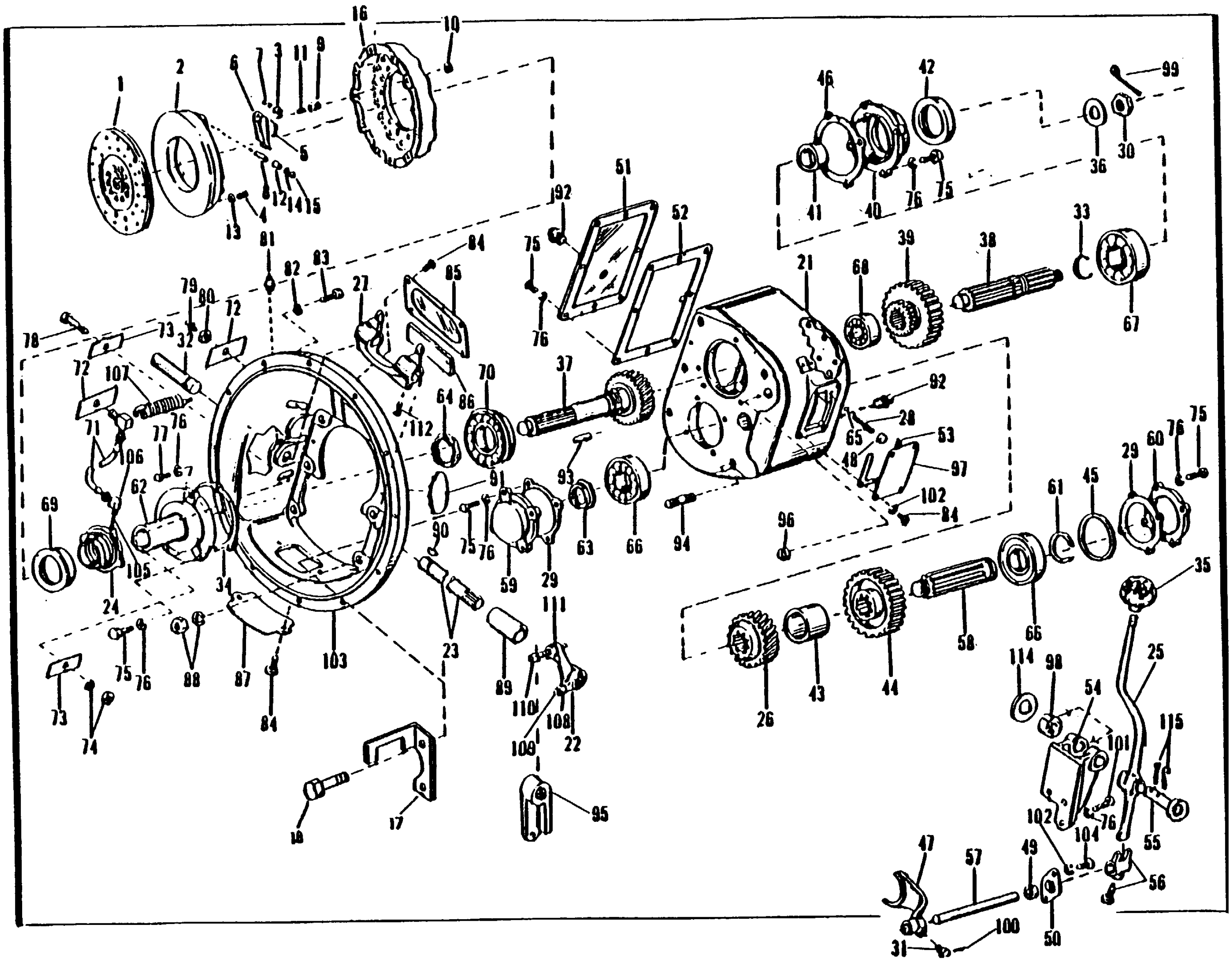


FIG. 11. TWO SPEED TRANSMISSION - ROTOR DRIVE

ROTOR DRIVE TWO-SPEED TRANSMISSION
REX PART NO. 602-10224-2
ROTOR DRIVE CLUTCH ASSEMBLY
REX PART NO. 102-9080-1 LIPE ROLLWAY CORP. 150-61-73

Item No.	Part Number	Description	No. Req'd
1	298-5174-92	Clutch Disc. (Lipe # 150-6-575)	1
-	102-9080-01	Clutch Plate Assy. (Lipe Rollwav Corp. #150-61-731) Incls. 2 thru 16	1
2	102-9080-02	Pressure Plate (Incls. Item 3) (**AC1-117)	1
3	102-9080-03	Needle Bearing (**X50-50)	6
4	102-9080-04	Pressure Spring (**C5-112)	18
5	102-9080-05	Retractor Spring (**C6-43)	3
6	102-9080-06	Release Lever (**C60-65)	3
7	102-9080-07	Eyebolt Pin (**C65-28)	3
8	102-9080-08	Pressure Plate Pin (**C71-24)	3
9	102-9080-09	Adjusting Nut (**C73-25)	3
10	102-9080-10	Lock Nut (**C73-26)	3
11	102-9080-11	Eyebolt Assy. (Incls. Item 12) (**AC74-20)	3
12	102-9080-03	Needle Bearing (**X50-50)	6
13	102-9080-12	Insulating Washer (**C93-2)	18
14	102-9080-13	Washer (**X10-41)	6
15	102-9080-14	Retaining Ring (**72-62)	3
16	102-9080-15	Flywheel Ring (**AC-2-144)	1
17	502-8247-80	Restrictor - Clutch Throw-out	1
18	398-2001-82	Cap Screw 3/8" x 1 1/2")	2
19	- - - - - - -	Not Used	-
20	- - - - - - -	Not Used	-
-	602-10224-02	Transmission (Incls. Items 21 thru 113)	
21	402-2596-2	Transmission Case	1
22	102-7308-1	Arm - Clutch Pedal Adjustment	1
23	102-3431-1	Shaft - Clutch Pedal	1
24	102-9394-01	Carrier - Clutch Bearing	1
25	*502-4880-80	Gearshift Lever	1
26	402-658-2	Countershaft Drive Gear	1
27	102-9335-01	Clutch Yoke Assembly	1
28	102-7283-1	Spring (Position Finder)	1
29	102-3368-1	Gasket - Countershaft Bearing Cover	2
30	102-7286-1	Slotted Nut - Mainshaft	1
31	102-7287-1	Locking Screw - Shifting Yoke	2
32	102-30245-01	Short Shaft - Clutch Pedal	1

Item No.	Part Number	Description	No. Req'd
33	298-8516-34	Snap Ring	1
34	102-3369-1	Gasket - Front Bearing Cover	1
35	298-4508-68	Ball for Shift Lever	1
36	398-20000-20	Cut Washer 5/16" x 2" x 11/64"	1
37	402-1661-2	Drive Gear & Clutch Shaft	1
38	102-4428-1	Splined Mainshaft	1
39	402-1670-2	Mainshaft Sliding Gear	1
40	402-646-2	Mainshaft Rear Bearing Cover	1
41	102-3359-I	Spacer	1
42	298-3035-68	Rear Oil Seal (Nat. #5096 - C.R. #24938)	1
43	102-3360-1	Spacer - Countershaft Gear	1
44	402-656-2	Gear (Countershaft Reverse Speed)	1
45	102-3361-1	Spacer (Countershaft Rear Bearing)	1
46	102-3370-1	Gasket (Mainshaft Rear Brg. Cover)	1
47	402-647-2	Shifting Yoke	1
48	102-7290-1	Plug - Position Finder	1
49	102-7291-1	Cork Seal	1
50	102-7292-1	Retainer - Cork Seal	1
51	402-1663-2	Cover (Transmission Case)	1
52	102-3371-1	Gasket	1
53	102-3372-1	Gasket (Handhole Cover)	1
54	402-1682-2	Bracket - Gearshift Lever	1
55	*502-2252-80	Pin - Gearshift Lever	1
56	402-649-2	Shifting Block	1
57	102-3407-1	Shifting Bar	1
58	102-3379-1	Countershaft	1
59	402-650-2	Cover (Countershaft Front Brg.)	1
60	402-650-2	Cover (Countershaft Rear Brg.)	1
61	298-8517-34	Snap Ring	1
62	402-1659-3	Cover (Front Bearing)	1
63	102-7293-1	Nut (Front Bearing)	1
64	102-7304-1	Nut - Drive Gear Bearing	1
65	X6326	Steel Ball ½"	1
66	X203519	Ball Bearing (Countershaft Front & Rear) (308MF).	2

ROTOR DRIVE TWO-SPEED TRANSMISSION
REX PART NO. 602-10224-2
ROTOR DRIVE CLUTCH ASSEMBLY
REX PART NO. 102-9080-1 LIPE ROLLWAY CORP. 150-61-73
(Continued)

Item No.	Part Number	Description	No. Req'd
67	298-251-2	Ball bearing - Mainshaft Rear (N.D. #41309)	1
68	298-253-2	Ball Bearing - Main shaft Pilot (N.D. #1206)	1
69	298-334-2	Bearing (Clutch Release) (Eaton #15967)	1
70	298-248-2	Ball Bearing (Drive Gear) (N.D. #47310)	1
71	298-5533-68	Flexible Hose	1
72	102-1584-1	Upper Dust Cover	2
73	102-1584-2	Lower Dust cover	2
74	- - - - - - -	Hex Nut ¼" N.C.	1
	- - - - - - -	Lock Washer ¼"	1
75	398-2001-77	Hex Head Cap Screw 3/8" - 16 x 1" - HT.	22
76	398-20000-37	Lock Washer 3/8"	16
77	102-7296-1	Hex Head Cap Screw 3/8" Special	1
78	398-201-46	Hex Head Cap Screw ¼" N.C. x 1" with Nut & L.W.	1
79	398-8000-19	Lubrication Fitting 1/8" - #1688B	1
80	398-11000-72	Jam Nut 5/8" - 18 N.F. - Light	1
81	398-8000-19	Lubrication Fitting 1/8"	1
82	398-20000-37	Lock Washer 3/8" & Cut Washer 3/8"	20
83	398-2005-56	Hex Head Cap Screw 3/8" x 1 ¼" N.C.	20
84	- - - - - - -	Round Head Cap Screw 5/16" 18 x 1 ½"	10
85	102-7285-1	Clutch Handhole Cover	1
86	102-1476-1	Felt Gasket	1
87	102-7301-1	Handhole Cover	1
	398-20000-41	Lock Washer 5/8"	5
88	298-27-71	Hex Nut 5/8" - 18 (Group #5)	5
89	102-9336-1	Spacer - Long Shaft	1
90	398-6000-93	Woodruff Key #607	1
91	298-102-47	Plug button	1
92	X6752	Pipe Plug Square Head ¾" N.P.T.	2

Item No.	Part Number	Description	No. Req'd
93	102-7297-1	Pin - Dowell	2
94	102-7298-1	Stud - Clutch housing	5
95	*402-589-2	Lever	1
96	102-7299-1	Thimble	1
97	102-7284-1	Handhole Cover	1
98	*102-6587-1	Bushing	1
99	398-3000-18	Cotter Pin 1/8" x 2"	1
100	102-7264-1	Locking Wire	1
101	398-2001-79	Hex Head Cap Screw 3/8" - 16 x 1 ¼" H.T. - H.C.	3
102	398-20000-64	Lock Washer 5/16"	6
103	102-9334-1	Clutch Housing (S.A.E. #2)	1
104	- - - - - - -	Round Head Cap Screw 5/16" - 18 x 7/18	2
105	- - - - - - -	Close Nipple 1/8" N.P.T.	1
106	- - - - - - -	Pipe Elbow 1/8" N.P.T. x 90°	1
107	102-7305-1	Tension Spring	1
	398-11000-39	Light Full Nut - 3/8"	1
108	398-2000-37	Lock Washer 3/8" (398-20000-37)	1
109	398-201-85	Hex Head Cap Screw 3/8" - 24 N.F. x 1 ¾" H.C. - H.T.	1
110	398-17000-83	Square Head Dog Point Set Screw ½" - 13 N.C. x 2"	1
111	398-11000-22	Hex Nut ½" - 13 N.C.	1
112	102-7310-1	Special Cap Screw 3/8" - 24 x 1"	2
113	- - - - - - -	Not Used	-
114	*398-95001-78	American Standard Cut Washer 21/32" x 5/14" x 3/32"	1
115	*398-3000-63	Cotter Pin 1/8" x 1 ½"	2

*Not included in 602-10224-02 Transmission Assembly
**Lipe Rollway corp. Part Numbers

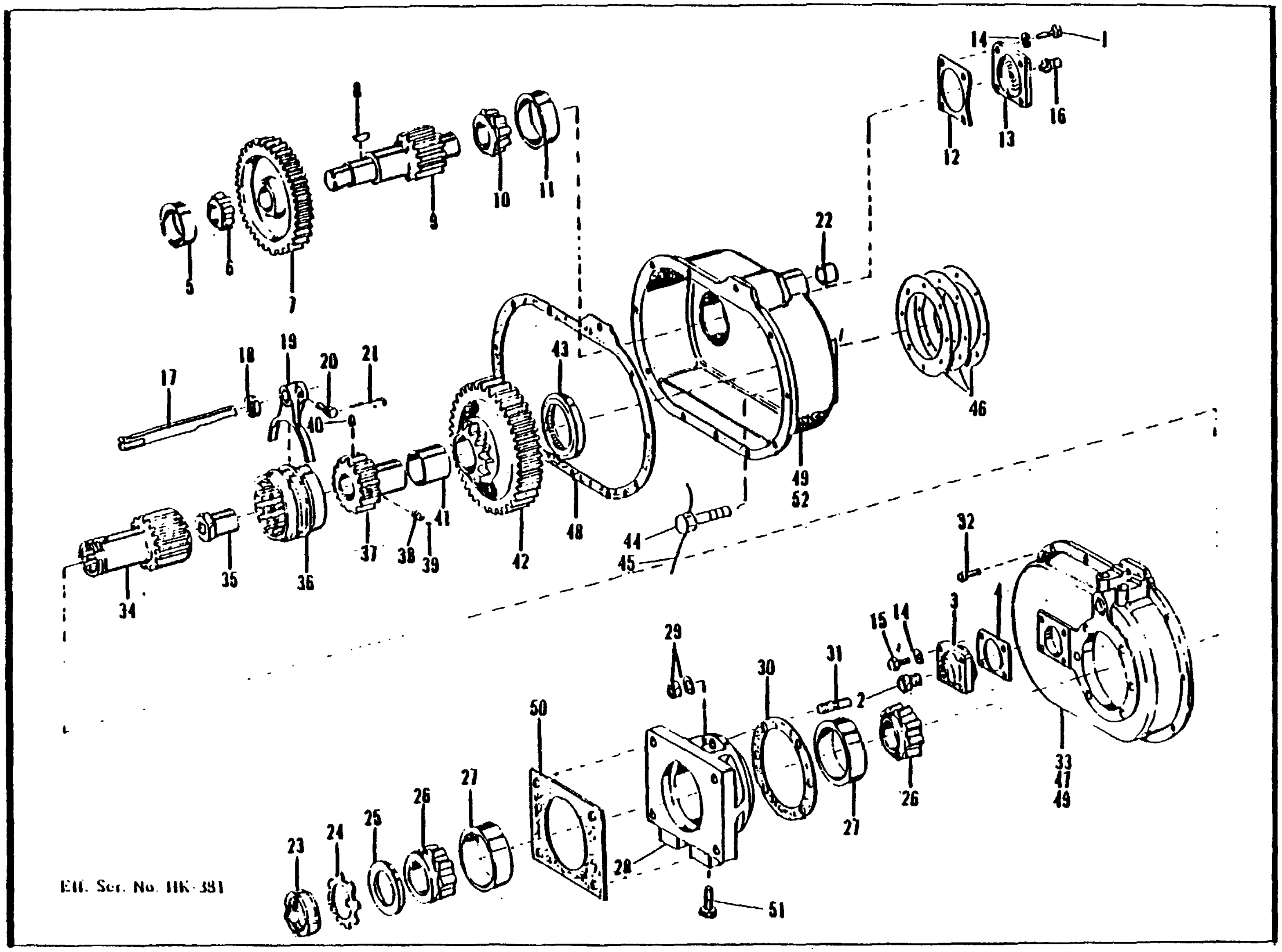


FIG. 12. TRACTION DRIVE TRANSMISSION (2 SPEED)

TRACTION DRIVE TWO-SPEED TRANSMISSION
INCLUDED IN AXLE ASSEMBLY 102-11053-1
MODEL NO. PRTA 592 H200 WITH NOSE BOX

Item No.	Part Number	Description	No. Req'd
1	102-7872-18	Cap Screw, Idler Pinion Rear Cap	1
2	102-6168-12	Plug - Speedometer Gear	1
3	102-6168-13	Front Cap for Idler Shaft Cover	1
	102-6168-14	Shim (.003")	3
4	102-6168-15	Shim (.005")	3
	102-6168-16	Shim (.010")	1
5	102-6168-17	Bearing Cup	1
6	102-6168-18	Bearing Cone	1
7	102-6168-19	Gear (55T) (Low Speed Idler)	1
8	102-6168-20	Key (Low Speed Idler)	1
9	102-6168-21	Pinion Idler Shaft (22T)	1
10	102-6168-22	Bearing Cone	1
11	X7857	Bearing Cup	1
12	102-6168-24	Gasket	1
13	102-7872-55	Cap Idler Shaft Pinion	1
14	102-6168-11	Lock Washer	7
15	102-6168-10	Cap Screw -Idler Pinion, Front & Rear Cap	7
	102-7872-18	Cap Screw	1
16	102-6168-28	Oil Breather	1
17	102-6592-94	Shaft - Hi-Lo Shift	1
18	102-6168-30	Oil Seal	1
19	102-6168-31	Fork - Hi-Lo Shift	1
20	102-7872-23	Lock Screw	1
21	102-6168-33	Lock Wire	1
22	102-6168-34	Plug	1
23	102-6168-35	Nut	1
24	102-6168-36	Lock Washer	1
25	102-6168-37	Washer	1
26	298-341-2	Bearing Cone	2
27	298-339-2	Bearing Cup	2
28	102-8095-26	Adapter - Hydraulic Motor w/Bearing Cup (Item 27)	1
29	398-20000-39	Lock Washer 1/2"	42
	102-6168-42	Nut	40
30	102-6168-43	Gasket for Adapter	1
31	102-6168-44	Stud	6
	102-6168-65	Bolt - Transmission Cover	10
32	102-6168-66	Nut	10
	398-20000-67	Lock Washer 3/8"	10
	102-6168-68	Dowel - Case to Cover	2
33	102-6168-69	Cover	1
34	102-6168-47	Input Pinion (24T)	1
35	102-6168-48	Nut - Clutch & Pinion	1
36	102-8095-25	Shift Collar	1
37	102-8095-88	Clutch Pinion (24T)	1
38	102-7872-44	Spring - Shift Shaft Lock	3
39	102-6168-52	Ball - Shift Shaft Lock	3
40	102-6168-53	Clutch Pinion Set Screw	1
41	102-6168-54	Bushing - Driven Gear	1
42	102-6168-55	Low Speed Driven Gear (57T)	1
43	102-6168-56	Oil Seal - Pinion Bearing	1
44	102-7872-17	Bolt - Transmission Case to Carr.	8
45	102-7872-11	Lock Wire Trans. Case to Carr.	1
	102-1514-22	Shim - Bevel Pinion Bearing (.003")	3
46	102-1514-23	Shim - Bevel Pinion Bearing (.005")	3
	102-1514-24	Shim - Bevel Pinion Bearing (.010")	1
47	102-7872-14	Plug - Trans. Case - Filler	1
	102-7872-14	Plug - Trans. Case - Drain	1
48	298-2515-68	Gasket	1
49	102-6168-70	Transmission Case Assy. (Items 32, 33 and 35)	1
50	102-1781-1	Gasket	1
51	- - - - - - -	Cap Screw, 5/8" x 1-1/2" U.N.C. w/C.W. & L.W.	2
52	102-7872-82	Trans. Case Only	1

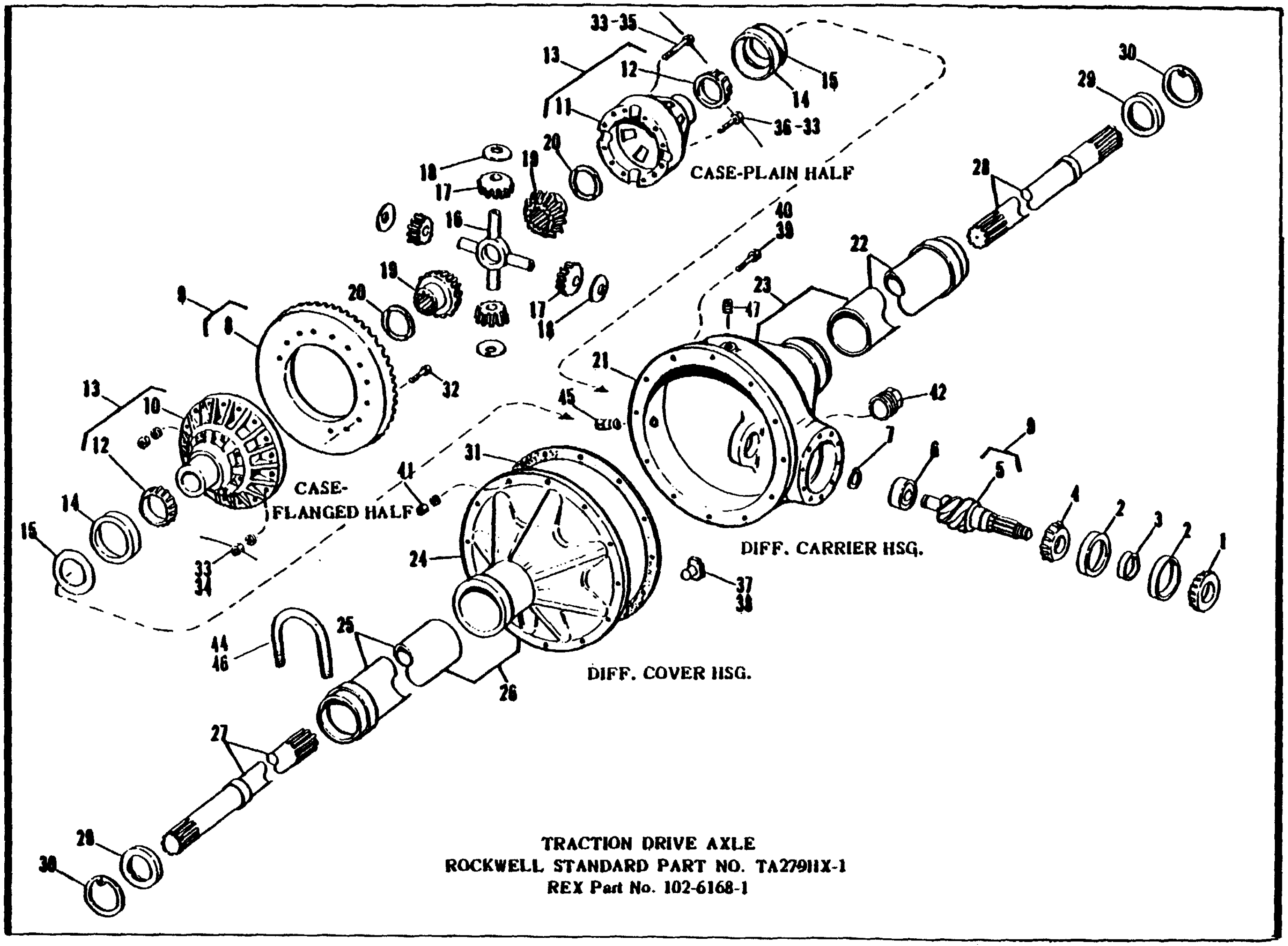


FIG. 13. TRACTION DRIVE AXLE

DIFFERENTIAL, CASE AND HOUSING
INCLUDED IN AXLE ASSEMBLY 102-11053-1
MODEL NO. PRTA 592 H200 w/NOSE BOX

Item No.	Part Number	Description	No. Req'd
1	102-6168-57	Bearing Cone	1
2	102-1514-20	Bearing Cup	2
3	102-6168-73	Spacer Set, .219" thru .254", 12 pcs. total per set (one ea. per number)	1
4	102-6168-61	Bearing Cone	1
5	102-6168-62	Bevel Pinion (Not Sold Separately) (See Item 9)	1
6	102-1514-15	Bearing	1
7	102-1514-14	Lock Ring	1
8	- - - - - - -	Bevel Gear (Not Sold Separately) (See Item 9)	1
9	102-6168-79	Gear Set (Set consisting of Items 5 and 8)	1
10	- - - - - - -	Diff. Case, Flanged Half (Not Sold Separately) (See Item 13)	1
11	- - - - - - -	Diff. Case, Plain Half (Not Sold Separately) (See Item 13)	1
12	102-1514-5	Bearing Cone - Diff. Case (Not Sold Separately) (See Item 13)	1
13	102-1574-6	Diff. Case and Cones Assy. (Contains Items 10, 11 and 12)	1
14	102-1514-9	Bearing Cup - Diff. Case	2
15	102-8095-21	Spacer Set - Diff. Brg. Cup, .137" thru .179"	1
	102-8095-20	Spacer Set - Diff. Brg. Cup, .146" thru .164"	2
16	102-1471-18	Diff. Spider	1
17	102-1471-6	Diff. Pinion Gear	4
18	102-6168-90	Diff. Thrust Washer	4
19	102-1471-5	Diff. Side Gear	2
20	- - - - - - -	Side Gear Thrust Washer	2
21	- - - - - - -	Diff. Carrier Housing (Not Sold Separately) (See Item 23)	1
22	- - -- - - -	Tube (LH.) (Not Sold Separately) (See Item 23)	1

Item No.	Part Number	Description	No. Req'd
23	102-7572-11	Diff. Carr. and Tube Assy. (Contains Items 21 and 22 Weldment)	1
24	- - - - - - -	Diff. Cover Housing and Thrust Block (Not Sold Separately) (See Item 26)	1
25	- - - - - - -	Tube (R.H.) (Not Sold Separately)	1
26	102-7872-83	Diff. Cover and Tube Assy. (Contains Items 24 and 25)	1
27	102-7572-10	Axle Shaft (R.H.)	1
28	102-6168-86	Axle Shaft (L.H.)	1
29	102-7572-83	Oil Seal - Axle	2
30	102-6168-89	Retainer - Oil Seal	2
31	102-1514-18	Gasket - Carrier and Cover	1
	102-6592-64	Bolt - Bevel Gear to Case Half, Flanged	12
32	102-1841-52	Washer	12
33	- - - - - - -	Lock Wire	2
34	102-1574-1	Nut, Bevel Gear to Case Bolt	12
35	- - - - - - -	Bolt, Long	8
36	102-7872-21	Bolt, Short	4
37	102-7872-38	Thrust Block	1
38	102-7872-26	Pin	1
39	102-9047-58	Cap Screw	10
	298-65-93	Bolt - Carrier Flange	10
40	102-7872-16	Cap Screw - Diff. Carrier Flange	2
41	102-6168-42	Nut	10
42	102-7572-20	Plug - Inspection	1
43	102-7572-85	Pad - Axle Spring (Not Illus.)	2
	- - - - - - -	"U" Bolt - Axle (Not Illus.)	4
44	102-8148-1	Lock Washer 1"	8
	- - - - - - -	Nut 1"	8
45	398-95002-74	Countersunk Pipe Plug 1/2"	1
46	102-8148-1	"U" Bolt, 1" w/lockwasher and Nut	4
47	102-7872-14	Plug - Oil Filter - Drain	2

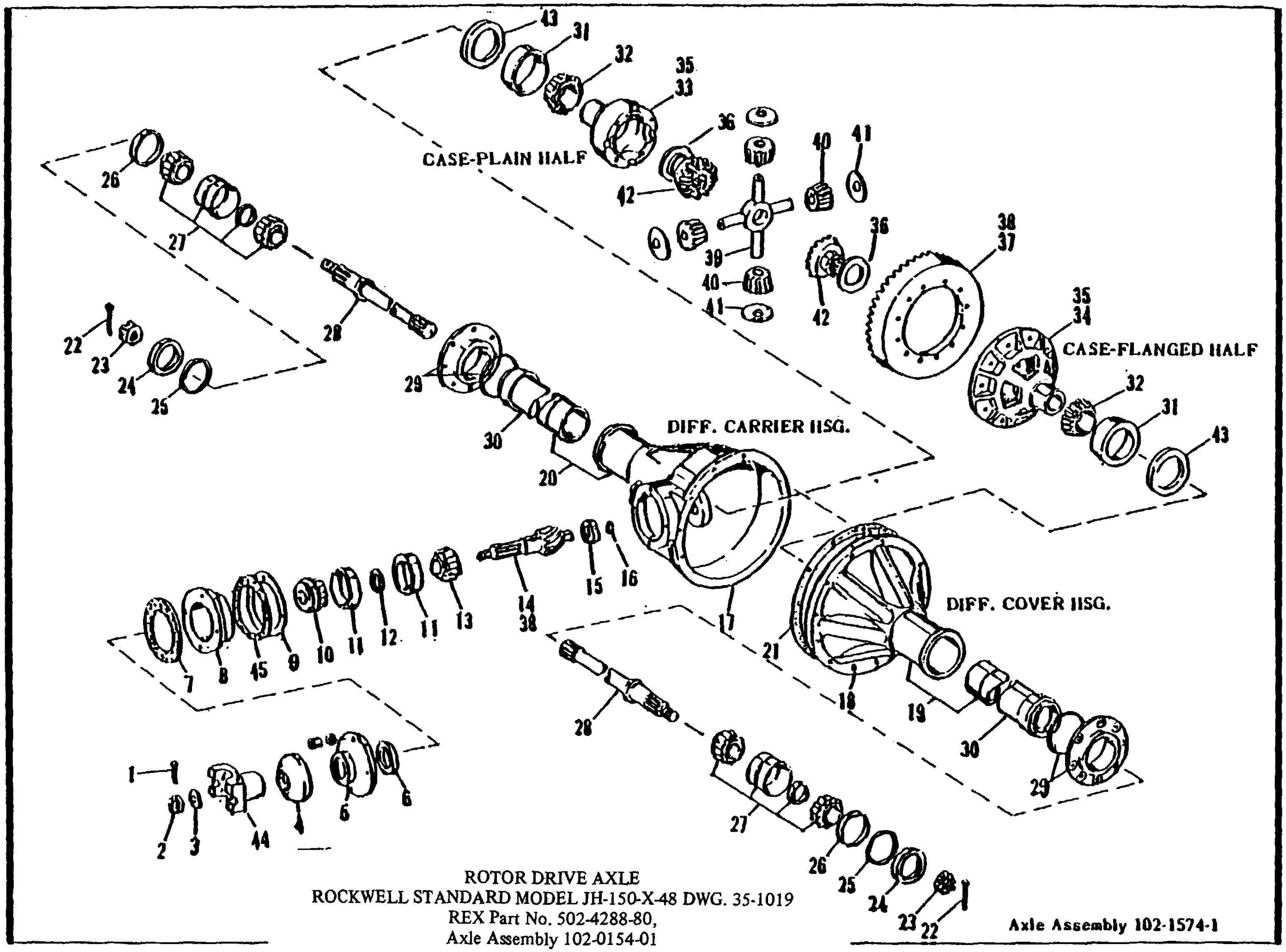


FIG. 14. ROTOR DRIVE AXLE

ROTOR DRIVE AXLE
ROCKWELL STANDARD MODEL JH-150-X-48 DWG. 35-1019
Axle Assembly 102-0154-01

Item No.	Part Number	Description	No. Req'd
1	102-1574-10	Cotter Pin *K-2412 (Not used with Lock Nut)	1
	102-7725-1	Slotted Nut *13399 (Used with Item 1)	
2	102-7872-84	Lock Nut *1227-C-939 (Does not require Cotter Pin Item 1)	1
3	102-1471-3	Washer *1229-E-1331	1
4	102-1471-23	Deflector *2297-P-562	1
5	102-1471-22	Cover-Seal *3866-Q-797	1
6	102-7872-45	Oil Seal-Bevel Pinion *A1205-B-1198	1
7	102-1514-75	Gasket-Pinion Bearing Cover *2804-W-791	1
8	102-1514-19	Pinion Bearing Cage with Bearing Cups (includes item 11) *A3826-U-255	1
	102-1514-22	Shim-Bevel Pinion Cage '2803-W-1791	1
9	102-1514-23	Shim-Bevel Pinion Cage *2803-X-1792	1
	102-1514-24	Shim-Bevel Pinion Cage *2803-Y-1793	1
10	102-6161-57	Bearing Cone *55176-C	1
11	102-1514-20	Bearing Cup *55443	2
12	102-6168-73	Spacer Set (Pinion Bearings) .219 thru .254 (12 Pcs.) - Use one as required '2203N1054/1065	1
13	102-6168-61	Bearing Cone *55137-C	
14	102-1574-16	Bevel Pinion & Shaft '35131 Not sold separately, (See item 38)	1
IS	102-1514-15	Bearing *122S-Z-52	1
16	102-1S14-14	Lock Ring *1229-Z-1300	1
17	102-1574-43	Differential Carrier Housing *300-A-625 Not sold separately, (See item 20)	1
18	102-1574-44	Differential Cover Housing '3800-J-660 Not sold separately, (See Item 19)	1
19	-	Differential Cover Housing a Tube Assembly Items 1i - 30 A 31 *A2-3800-J-660	
20	-	Differential Carrier Housing & Tube Assembly Items 17 - 30 & 31 *AI-380-A-625	1

Item No.	Part Number	Description	No. Req'd
21	102-1514-16	Gasket- Differential Carrier A Cover Housing *220-L-272	1
22	102-1574-21	Cotter Pin-Axle Shaft Nut *K-2416	2
23	102-7172-24	Nut-Axle Shaft *1227-Z-936	2
24	102-1471-12	Oil Seal-Axle Shaft *A1055-45-47	2
25	102-1471-11	Snap Ring-Axle Shaft *1854-D-316	2
26	102-1471-10	Space-Axle Shaft '*844-L-584	2
27	102-1471-9	Bearing-Axle Shaft 1828-Q-225	2
28	102-1471-7	Axle Shaft *3802-R-1110	2
29	402-588-2	Flange-Axle Tube	2
30	102-1471-8	Axle Tube *3816-Q-511 Not sold separately. (See Items 19 & 20)	2
31	102-1514-9	Bearing Cup *33472	2
32	102-1514-5	Bearing Cone *33281	2
33	102-1574-41	Differential Case-Plain Hall *3235-P-354 Not sold separately, (See Item 35)	1
34	-	Differential Case-Flanged Hall *3235-X-882 Not sold separately. (See Item 35)	1
35	102-1574-6	Differential Case Assembly *A-323S-X-UI2, Includes: Items 33, 34, 59, 60 & 61	
36	102-1514-11	Thrust Washer *1229-1-1027	2
37	102-1574-20	Bevel Drive Gear *353550 Not sold separately. (See Item 38)	1
38	102-1514-18	Gear Set *A35350-Assembly of *35131 & *35350 (See Items 37 & 14)	1
39	102-1471-18	Spider *3278-D-82	1
40	102-1574-24	Differential Pinion *2233-M- 117	4
41	102-1514-12	Pinion Thrust Washer *1229-L-1026	4
42	102-1574-23	Differential Side Gear *2234-G-267	2
	102-7172-30	Spacer-Differential Bearing Cup 125 *1844-.X-518	2
43	102-7872-31	Spacer- Differential Bearing Cup 126 *'144-Y-S19	2
	102-7872-82	Spacer-Differential Bearing Cup 131 *1844-Z-520 Use All As Required)	2

ROTOR DRIVE AXLE
ROCKWELL STANDARD MODEL JH-150-X-48 DWG. 35-1019
Axle Assembly 102-0154-01

Item No.	Part Number	Description	No. Req'd
	102-1574-5	Companion flange *A3080-L-1728	1
44	298-6071-91	End Yoke	1
45	102-1471-16	Gasket-Pinion Bearing Cage *2802-L-792	1
		MISCELLANEOUS PARTS - NOT ILLUSTRATED	
46	102-1574-4	Pinion Bearing Cage Stud *4-X-690	1
47	102-1574-3	Pinion Bearing Cage Lockwasher *WA-19	1
48	102-1574-2	Pinion Bearing Cage Nut *N-19-1	1
49	102-7572-14	Differential Carrier Housing Bolt *5-1814-1	10
50	102-1514-36	Differential Carrier Housing Stud *4-X-186	2
51	102-6168-41	Differential Carrier Housing Lockwasher *WA-18	12
52	102-6168-42	Differential Carrier Housing Nut *N-18-1	12
53	102-7872-14	Differential Carrier Housing Fill Plug *P-18	1
54	102-1841-53	Differential Carrier Housing Drain Plug *P-112	2
55	102-7572-20	Differential Carrier Housing Inspection Plug *1250-5-149	1
56	102-7872-38	Differential cover Housing Thrust Black *2297-A-573	1
57	102-7872-26	Differential Cover Housing Pin *1246-G-293	1
58	102-6168-28	Differential Cover Housing Oil Breather *1199-J-166	1
59	102-7872-22	Differential Case Bolt-Long *15-X-927	8
60	102-7872-21	Differential Case Bolt-Short *15-X-926	4
61	102-6168-83	Differential Case Bolt-Lockwire *LW-1626	1

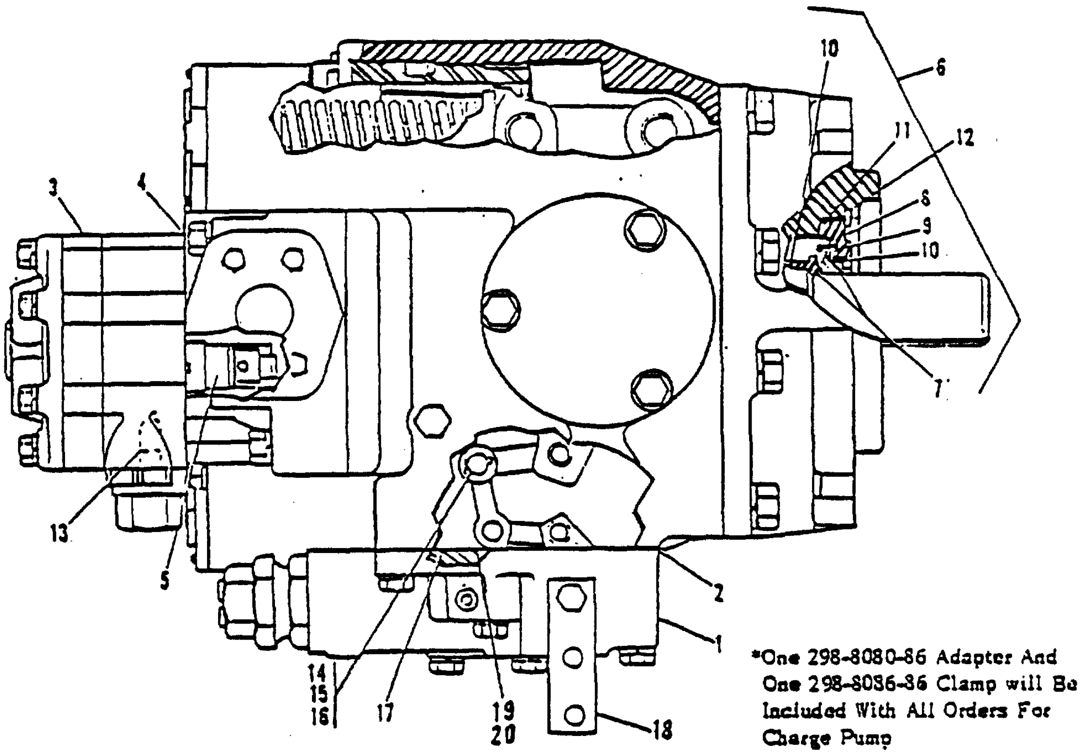
Item No.	Part Number	Description	No. Req'd
		BEARING SPACERS & SHIMS - NOT ILLUSTRATED	
	102-1574-49	Spacer Differential Bearing Cup .146" *1244-D-394	2
	102-1574-50	Spacer Differential Bearing Cup .149" *1244-D-395	2
	102-1574-51	Spacer Differential Bearing Cup .152" *1244-D-396	2
	102-1574-52	Spacer Differential Bearing Cup .155" *1244-D-397	2
	102-1574-53	Spacer Differential Bearing Cup .158" *1244-D-398	2
	102-1574-54	Spacer Differential Bearing Cup .161" *1244-D-400	2
	102-1574-55	Spacer Differential Bearing Cup .164" *1244-D-401	2
	102-1574-56	Spacer Differential Bearing Cup .134" *1244-D-479	2
	102-1574-57	Spacer Differential Bearing Cup .137" *1244-D-480	2
	102-1574-58	Spacer Differential Bearing Cup .140" *1244-D-481	2
	102-1574-59	Spacer Differential Bearing Cup .167" *1244-D-484	2
	102-1574-60	Spacer Differential Bearing Cup .170" *1244-D-485	2
	102-1574-61	Spacer Differential Bearing Cup .173" *1244-D-486	2
	102-1574-62	Spacer Differential Bearing Cup .176" *1244-D-487	2
	102-1574-63	Spacer Differential Bearing Cup .179" *1244-D-488	2
	102-1574-64	Shim-Bevel Pinion bearing.439" *2203-W-543	1
	102-1574-65	Shim-Bevel Pinion bearing.439" *2203-W-544	1
	102-1574-66	Shim-Bevel Pinion bearing.439" *2203-W-545	1

ROTOR DRIVE AXLE
ROCKWELL STANDARD MODEL JH-150-X-48 DWG. 35-1019
Axle Assembly 102-0154-01

Item No.	Part Number	Description	No. Req'd
	102-1574-67	Shim-Bevel Pinion Bearing .442” *2203-Z-546	1
	102-1574-68	Shim-Bevel Pinion Bearing .443” *2203-A-547	1
	102-1574-69	Shim-Bevel Pinion Bearing .444” *2203-B-548	1
	102-1574-70	Shim-Bevel Pinion Bearing .445” *2203-C-549	1
	102-1574-71	Shim-Bevel Pinion Bearing .446” *2203-D-550	1
	102-1574-72	Shim-Bevel Pinion Bearing .447” *2203-E-551	1
	102-1574-73	Shim-Bevel Pinion Bearing .454” *2203-M-559	1
	102-1574-74	Shim-Bevel Pinion Bearing .455” *2203-N-560	1
	102-1574-75	Shim-Bevel Pinion Bearing .456” *2203-P-562	1
	102-1574-76	Shim-Bevel Pinion Bearing .457” *2203-Q-563	1
	102-1574-77	Shim-Bevel Pinion Bearing .458” *2203-R-564	1
	102-1574-78	Shim-Bevel Pinion Bearing .459” *2203-S-565	1
	102-1574-79	Shim-Bevel Pinion Bearing .460” *2203-T-566	1
	102-1574-80	Shim-Bevel Pinion Bearing .461” *2203-U-567	1
	102-1574-81	Shim-Bevel Pinion Bearing .462” *2203-V-568	1
	102-1574-82	Shim-Bevel Pinion Bearing .463” *2203-W-569	1
	102-1574-83	Shim-Bevel Pinion Bearing .464” *2203-X-570	1
	102-1574-84	Shim-Bevel Pinion Bearing .465” *2203-X-571	1
	102-1574-85	Shim-Bevel Pinion Bearing .466” *2203-Z-572	1

Item No.	Part Number	Description	No. Req'd
	102-1574-86	Ship-Bevel Pinion Bearing .467” *2203-A-573	1
	102-1574-87	Ship-Bevel Pinion Bearing .468” *2203-B-574	1
	102-1574-88	Ship-Bevel Pinion Bearing .469” *2203-D-1018	1
	102-1574-89	Ship-Bevel Pinion Bearing .470” *2203-E-1019	1
	102-1574-90	Ship-Bevel Pinion Bearing .471” *2203-F-1020	1
	102-1574-91	Ship-Bevel Pinion Bearing .472” *2203-G-1021	1
	102-1574-92	Ship-Bevel Pinion Bearing .473” *2203-H-1022	1
	102-1574-93	Ship-Bevel Pinion Bearing .474” *2203-J-1024	1
	102-1574-94	Ship-Bevel Pinion Bearing .475” *2203-K-1025	1
	102-1574-95	Ship-Bevel Pinion Bearing .476” *2203-L-1026	1
	102-1574-96	Ship-Bevel Pinion Bearing .447” *2203-M-1027	1
	102-1574-97	Ship-Bevel Pinion Bearing .448” *2203-F-552	1
	102-1574-98	Ship-Bevel Pinion Bearing .449” *2203-G-553	1
	102-1574-99	Ship-Bevel Pinion Bearing .450” *2203-H-554	1
	102-1574-7	Ship-Bevel Pinion Bearing .451” *2203-J-556	1
	102-1574-8	Ship-Bevel Pinion Bearing .452” *2203-K-557	1
	102-1574-9	Ship-Bevel Pinion Bearing .453” *2203-L-558	1

*Rockwell Standard Corporation - Part Numbers - Contact Transmission & Axle Division - Oshkosh, Wisconsin.

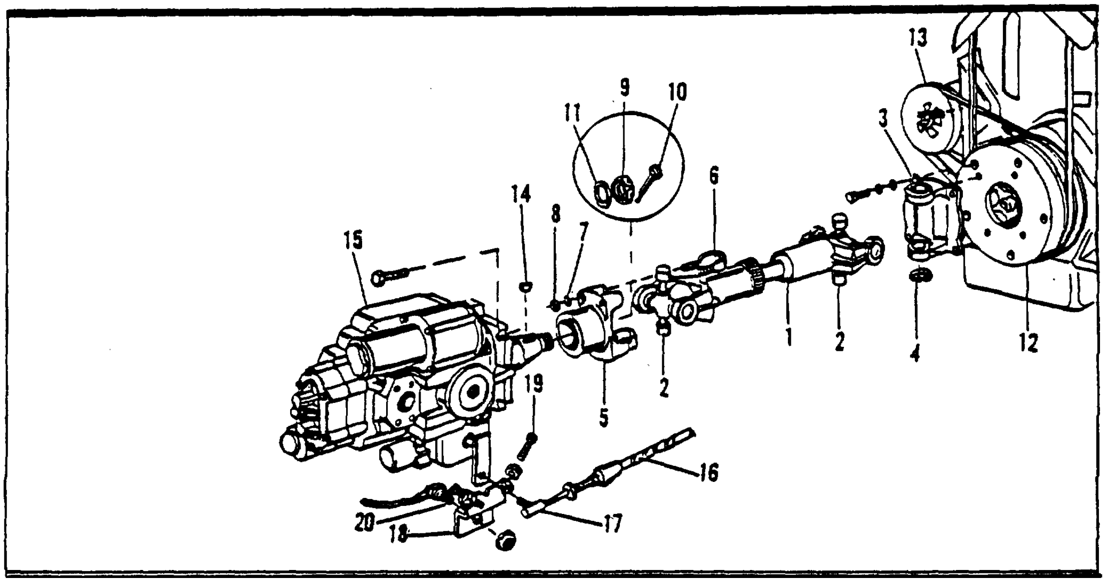


LEFT HAND ROTATION
TRACTION DRIVE HYDROSTATIC PUMP

SUNDSTRAND PART NO. 22-2052
REX PART NO. 102-8346-1

Item No.	Part Number	Description	No. Req'd
1	102-4365-4	Control Valve	1
2	102-4365-6	Control Valve Gasket	1
3	102-4365-7	Charge Pump	1
4	102-1365-11	Charge Pump Gasket	1
5	102-4365-12	Check Valve	1
6	102-4365-1	Seal Kit - Consists of Items 7 thru 11	1
12	102-4365-35	Retaining Ring	2
13	102-4365-52	Charge Pump Rel. Valve Poppet	1
14	102-4365-48	Cotter Pin	1
15	102-4365-49	Pin	1
16	102-4365-50	Washer	1
17	102-4365-61	"O" Ring	3
18	102-4365-46	Control Shaft Handle	1
19	102-4365-34	"O" ring	1
20	102-4365-36	Seal Retainer	1

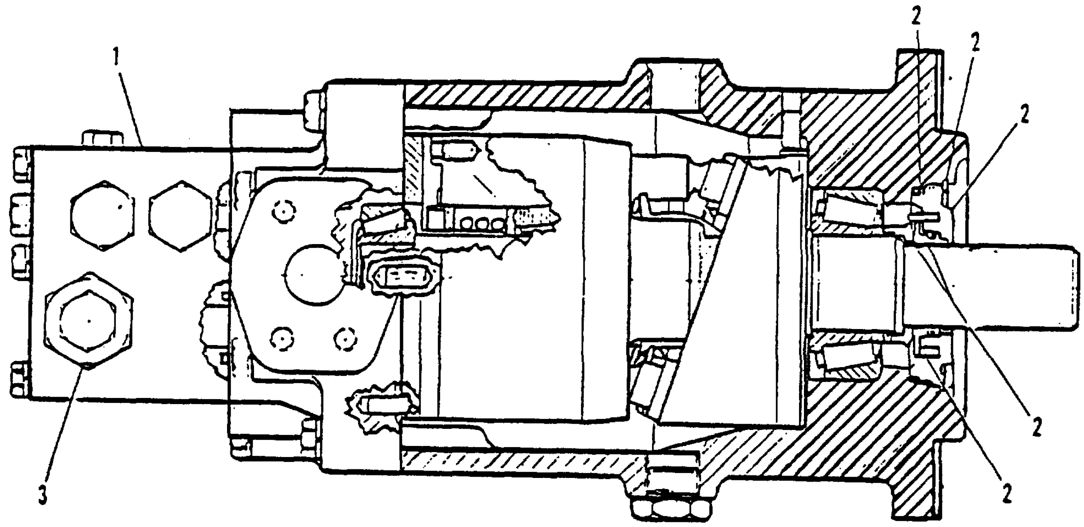
FIG. 15. TRACTION DRIVE PUMP



HYDROSTATIC PUMP - TRACTION DRIVE
UNIVERSAL JOINT & CONNECTIONS TO PUMP AND ENGINE
PUSH PULL UNIT - FORWARD - REVERSE
NEUTRAL START SWITCH
- SELF PROPELLED PULVIMIXER -

Item No.	Part Number	Description	No. Req'd
1	291251-58	Tube Assembly (Includes item 2)	1
2	102-437-18	Journal & Bearing Kit (Spicer #5-153X)	2
3	X203765	Flange Yoke	1
4	X203741	Snap Ring (Spicer #2-7-29)	2
5	102-9393-1	End Yoke (Spicer #2-1-834)	1
6	X8005B	"U" Bolt	2
7	398-20000-64	Lock Washer 5/16"	4
8	398-11000-18	Hex Nut 5/16"	4
9	102-7725-1	Slotted Hex Nut 1"-20 U.N.F.	1
10	398-3000-18	Cotter Pin 1/8 x 2"	1
11	27284	Special Washer (Use if needed)	1
12	102-30139-1	Adapter - Engine - for Hydrostatic Drive	1
13		Diesel Engine - Reference only - see separate illustration	-
14		Woodruff Key 3/8 x 1-1/2"	1
15	102-8346-1	Sundstrand Hydrostatic Pump (Model 22-2052) includes slotted nut - item 9, cotter pin -- item 10, and woodruff key - item 14. - See separate illustration	1
16	298-156-17	Push Pull Control Cable	1
17	X202821	Ball Joint 1/4"	1
	398-17000-70	Hex Nut 1/4" U.N.F.	1
18	502-2157-80	Stop Bracket	1
19		Square Head Set Screw 3/8 x 1-1/2" (U.N.C.)	2
20	298-6085-17	Neutral Start Switch (Cole-Hersee #9233)	1

FIG. 16. TRACTION DRIVE PUMP WITH UNIVERSAL JOINT CONNECTIONS (FRONT OF DIESEL)



TRACTION DRIVE
FIXED DISPLACEMENT HYDROSTATIC MOTOR SERVICE PARTS
FOR REX SELF-PROPELLED PULVI MIXER
REX PART NO. 102-8506-1
SUNDSTRAND SERIES 22-3055

Item No.	Part Number	Description	No. Req'd
1	102-4365-78	Manifold Assembly	1
2	102-4365-1	Seal Kit	1
3	102-4365-77	Relief Valve Assembly	1

FIG. 17. TRACTION DRIVE MOTOR

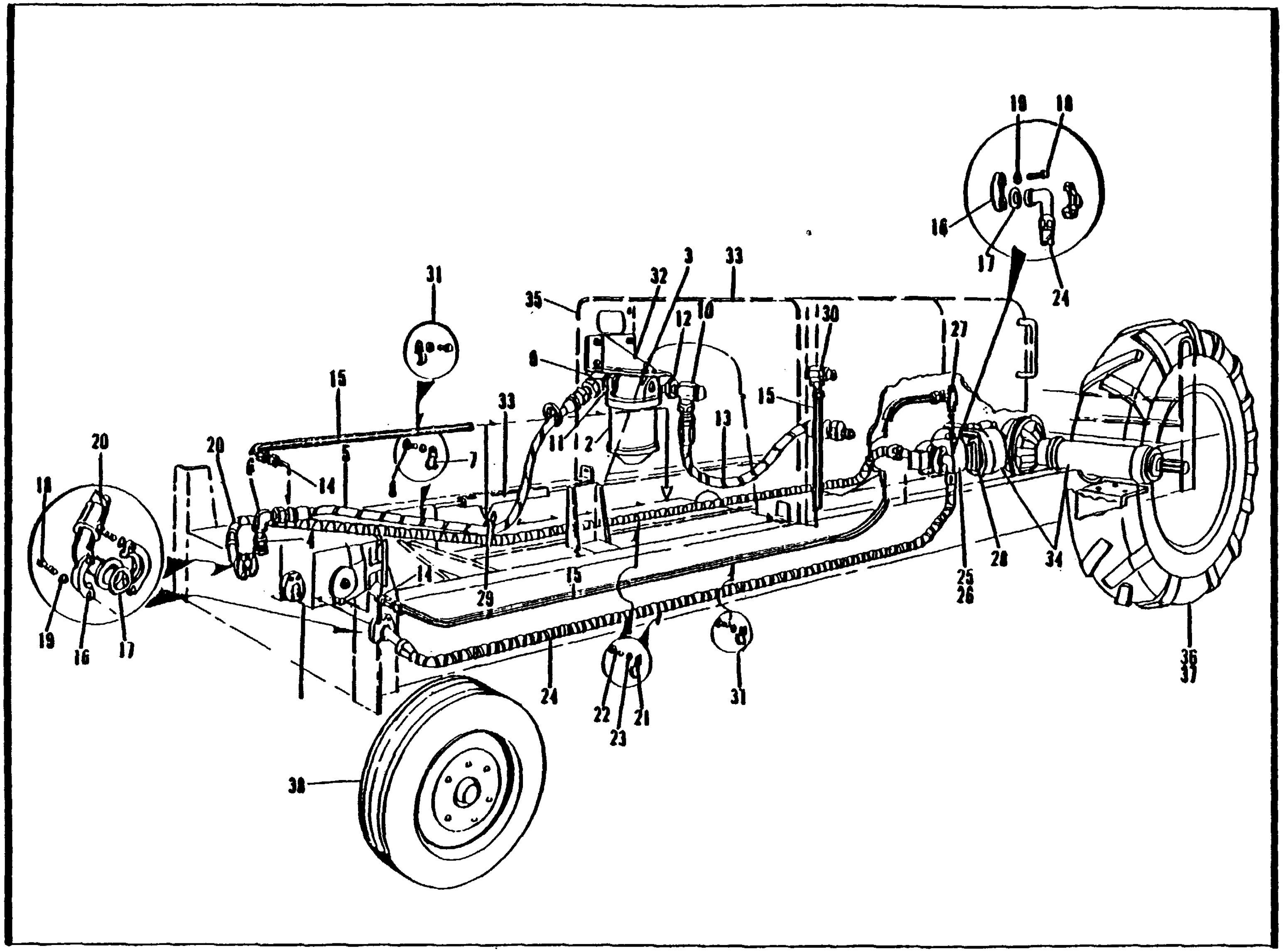


FIG. 18. TRACTION DRIVE HYDRAULIC LINES

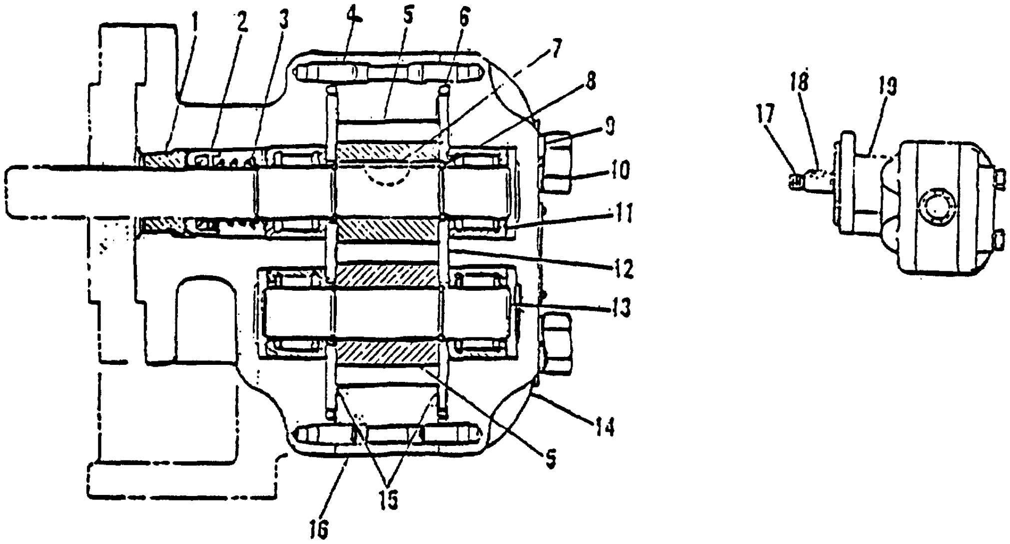
HYDRAULIC LINES & FITTINGS - TRACTION DRIVE WHEELS & TIRES REX HYDROSTATIC DRIVE PULVI MIXER

Item No.	Part Number	Description	No. Req’d
1	102-8346-1	Hydrostatic Pump (Sundstrand Series 22-2052) (L.H. Rotation) (Ref. only) (See Separate Illustration)	1
	298-57-53	Oil Filter - For Suction Installation (Gresen Model FR251-100A per Spec. No. F4-F)	1
2	298-3525-68	Service “O” Ring for Gresen Filter (Gresen No. 1576)	1
	298-6505-68	Service Filter Element - 10 Micron (Gresen No. 1509)	1
	398-2001-60	Cap Screw 5/16” x 1”	2
3	398-20000-64	Lock Washer	2
4	298-8078-86	Straight Adapter (Aeroquip #202702 - 10-12)	1
5	102-3222-3	Hose Assembly - ¾” I.D. x 112” S.A.E. 100R4 - 1-1/16-12 Swivel Female J.I.C. 37° Flare One End and ¼” Swivel Male N.P.T.F. Thread on Other (Suction Line - Filter to Pump)	1
6	298-8084-86	Elbow - 90° (Anchor #12JMA - 12JUFS or Parker #12C6BX-S)	1
7	298-153-47	Clamp	1
	398-2002-21	Cap Screw ½” x 1 ½”	1
8	398-20000-39	Lock Washer ½”	1
	398-11000-22	Hex Nut ½”	1
9	298-2068-62	Adapter ¼” N.P.T. x 90° (Anchor #12MA - 12UFS)	1
10	298-2167-62	Adapter 90° (anchor #16MA - 16UFS)	1
11	298-14511-86	Reducer Bushing 1 ¼” x ¼” N.P.T.F.	1
12	298-14504-86	Reducing Bushing 1 ¼” x 1” N.P.T.	1
13	102-3104-1	Hose - Suction - Tank to Filter - 1” I.D. x 30” long - 1” Male N.P. T. Both Ends (Inperial Eastman FA16 - 16MB-30 - 1 ½” O.D.)	1
14	298-2102-62	Straight Swivel Adapter - ½ - 14 Female Pipe Swivel to 7/8-14 Str. Thread “O” Ring Boss w/”O” Ring (Aeroquip #2066-8-10)	
15	502-2083-80	Hose - Return, Motor to Pump - Pump to Tank, 5/8” I.D. x 126” long - 29/32” O.D. w/1/2” M.P.T. Fitting (Aeroquip #2556-10)	-*
16	298-8033-86	Clamp (Anchor 16SF2H, Aeroquip #74446-16) Half	8
17	102-159-4-4	“O” Ring (Imperial Eastman 24 -16PA77)	4
18	102-1594-3	Cap Screw 3/8-16 N.C., 2” x 1 ¼” long (Eastman 620-74)	16
19	398-20000-37	Lock Washer 3/8”	16
20	102-6549-1	High Pressure Hose - Pump to Motor w/One Straight and One 45° Split Flange Fittings 1” - Overall Length 11;-5 ½” (anchor 16SL4) (16SF - 16SF45 - 137.50”) or (Stratoflex 3270C16 - SA16 - S45A16 - 137 ½)	1
21	102-2541-1	Clamp	4
22	398-2001-82	Cap Screw 3/8” x 1 ½”	4
	398-20000-37	Lock Washer 3/8”	4
23	398-11000-19	Hex Nut 3/8”	4
24	102-6550-1	High Pressure Hose - Motor to Pump w/One 90° Split Flange and One 45° Split Flange Fittings 1” - Overall Length 10’-6” (Anchor 16SL4) (16SF90 - 16SF45 - 126.00”)	1
25	102-8506-1	Hydrostatic Motor - Traction Drive (Sundstrand Series 22-3055) (See Separate Illustration	1

HYDRAULIC LINES & FITTINGS - TRACTION DRIVE WHEELS & TIRES REX HYDROSTATIC DRIVE PULVI MIXER (CONTINUED)

Item No.	Part Number	Description	No. Req'd
	398-2005-88	Nylok Cap screw ½" x 1 ¾" HCHT	8
26	398-20001-13	Cut Washer ½" S.A. E.	8
27	298-2093-62	Adapter Fitting - Swivel Adapter Union - 90° elbow - 7/10 -14 (O ring) Boss to ½" N.P.T. Female (Imperial Eastman 600B - (10X08) or Equal	1
28	102-1781-1	Gasket	1
29	298-4516-68	Hose Tie - Hvy. Duty	1
30	298-2075-62	Union - 90° Adapter ½" N.P.T. Male to ½" N.P.T. Female (Anchor #8 MA - 8UFS)	1
31	298-157-47	Clamp	2
32	502-4691-80	Bracket - Oil Filter	1
33	102-340-1	Channel Rubber	1
34	102-6168-1	Axle and Two Speed Transmission Assembly (Traction) - Rockwell Model TA-279-HX1 - See Separate Illustrations	1

Item No.	Part Number	Description	No. Req'd
35	502-4692-80	Hood Extension (R.H.) - (Reference Only)	1
	298-6015-68	Tire 18.4 x 34/15.00 x 34 6 Ply (Standard)	2
36	298-6017-68	Tube for 298-6015-68 tire (Standard)	2
	298-5534-68	Plug - Valve Hole (Standard)	2
	502-5618-80	Wheel for 15 x 34 Tire (Standard)	2
	298-6023-68	Tube (All Weather Option)	2
37	298-5534-68	Plug 0 Valve Hole	2
	502-5650-80	Base Rim Assembly (All Weather	2
	298-4019-47	Wheel - Front (#8 x 24) Reference Only	2
38	298-6012-68	Tire - Implement - 8 Ply 9.00 x 24	2
	298-06056-68	Rim Valve	2



HYDRAULIC PUMP
TAILBOARD - SPRAY BAR - CRAME RAMS
REX PART NO. 298-49-53
HYDRECO PART NO. 1512C12C1

Item No.	Part Number	Description	No. Req'd
1	102-6417-10	Seal (*11X15X1)	1
2	102-6417-11	Seal Assembly (*N15-10)	1
3	102-6417-12	Washer (*A408x17)	1
4	102-6417-13	Dowel Pin (*A500x2)	4
5	102-6417-14	Gear (*6X1512X1)	2
6	102-6417-15	"O" Ring (*A395X65)	2
7	102-6417-16	Woodruff Key (*A258X5)	1
8	102-6417-17	Snap Ring (*812X49)	5
9	102-6417-18	Lock Washer (*A419X6)	4
10	102-6417-19	Cap Screw (*A438X7)	4
11	102-6417-20	Bearing (*A340X6)	4
12	102-6417-21	Wear Plate (*12X15X1)	1
	102-6417-22	Wear Plate (*12X15X2)	1
13	102-6417-23	Driven Shaft (*15-5-125)	1
14	102-6417-24	Ported Cover (*3X15X7)	1
	102-6417-25	Shim (.001) Amber (*712X94A) (As Required)	-
15	102-6417-26	Shim (.002) red (*712X94B) (As Required)	-
	102-6417-27	Shim (.0015) Purple (*712X94C) (As Required)	-
16	102-6417-28	Housing (*1X1512X1)	1
17	102-6417-29	Shaft (*4X1512X9)	1
18	102-6417-30	Woodruff Key (*A258X6)	1
19	402-1599-2	Adapter	1
		*Hydreco - Kalamazoo, Michigan Part Numbers	

FIG. 19. HYDRAULIC PUMP FOR TAILBOARD - SPRAY BAR AND CRANE RAMS

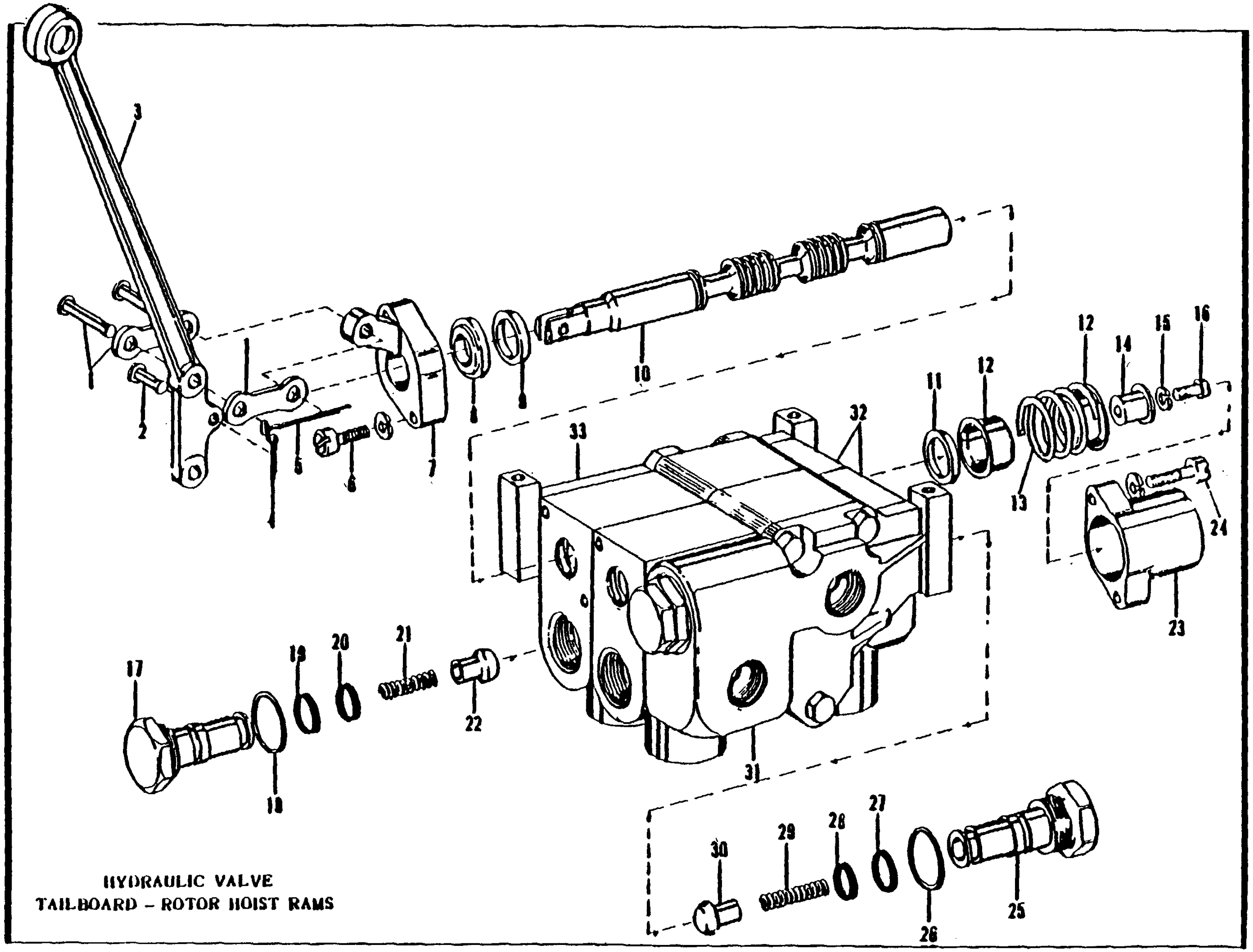


FIG. 20. HYDRAULIC CONTROL VALVE FOR TAILBOARD AND ROTOR LIFT RAMS

HYDRAULIC CONTROL VALVE
FOR ROTOR HOIST RAM AND TAILBOARD CONTROL RAM
(GRESEN MFG. CO. "CP4" - 2 SPOOL)
REX PART NUMBER 102-6208-1

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	102-6208-10	Handle Link (*928)	2		102-6208-18	Spool Seal (*1820)	2
2	102-6208-20	Handle Link (*1857)	2	20	102-6206-16	Spool Seal (*1818)	2
3	102-6208-14	Handle (*1802)	2	21	102-6208-29	Spring (*2796)	2
4	102-8503-24	Cotter Pin (*086)	2	22	102-8503-18	Check Ball (*2781)	2
5	102-8503-14	Cotter Pin (*929)	2	23	102-6208-30	Bonnet (*1811)	2
6	102-6208-21	Cop Screw (*1808)	4	24	102-6208-21	Cop Screw (*1808)	4
7	102-6208-13	Gland & Handle Support (*1801)	2	25	102-6208-27	Relief Valve (*1817)	2
8	102-6208-12	Packing for Gland (*1800)	2	26	102-6208-28	Gasket - Relief Valve (*2707)	2
9	102-6208-11	Seal for Spool (*1129)	2	27	102-6208.19	Spool Seal (*1821)	2
10	102-6208-22	Spool (*1804)	2	27	102-6208-17	Spool Seal (*1819)	2
11	102-6208-11	Seal for Spool (*1129)	2	28	102-6208-18	Spool Seal (*1820)	2
12	102-6208-23	Collar (*1809)	4		102-6208-16	Spool Seal (*1818)	2
13	102-6208-24	Spring (*1807)	2	29	102-6208-29	Spring (*2796)	2
14	102-6208-15	Retainer (*1810)	2	30	102-8503-18	Check Ball (*2781)	2
15	102-6208-25	Washer (*1813)	2	31	102-6208-31	Housing - End (*1815)	1
16	102-6208-26	Cap Screw (*1812)	2	32	102-6208-32	Spool Housing (*1814)	2
17	102-6208-27	Body - Relief Valve (*1817)	2	33	102-6208-33	Housing - End (*1816)	1
18	102-6208-28	Gasket - Relief Valve (*2707)	2				
19	102-6208-19	Spool Seal (*1821)	2				
	102-6208-17	Spool Seal (*1819)	2				

* Gresen Mfg. Co., Minneapolis, Minnesota part numbers.

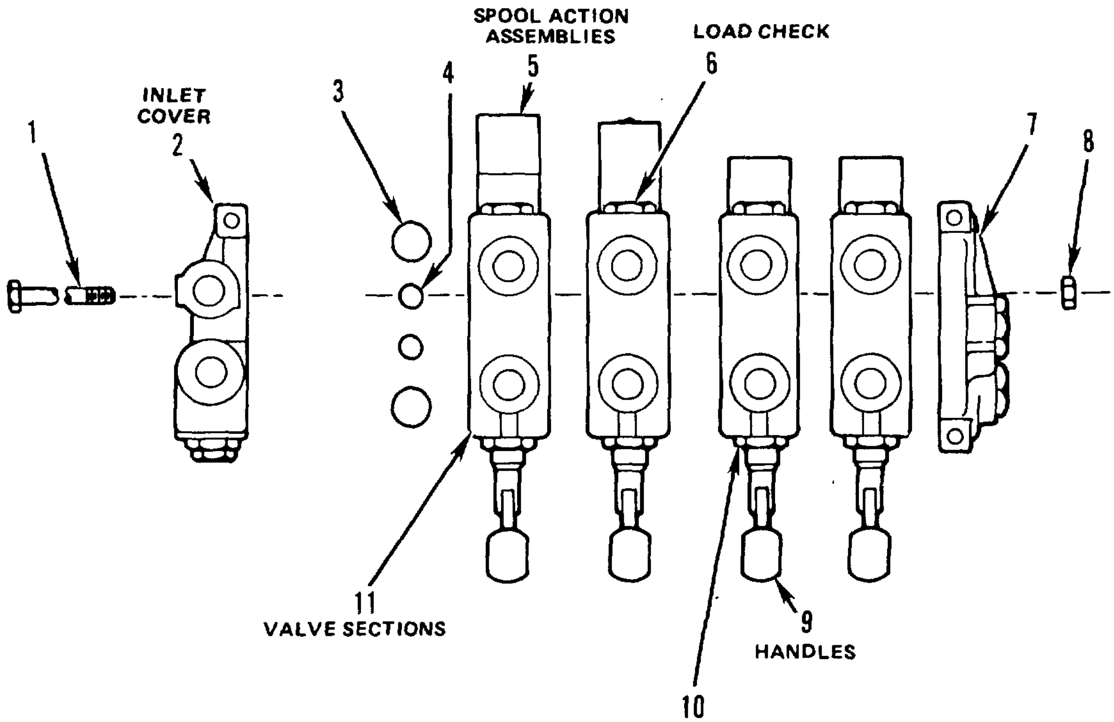
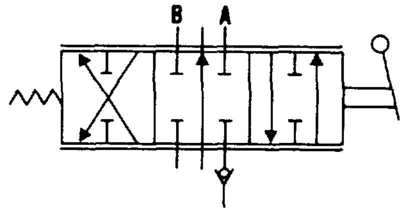


FIG. 21. MODEL V20 DIRECTIONAL CONTROL VALVE TYPICAL MAIN ASSEMBLY

GRESEN HYDRAULIC VALVE

Item No.	Part Number	Description	No. Req'd
1	K-6107-A	* STUD KIT, 4-SECTION	1
2	8398-014	COVER, LEFT	1
3	6815-001	** O-RING, EXHAUST, LARGE	2 plus 2 per section
4	6814-001	** O-RING, PRESSURE SMALL	2 plus 2 per section
5		POSITIONER, STANDARD SPOOL	A/R
6		PLUG, LOAD CHECK	A/R
7	6770	COVER, RIGHT	1
8	9310-006	* NUT, STUD, NOT SOLD SEPARATELY	3
9		HANDLE ASSEMBLY, VERTICAL	A/R
10		BRACKET, STANDARD HANDLE	A/R
11	8072-	VALVE SECTION, 4-WAY, 3-POSITION	A/R

*Each Stud Kit contains 3 Assembly Studs and 3 Stud Nuts. Torque Stud Nuts to 32 ft. lbs. (43.5 N •m).
**Buna-N seals are standard for all Gresen valve assemblies. Optional Viton seals are available. See Cross Reference Tables on page 49.



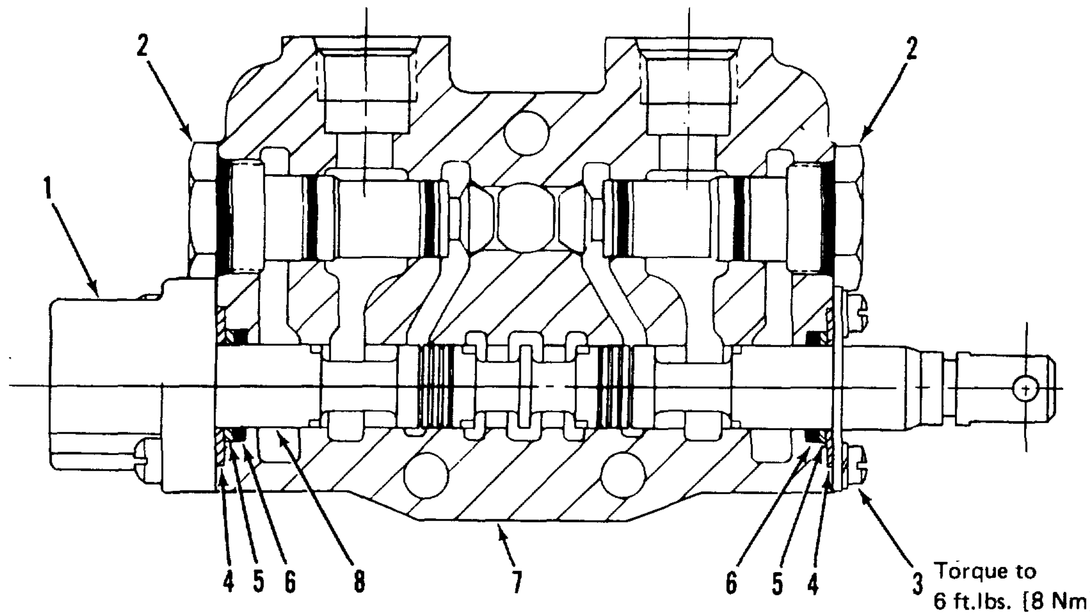


FIG. 22. 4-WAY, 3-POSITION VALVE SECTION

4-WAY, 3-POSITION VALVE SECTION

Item No.	Part Number	Description	No. Req'd
1	K-6125	POSITIONER, Spool, Standard (See Figure 5)	1
2	K-6030-A	CHECK, Load (See Figure 8)	2
3	K-6033-A	RETAINER ASSEMBLY, Standard, Includes Screws	1
4	6752-001	RETAINER, Plate Washer	2
5	3265-001	WASHER, Back-Up See Note 1	2
6	7700-001*	SEAL, O-Ring	2
7	8072-	HOUSING, Standard) See Note 2	1
8	8084-001	SPOOL, 4-Way	1

Notes:

1. Seal and washer not sold separately. Order Seal Kit No. K-6035-A.

2. These are matched parts and are not sold separately.

***Buna-N seals are standard for all Gresen valve assemblies. Optional Viton seals are available. See Cross Reference Tables on page 49.**

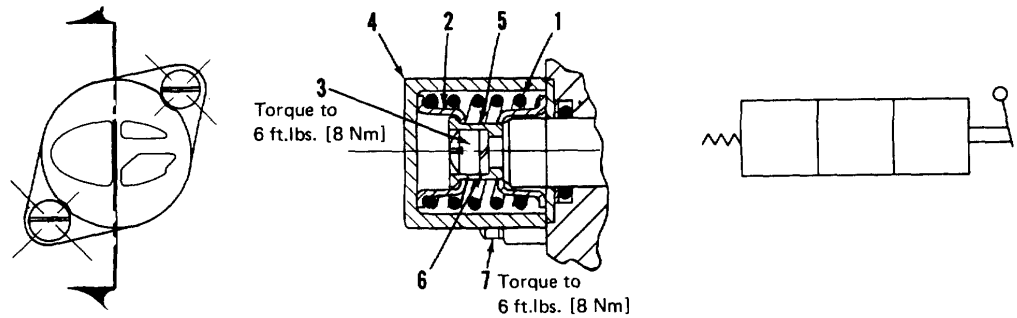


FIG. 23. STANDARD SPOOL POSITIONER

STANDARD SPOOL POSITIONER

Item No.	Part Number	Description	No. Req'd
	K-6125	REPLACEMENT KIT (Contains all items listed below)	
1	7433-001	SPRING, Return	1
2	1809-001	COLLAR, Spring	2
3	1812-001	SCREW, Fillister Head 5/16-18 by 3/4 inch long	1
4	1811-001	BONNET	1
5	1810-001	COLLAR, Spool	1
6	1813-001	WASHER, Lock	1
7	1808-001	SCREW, Fillister Head, 1/4-20 by 7/8 inch long	2

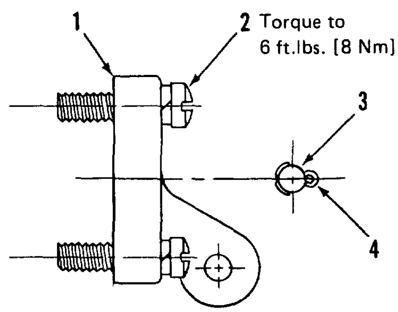


FIG. 24. HANDLE BRACKET ASSEMBLY

HANDLE BRACKET ASSEMBLY

Item No.	Part Number	Description	No. Req'd
	K-6031	REPLACEMENT KIT, Standard, (Contains items 1 and 2)	
	K-6037	SERVICE KIT, Heavy Duty, (Contains items 1 and 2)	
1	1801-001	BRACKET, Die Cast (Standard)	1
	1801-002	BRACKET, Die Cast (Optional, for use with CRA Relief)	1
	7355-001	BRACKET, Cast Iron (Optional, Heavy Duty)	1
2	1808-001	SCREW, Fillister Head Machine, 1/4-20 by 7/8 inch long	2
3	1857-001	PIN	1
4	0086-001	PIN, Cotter	1
5	1800-001	SEAL, Wiper, optional (not shown)	1

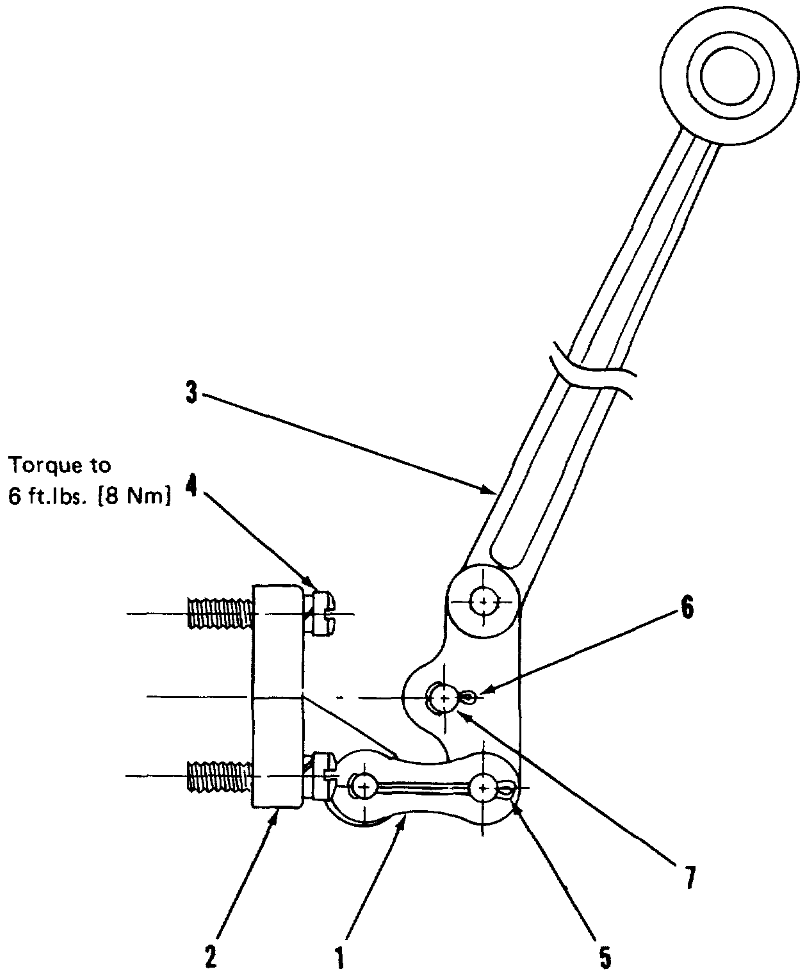


FIG. 25. OPTIONAL VERTICAL HANDLE AND BRACKET ASSEMBLY

OPTIONAL VERTICAL HANDLE AND BRACKET ASSEMBLY

Item No.	Part Number	Description	No. Req'd
	K-6004-A	REPLACEMENT KIT, Standard (Black plastic coated handle) All Replacement Kits contain all items listed below except No. 7355-001, Bracket	
1	3452-001	PLATE, Link (less pins)	1
	3453-001	PLATE, Link (with pins)	1
2	1801-001	BRACKET, Die Cast (Standard)	1
3	1802-001	HANDLE, Standard Vertical, Black plastic coated	1
4	1808-001	SCREW, Fillister Head Machine, 1/4-20 by 7/8 inch long	2
5	0929-001	PIN, Cotter	1
6	0086-001	PIN, Cotter	1
7	1857-001	PIN	1
8	1800-001	SEAL, Wiper, optional (not shown)	1

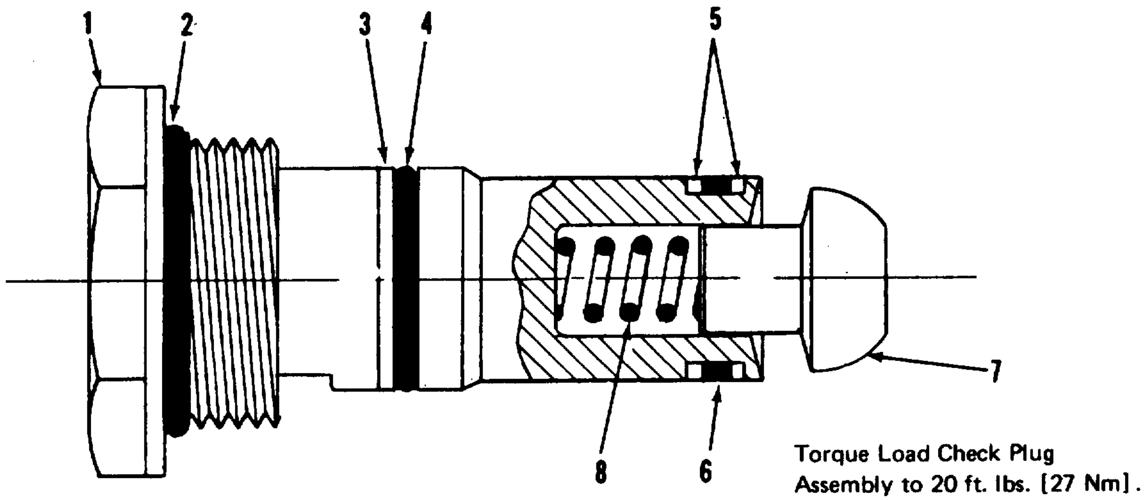


FIG. 26. LOAD CHECK PLUG ASSEMBLY

LOAD CHECK PLUG ASSEMBLY

Item No.	Part No.	Description	Quantity Per Plug Assembly
	K-6030-A*	REPLACEMENT LOAD CHECK PLUG ASSEMBLY	
	K-6032*	SEAL KIT, (Contains items 2, 3, 4, 5 and 6)	
1	3411-001	Plug, Lift Check, Steel (Heavy Duty)	1
2	2707-001*	SEAL, O-Ring	1
3	1821-001	WASHER, Back-Up, Outer } Not Sold	1
4	1819-001*	SEAL, O-Ring, Outer } Separately	1
5	1820-001	WASHER, Back-Up, Inner } Order K-6032	2
6	1818-001*	SEAL, O-Ring	1
7	2781-001	POPPET, Lift Check	1
8	1868-001	SPRING, Lift Check	1

*Buna-N seals are standard for all Gresen valve assemblies. Optional Viton seals are available. See Cross Reference Tables on page 49.

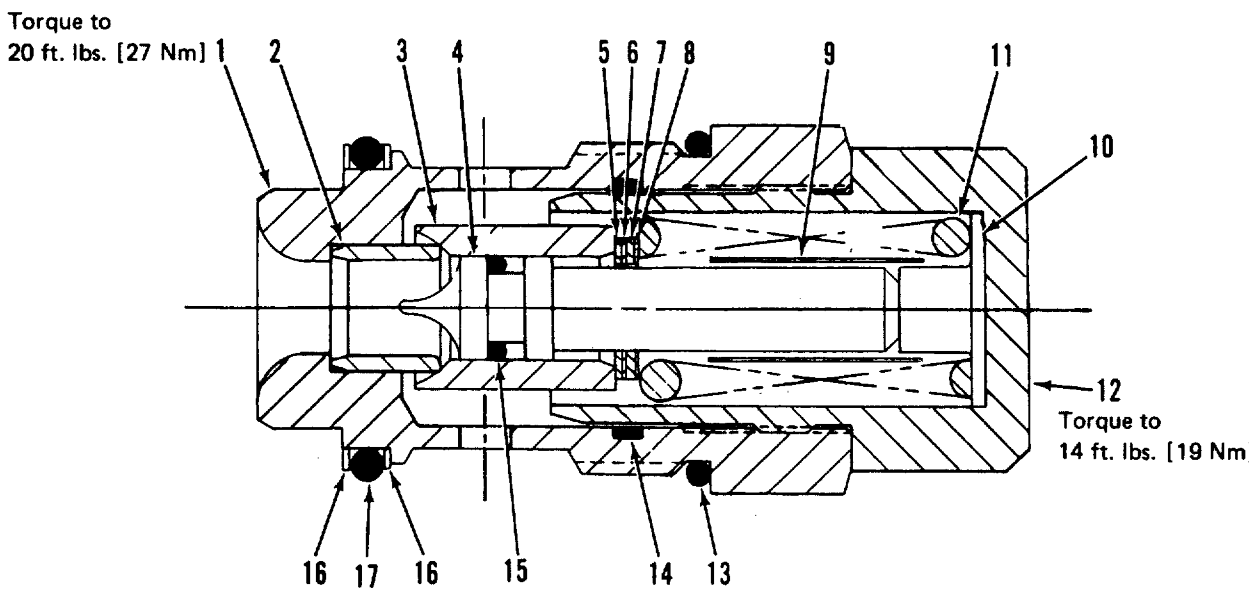


FIG. 27. MODEL RDSON MAIN RELIEF VALVE (NON-ADJUSTABLE)

MODEL RD50N MAIN RELIEF VALVE (Non-Adjustable Type)

Item No.	Part No.	Description	Quantity Per Plug Assembly
	K-6126-A*	SEAL KIT (Contains items 13 thru 17)	
1	8114-001	BODY, Relief	1
2	8036-001	SEAT	1
3	8115-001	POPPET	1
4	8041-001	GUIDE, Poppet	1
5	0462-001	SHIM (.010 inch [0,25 mm] thick)	A/R
6	0459-001	SHIM (.020 inch [0,5 mm] thick)	AIR
7	0458-001	SHIM (.040 inch [1,0 mm] thick)	A/R
8	8430-001	SHIM (.005 inch [0,13 mm] thick)	AIR
9	7874-001	SLEEVE, Spring Dampening	1
10	1870-001	SPRING, (Standard, S.S., 1001-2500 PSI [70-172 bar] Crack)	1
11	8436-001	SPACER, Poppet Guide	1
12	8437-001	CAP	1
13	1615-001*	SEAL, O-Ring	1
14	6814-001*	SEAL, O-Ring Not Sold	1
15	8769-001	SEAL, Teflon Separately	1
16	6530-001	RING, Back-Up Order K-6126-A	2
17	1718-001	SEAL, O-Ring ,	1

*Buna-N seals are standard for all Gresen valve assemblies. Optional Viton seals are available. See Cross Reference Tables on page 49.

Standard Buna-N Seals and O-Rings

All standard Gresen products utilize Buna-N seals which are compatible with petroleum base, water-in-oil emulsions, and water-glycol fluids. Phosphate ester type fire-resistant fluids will cause Buna-N seals to swell. This swelling is not normally detrimental to static seals, but will be a problem for dynamic seals such as valve spool seals. Swelling of these seals can result in binding spools. The temperature range of Buna-N seals is -40°F to + 225°F [-40°C to 107°C].

Table 1. Cross Reference For Seals and O-Ring, Buna-N to Viton

Buna-N Part No.	Viton Part No.	Application
1129-001	None	
1615-001	7447-001	Section Seal, Exhaust
1718-001	7446001	WC Relief, NR Plug
1721-001	7612-001	Power Beyond Sleeve, Inner
1800-001	None	
1818-001	7444-001	Inner Check Plug Seal
1819-001	7445-001	Outer Check Plug Seal
1853-001	7613-001	Quad Seal, Float
2706-001	None	
2707-001	7448-001	Check Plug Seal
2709-001	6277-001	Power Beyond Sleeve, Outer
6806-001	None	
6814-001	7450-001	Section Seal, Pressure
6815-001	7451-001	Section Seal, Exhaust
7700-001	7449-001	Spool Seal
7749-001	7614-001	Spool Seal, Float

Optional Viton Seals and O-Rings

Viton seals are recommended for most applications that use phosphate-ester type fluids. Viton seals will not swell when in contact with phosphate-ester type fluids. The temperature range for Viton seals is -20°F to +400°F [-29°C to +250°C] in dynamic applications and -40°F to +400°F [-40° to +250°C] in static applications. Viton seals are available for Gresen Models CP and CT valves.

Table 2. Cross Reference For Seal Kits, Buna-N to Viton

Buna-N Kit No.	Viton Kit No.	Application
K-6001-A	None	
K-6002-A	None	
K-6005-A	K-6041	RC Relief
K-6006-C	K-6042	WC Relief
K-6017-A	K-6053-A	Power Beyond (1/2 NPTF)
K-6018-A	K-6054-A	Power Beyond (SAE 8)
K-6019-A	K-6055-A	Power Beyond (SAE 10)
K-6021	K-6043	Anti-Cavitation Check
K-6027-A	K-6046	Section Seal, 3-Way, 4-Way
K-6028-B	K-6049	Section Seal, Float
K-6030-A	K-6047	Check Plug
K-6032	K-6041	Load Check, Anti-Cav. Check, RC Relief
K-6034-C	None	
K-6035-A	K-6048	Spool Seal
K-6039	None	
K-6040-C	None	

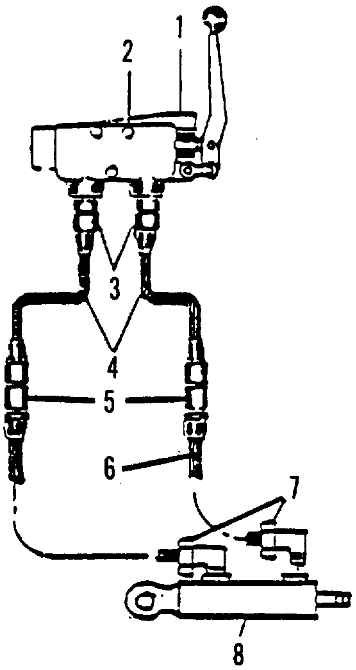


FIG. 28. HYDRAULIC LINES - VALVE TO SPRAY BAR

Item No.	Part No.	Description	Quantity Per Plug Assembly
1	*102-6301-1	VALVE (See Sep. Illus.)	1
2	298-163-47	STUD SET FOR VALVE	3
3	298-8037-86	HALF UNION (Eastman 648F)	2
4	502-2086-81	TUBE	2
5	298-8046-86	COUPLING (Eastman 646F)	2
6	102-2700-9	HYDRAULIC HOSE	2
7	298-2056-62	UNION 90° ADAPTER	2
8	102-7818-1	HYDRAULIC CYLINDER SPRAY BAR (See Sep. Illus.)	1

*See Hydraulic Control Valve - Rotor and Tailboard Illustration.

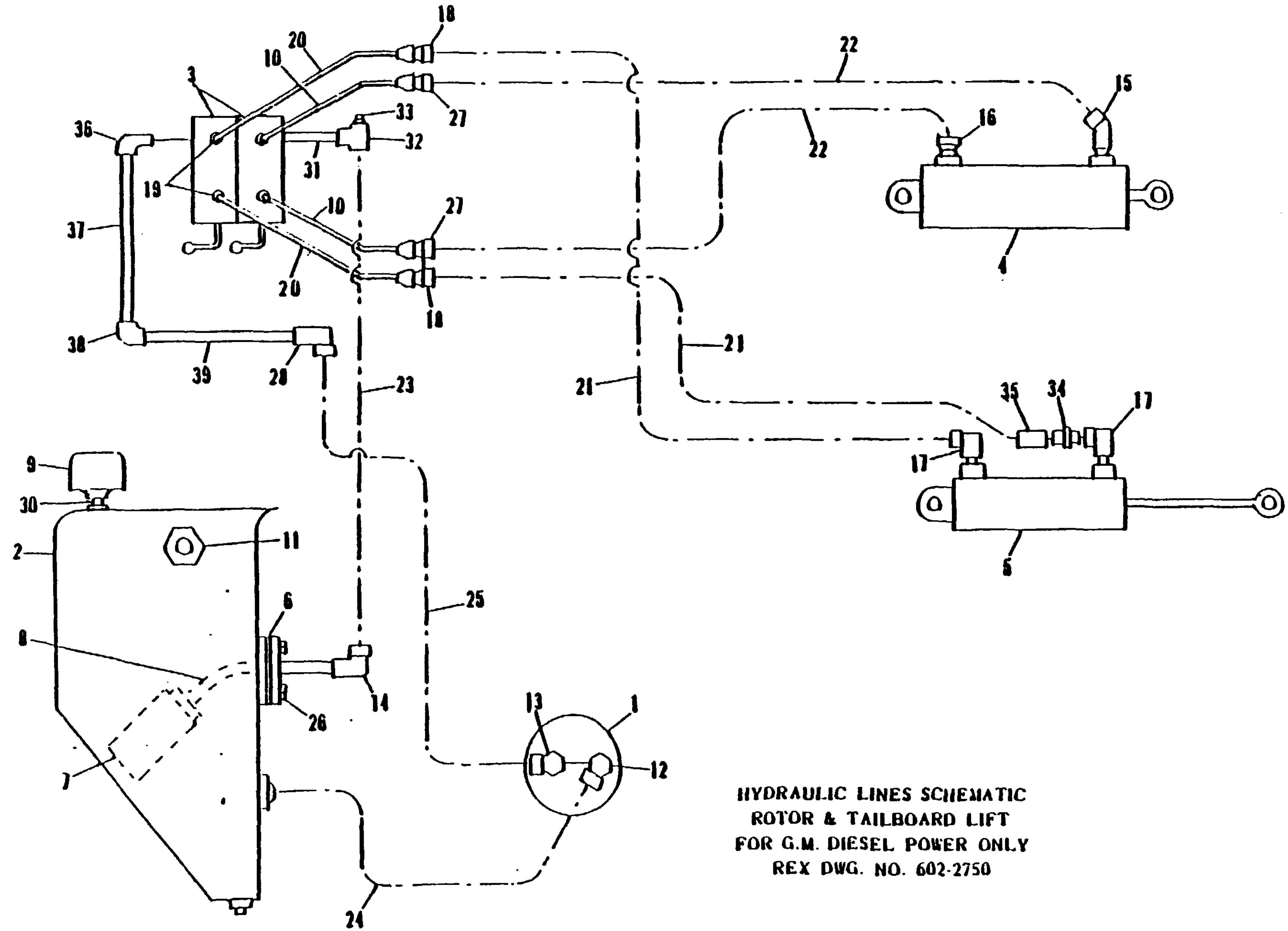
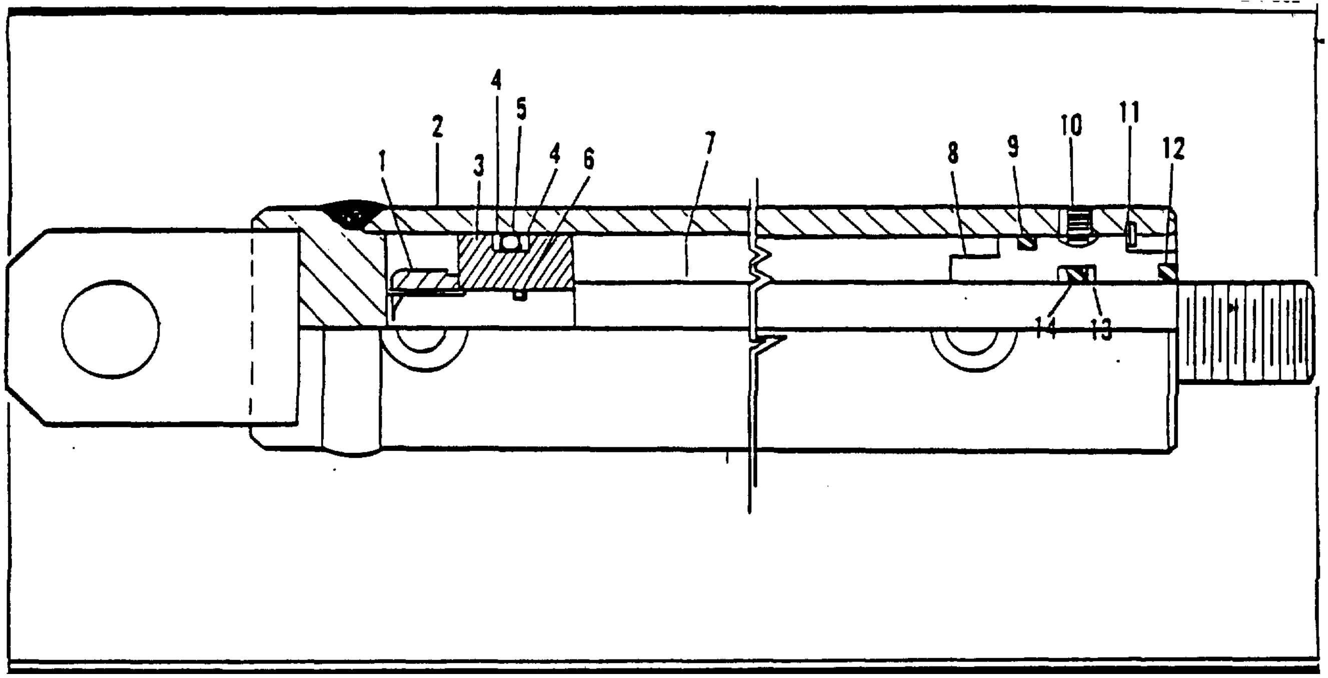


FIG. 29. HYDRAULIC LINES SCHEMATIC FOR ROTOR AND TAILBOARD

HYDRAULIC LINES SCHEMATIC
ROTOR & TAILBOARD LIFT
FOR G.M. DIESEL POWER ONLY
REX DWG. NO. 602-2750
SELF-PROPELLED PULVI MIXERS

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
	298-49-53	Hyd. Pump-Rotor & Tailboard Lift		18	298-9041-86	Coupling ½" Tube - ¼" N.P.T.	2
		(see Separate Illustration)	1	19	298-8037-86	Half Union ½ " Tube - ½" N.P.T.	4
1	402-1599-2	Adapter-Hyd. Pump	1	20	502-2086-81	Tube	2
	— — — —	Nut 3/8" w/L.W.	2	21	102-2834-3	Hose ¼" - 17' lg.	2
	298-2072-62	Union 45° Adapter	1	22	102-2700-5	Hose 3/8" - 12' - 2" lg.	2
	298-2067-62	Union 90° Adapter	1	23	102-2758-5	Hose ¼" - 13" lg.	1
2	502-6009-80	Oil Reservoir	1	24	102-2758-6	Hose ¾" - 16" lg.	1
3	102-6208-1	Hydraulic Valve-Tailboard Lift &		25	102-2760-5	Hose ½" - 30" lg.	1
		Rotor Lift (See Separate Illustration)	1	26	298-23-93	Self Lock, Cap Screw	6
4	102-4283-1	Hyd. Cyl. Rotor Lift (See Sep. Illus.)	1	27	298-8046-86	Coupling ½" Tube - 3/8" N.P.T.	2
5	102-2786-1	Hyd. Cyl Tailboard (See Sep. Illus.)	1	28	298-2230-62	Adapter	1
6	102-6203-1	Gasket	1	29	102-7970-1	Hyd. Valve - Rotor Lift	
7	298-70-53	Strainer	1			(See Separate Illustration)	1
8	502-3867-80	Flange	1	30	— — — —	Close Nipple ¼" N.P.T.	1
9	X7258	Breather	1	31	— — — —	Nipple ¼" X 5" T.B.E.	1
10	502-2086-80	Tube	2	32	398-14005-33	Pipe Tea ¼" N.P.T.	1
11	298-13014-86	Sight Gauge	1	33	398-14006-64	Pipe Plug Socket Hd. ¼" Countersunk	1
12	298-2072-62	Adapter ¼" X ¼" - 45°	1	34	298-2174-62	Straight Fitting	1
13	298-2067-62	Adapter ¼" X ½" - 90°	1	35	298-101-53	Needle Valve	1
14	298-2103-62	Adapter 1" X ¼" - 90°	1	36	— — — —	Street Ell ¼" N.P.T. - 90°	1
15	298-2069-62	Adapter 3/8" X 3/8" - 45°	1	37	398-95002-42	Nipple ¼" X 4" T.B.E.	1
16	298-2064-62	Adapter 3/8" X 3/8" Straight	1	38	— — — —	Elbow ¼" N.P.T - 90°	1
17	298-2095-62	Adapter 9/16 - 18, "O" Ring ¼" - 90°	2	39	— — — —	Nipple ¼" X 12" T.B.E.	1

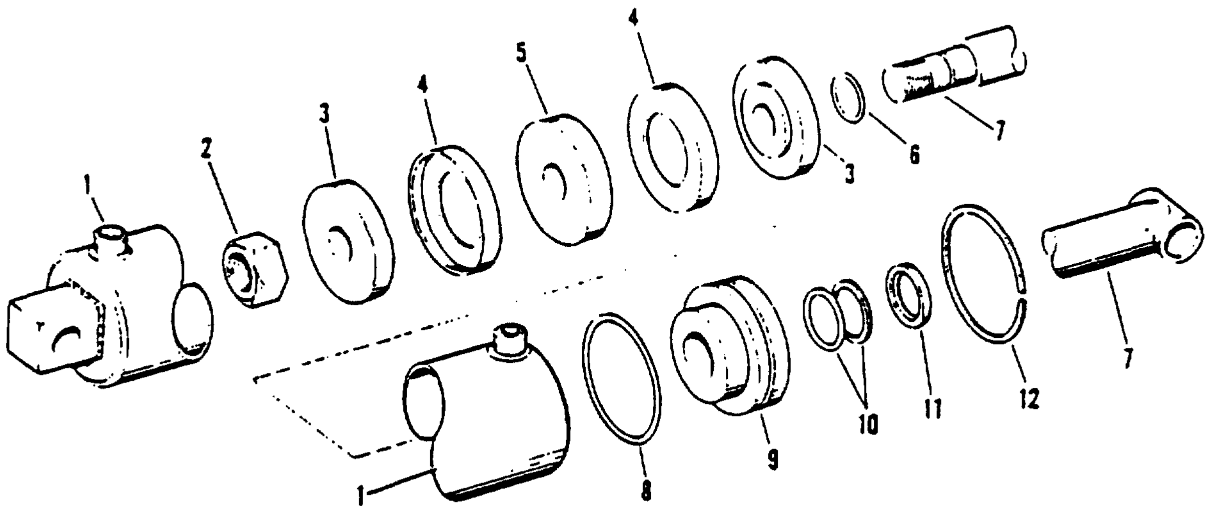


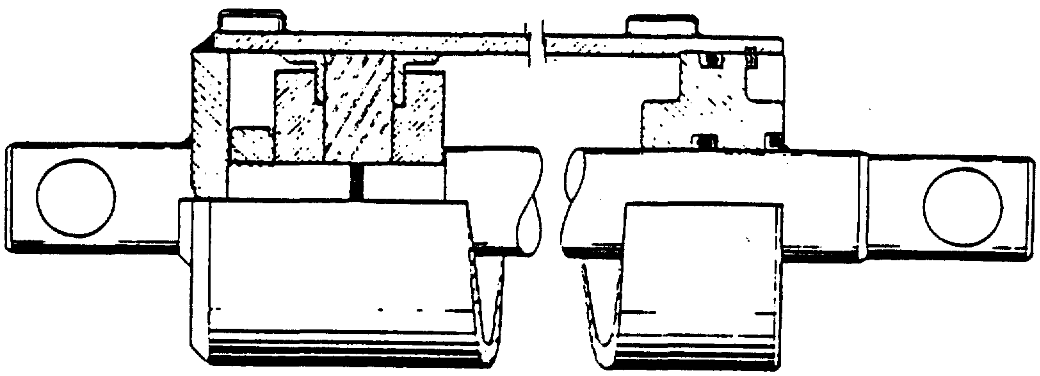
**HYDRAULIC CYLINDER WITH FABRICATED CLEVIS
USED AS A SUBSTITUTE WHEN CROSS MFG. CO.
CYLINDER WITH CAST CLEVIS IS NOT AVAILABLE
T. J. BROOKS CO. 1-1/2" x 5" STROKE
REX PART NO. 102-9751-1
USED ON HDS-E SPRAY BAR AND 5TH WHEEL**

Item No.	Part No.	Description	No. Req'd
1	102-9751-20	Nut (DH- 9)	1
2	102-9751-23	Cylinder (IDHA 1-113)	1
3	102-9751-22	Piston (*DH4-75)	1
4	102-9751-21	Back Up (*S17-23)	2
5	102-9751-16	“O” Ring (*S7-23)	1
6	102-9751-19	“O” Ring (*S7-9)	1
7	102-9751-18	Rod (DH2-107)	1
8	102-9751-17	Gland (*DH3-73)	1
9	102-9751-16	“O” Ring (*S7-23)	1
10	102-9751-15	Set Screw (*DH15-9)	1
11	102-9751-14	Ret. Ring (*RRT-150)	1
12	102-9751-13	Wiper (*KH14-17)	1
13	102-9751-12	Back Up (*S17-15)	1
14	102-9751-11	“O” Ring (*S7-15)	1

*T. J. Brooks Company - 2233 W. Mill Road, Milwaukee. Wis. 53209 part numbers

FIG. 30. HYDRAULIC CYLINDER FOR SPRAY BAR AND FIFTH WHEEL

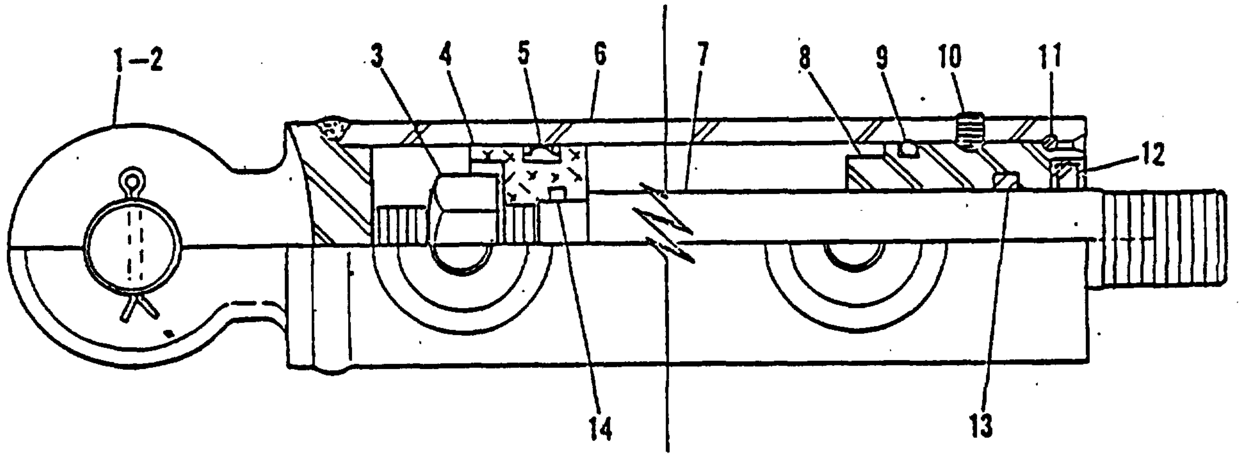




HYDRAULIC CYLINDER (RAM)
"BROOKS 5 x 12"
ROTOR LIFT (HOIST)
REX PART NO. 102-4283-1

Item No.	Part No.	Description	No. Req'd
1	102-4283-1	Rotor Lift Cylinder Complete	1
2	102-4283-13	U.N.F. Jam Nut	1
3	102-4283-6	Pocking Adnpter	2
4	102-4283-7	Fnb. From. P;cking	2
5	102-4283-5	Piston	1
6	102-4283-12	"O" Ring	1
7	102-4283-2	Rod	1
8	102-4283-10	"O" Ring	1
9	102-4283-4	Gland Bushing	1
10	102-4283-8	Rod Packing	1
11	102-4283-9	Dirt Seal	1
12	102-4283-11	Snap Ring	1

FIG. 31. HYDRAULIC CYLINDER RAM FOR ROTOR LIFT



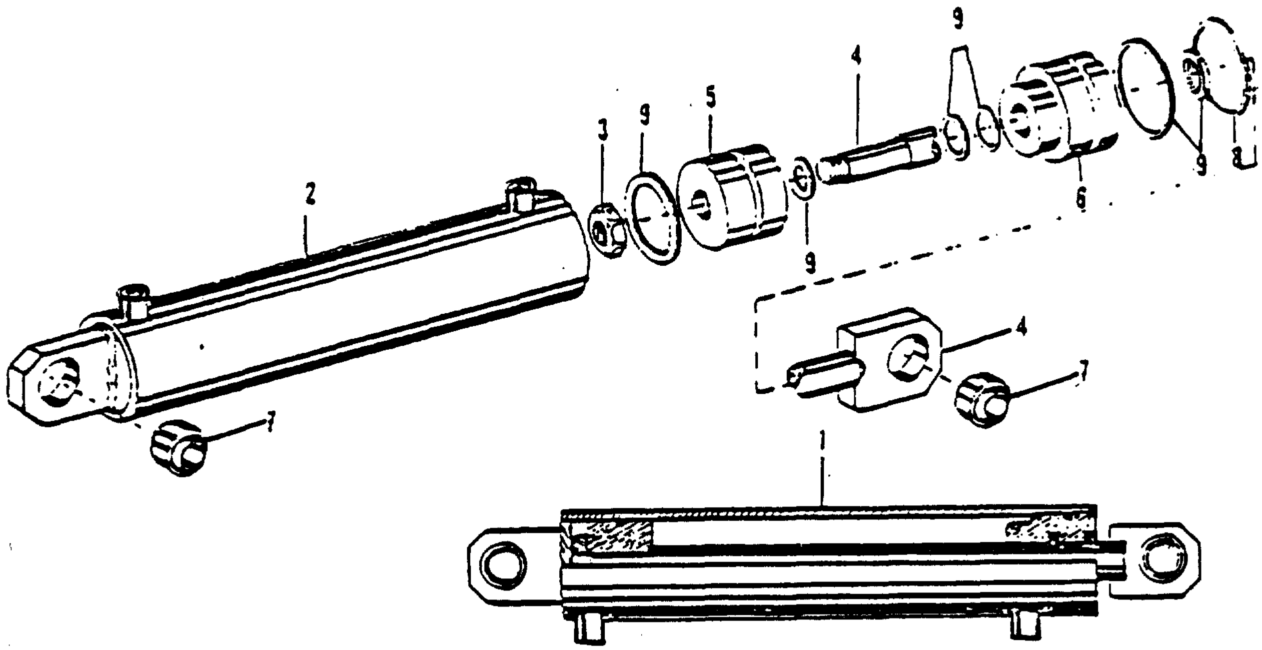
Due to Availability 102-9751-1 Hydraulic Cylinder (with Fabricated Clevis), 502-2051-80 Pin, and Cotter Pin 3/16" X 1 ¼" may be used in place of 102-7818-1 Cylinder (with Cast Clevis), See Separate Illustration.

HYDRAULIC CYLINDER
SPRAY BAR OR TACH. DRIVE WHEEL CONTROL
1-1/2" x 5" DOUBLE ACTING CYLINDER
CROSS MFG. CO. PART NO. 2-15-050-NW-B-C
REX PART NO. 102-7818-1

Item No.	Part No.	Description	No. Req'd
1	102-7818.10	Cotter Pin (*1A0283)	2
2	102-7818-11	Clevis Pin (*1C2258)	1
3	102-7818-12	Nut (*1A0194)	1
4	102-7818-13	Piston (*1C1542)	1
5	**102-7818-14	Sel - "T" Ring (*1A0340)	1
6	102-7814-15	Tube Assembly (*1C7892)	1
7	102-7814-16	Rod -1/4 " Dio. (*1C3066)	1
8	102-7814-17	Hed (* 1C1544)	1
9	**102-7814-18	"O" Ring (*1A0020)	1
10	102-7814-19	Set Screw (*lAO190)	1
11	102-7814-20	Wire Retaining Ring (*1A0196)	1
12	**102-7814-21	Seal - Wiper - Lip Type (*1A0197)	1
13	**102-7814-22	Seal - "T" Ring (*1A0316)	1
14	**102-7814-23	"O" Ring (*1A0108)	1
—	102-7814-24	Seal Kit Consists of Ports 5, 9, 12, 13 & 14 (Marked **)	1

*Cross Manufacturing Co., Inc., P.O. Box 67, Lewis, Kansas part numbers.

FIG. 32. HYDRAULIC CYLINDER FOR SPRAY BAR AND FIFTH WHEEL



HYDRAULIC CYLINDER
FOR TAILBOARD AND 4" ASPHALT VALVE
2-1/2" BORE x 9-1/2" STROKE
COLUMBUS PART NO. B-507
REX PART NO. 102-2786-1

Item No.	Part No.	Description	No. Req'd
1	102-2786-1	Hydraulic Cylinder Complete (*B-507)	1
2	102-2786-2	Cylinder Barrel (*B-507-1)	1
3	102-2786-3	Hex Nut (*B8-507-2)	1
4	102-2786-4	Shaft (*B-507-3)	1
5	102-2786-5	Piston (*B-507-4)	1
6	102-2786-6	Cylinder Head (*B-507-5)	1
7	102-2786-7	Bearing (RSC *B12.9L) (*B-507-6)	2
8	102-2786-8	Snap Ring (*B-507-7)	1
9	102-2786-9	Service Kit (Shaft seals) Consisting of: 2 - "O" Ring (*B-507-8A) 1 - "O" Ring (*B-507-8B) 1 - Dust Seal (*B-507-8C) 1 - "O" Ring (*B-507-8D) 1 - Leather Ring (*B-507-8E)	1

* Columbus Hydraulics Inc. part numbers.

FIG. 33. HYDRAULIC CYLINDER FOR TAILBOARD

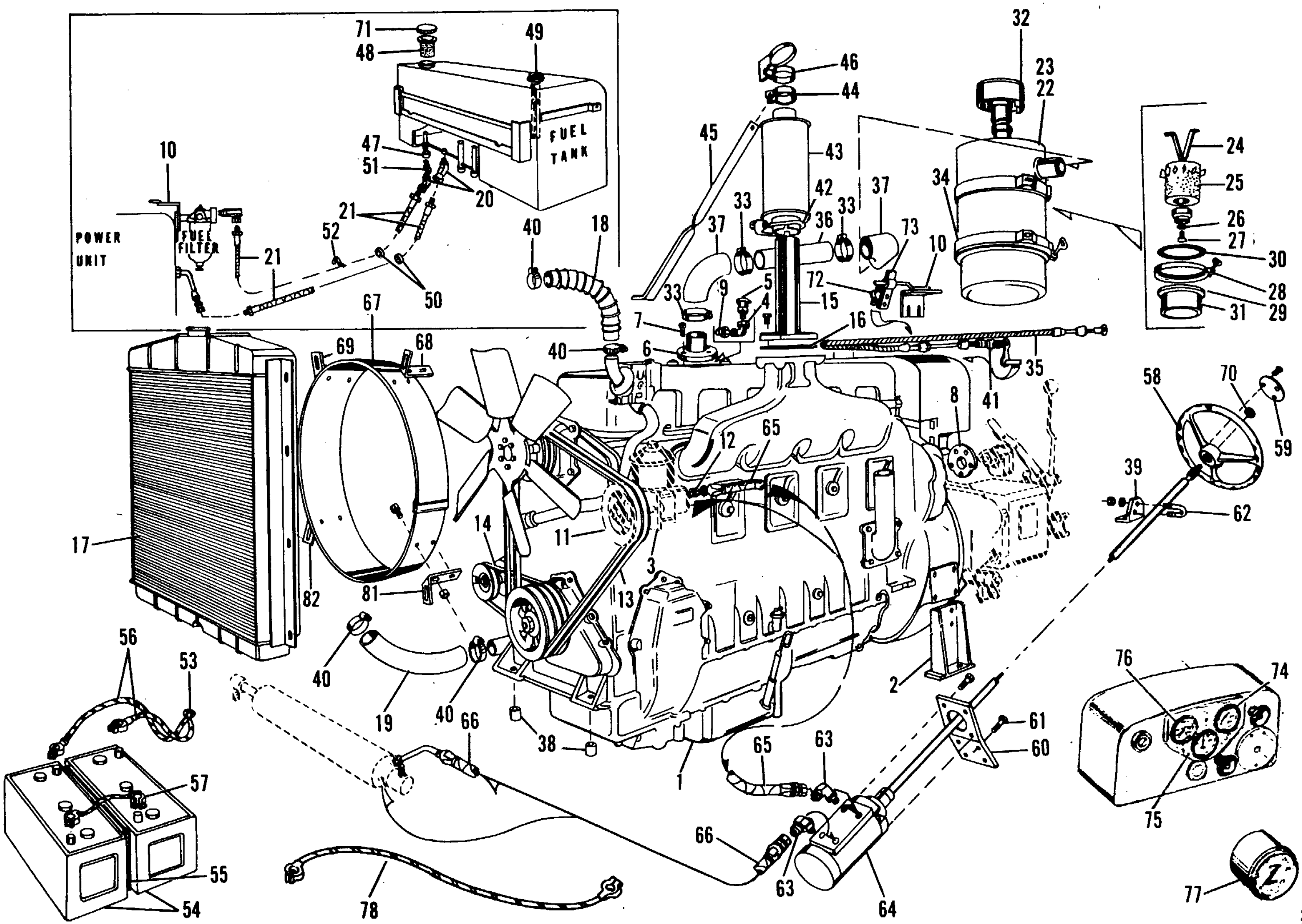


FIG. 34. GENERAL MOTORS DIESEL POWER UNIT

GENERAL MOTORS DIESEL POWER UNIT - CONTINUED

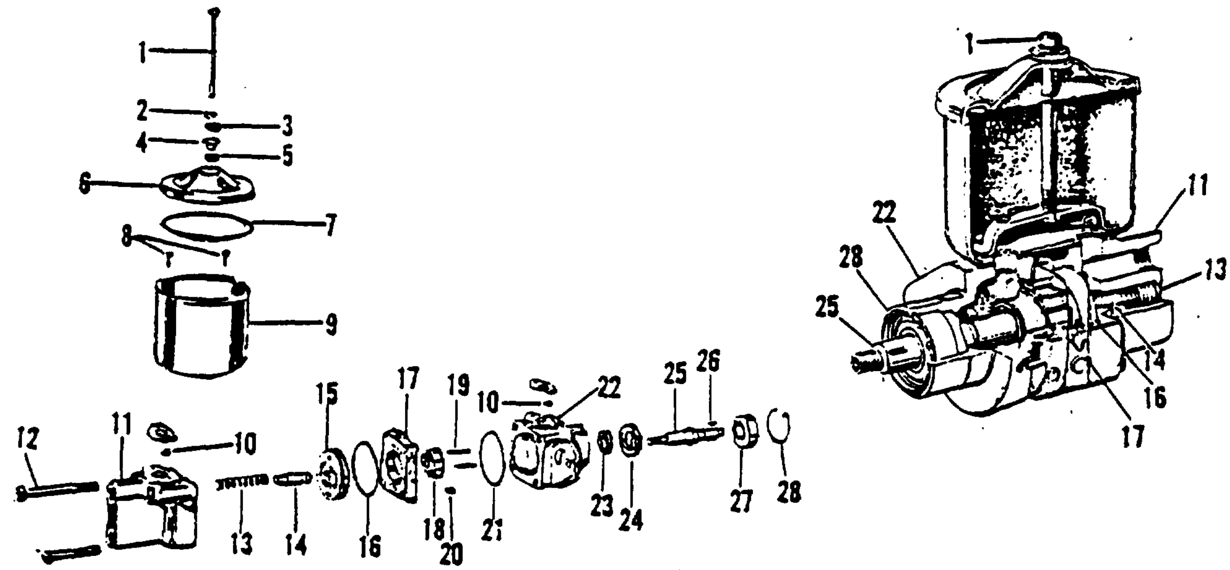
Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
13	298-7078-91	Fan Belts - .5 x 68 Long - Set of		40	298-9027-86	Hose Clamp	4
		Two Belts (G.M. #5136266)	1		X202821	Ball Joint 1/4"	1
14	— — — —	Alternator Belt (G.M. #5133515)	1	41	398-11000-37	Hex Nut 1/4" U.N.F.	1
15	502-1737-80	Exhaust Pipe	1		398-20000-36	Lock Washer 1/4"	1
16	298-5015-92	Gasket - Exhaust Pipe	1	42	298-91-47	Clamp	1
17	102-5128-1	Radiator	1	43	298-5016-92	Muffler	1
18	298-5617-68	Upper Radiator Hose	1	44	102-1434-1	Clamp	1
19	102-3127-1	Lower Radiator Hose	1	45	102-1438-1	Brace	1
20	298-2069-62	Union - 450 Adapter 3/8" NPT		46	298-5014-92	Cap	1
		Male x 3/8" NPT Female		47	398-1400049	Pipe Coupling 3/8"	1
		(Anchor #6MAX-6UFS)	2	48	298-5010-92	Strainer	1
21	102-2759-2	Fuel Line Hose - Suction &		49	102-9217-1	Fuel Gauge	1
		Return Line (48" lg.)	2	50	298-5526-68	Grommet - Fuel Lines	6
22	298-5144-92	Air Cleaner Assembly -		51	298-25-98	Brine Cock	1
		(Donaldson #FWA14-0002)		52	298-36-47	Pipe Clamp 3/4" I.D.	2
		Consists of Items 32 thru 40			298-5525-68	Grommet	1
		Assembled	1	53	398-99004-15	Hose 1-1/4 x 3 Ply x 18" lg. -	
23	102-8210-1	Body (Donaldson P10-3832)	1			(Battery Cable Protector)	1
24	102-8210-2	Yoke (Donaldson P10-3792)	1	54	298-3251-17	Battery - 6 Volt (Exide - T4.	
25	102-8210-3	Element (Donaldson P10-1241)	1			ESB Part No. 4911)	
26	102-8210-4	Gasket Washer (Donaldson P18462)	1		102-1429-1	Spacer - (Wood)	4
27	102-8210-5	Thumb Screw (Donaldson P16984)	1	55	102-1439-1	Spacer (Wood)	1
28	102-8210-6	Clamp (Donaldson P-10-866)	1	56	102-7893-1	Battery Cable	2
29	102-8210-7	Baffle (Donaldson P10-1241)	1	57	102-1544-1	Cable - Battery	1
30	102-8210-9	Cup Gasket (Donaldson P17-335)	1	58	298-68-47	Steering Wheel	1
31	102-8210-8	Cup (Donaldson P10-1242)	1	59	298-69-47	Cap - Steering Wheel	1
32	298-5146-92	Hood - Air Cleaner	1	60	102-3846-1	Bracket - Steering Column Valve	1
33	298-9026-86	Hose Clamp	4		398-2001-76	Cap screw 3/8 x 1"	6
34	298-5170-92	Mounting Band	2	61	398-20000-37	Lock Washer 3/8"	8
35	298-155-47	Push Pull Cable - Throttle			398-20000-23	Cut Washer 3/8"	8
		(Morse 43C x 5 ft. Long)	1		298-1012-4	"U" Bolt	1
36	102-3557-2	Tube - (Air Cleaner)	1	62	398-11000-19	Hex Nut 3/8"	2
37	298-5092-92	Elbow - 900 (Air Cleaner)	2		398-20000-37	Lock Washer 3/8"	2
38	102-1472-1	Spacer	2	63	298-6516-86	Fitting - 900 Elbow "O" Ring Seal	
39	102-6201-1	Bracket	1			(Eastman #F28-6 x 6)	4

GENERAL MOTORS DIESEL POWER UNIT - CONTINUED

Item No.	Part Number	Description	No. Req'd
1	102-9612-1	Engine - Diesel - General Motors Corps Series 4-71 Model 1043-7100 Complete with the Following Features:	
		Type 486 Flywheel Housing S.A.E. #2 Str. Right Side	
		Type 24 Oil Pump - Right Hand Mount	
		Type 394 Oil Filter - Full Flow	
		Type 1101 Fan - 22" Section - 6 Blade	
		Type 15 Water By-pass Tube	
		Type 85 Governor - Variable - & Open Linkage	
		Type 2053, AC Alternator - 12 Volt 42 Amp - Clockwise Insulation	
		Type 45 Wire Harness	
		Type 108 Oil Distributing System	
		Type 1 Oil Lines	
		Type 347 Crankshaft Pulley - 3 Groove, 7.5" (6K1A-381)	
		Type 97 Injector - Size N65	
		Type 3 and 35 Engine Mounting - Foot (6Q-445)	
		Type 16 Starter - 12 Volt Insul.	
		Type 563 Tachrometer Drive Gear, R.H. Accessory Drive	
		Flywheel 6C3-978 Assembly No. 5121592	
		Type 373 Dip Stick	
		Type 601 Ventilating System	
		Type NT Shutdown Control - 50" lg. - Manual	
		Type 202 Air Inlet Housing - Right Side	
		Type 172 Hydraulic Pump Drive for Hydreco #1512C12C1 Gear, Left Hand Accessory Drive	
1 (Cont'd.)		Type 21 Oil Pan - 30° Pan - Center Pump	
		Type 887 Oil Cooler - 8 Plate Core Assy -	
		Type 10 Crankshaft Cover	
		Type 48 Straight Water Connection	
		Type 46 Throttle Control - Open Linkage	
		Type 318 Rocker Cover	
		Type 912 Instruments - Ammeter - Oil Pressure, Water Temperature - Tachometer	
		Type 15 Vibration Damper - (6C2-127) (Added)	
		Note Type 241 Adapter Flange for Exhaust Pipe Not Used	
	502-4143-80	Rear Support for Engine	2
	398-2002-21	Cap Screw 1/2 x 1-1/2"	4
2	398-20000-39	Lock Washer 1/2"	4
	398-11000-27	Hex Nut 1/2"	4
3	102-30382-1	Pump Mount Bracket (Power Steer)	1
4	398-14001-28	Street Elbow 1/8 x 900	1
5	298-9247	Ether Cup	1
6	402-1598-2	Air Inlet Flange	1
	398-2001-60	Cap Screw 5/16 x 1"	4
7	398-20000-64	Lock Washer 5/16"	4
	402-1599-2	Adapter - Hydraulic Pump	1
8	398-11000-39	Hex Nut 3/8"	2
	398-20000-37	Lock Washer 3/8"	2
9	398-14000-1	Reducing Bushing 1/4 x 1/8"	1
10	502-3869-80	Bracket - Throttle Cable	1
11	102-30371-1	Driven Sheave	1
	298-2083-62	Adapter Union "O" Ring - 3/4 - 16 S.A.E. Male to 3/8" FPT	
12		(Anchor #8BC - 6UFS)	2
	298-3515-68	"O" Ring (Anchor #M383-8)	2

GENERAL MOTORS DIESEL POWER UNIT - CONTINUED

Item No.	Part Number	Description	No. Req'd
64	102-8403-1	Steering Valve Unit (Separate Parts List for Valve not Included in this Parts Book - Repair of this Unit is not Recommended by Manufacturer) (Ross Gear Division) No. HGA500-594, Item No. HGA08 - Gerotor Width .500" Displacement 5.9 cu. in./Rev., Steering Column Length 29"	1
65	502-8015-80	Hose Assembly - Medium Pressure - 34" Long	2
66	502-8016-80	Hose Assembly - Medium Pressure - 69" Long	2
67	102-2943-1	Fan Shroud	1
68	502-2041-80	Clip - Fan Shroud	2
69	502-2041-81	Clip - Fan Shroud	2
70	102-1520-10	Wheel Nut (Ross No. 026045)	1
71	298-34-47	Filler Cap - Style No. 3 - Stolper #2302J026	1
72	298-15847	Cable Clamp	I
73	298-157-47	Bracket - Cable Clamp	1
74	102-6753-17	Engine Oil Pressure Gauge (GM1508352)	1
75	102-9612-10	Water Temperature Gauge (GM1513549)	1
76	102-6753-16	Ammeter (GM1501170)	1
77	102-9612-11	Tachrometer & Hour Meter (GM1536865)	1
78	102-30345-5	Battery Cable 72"	1

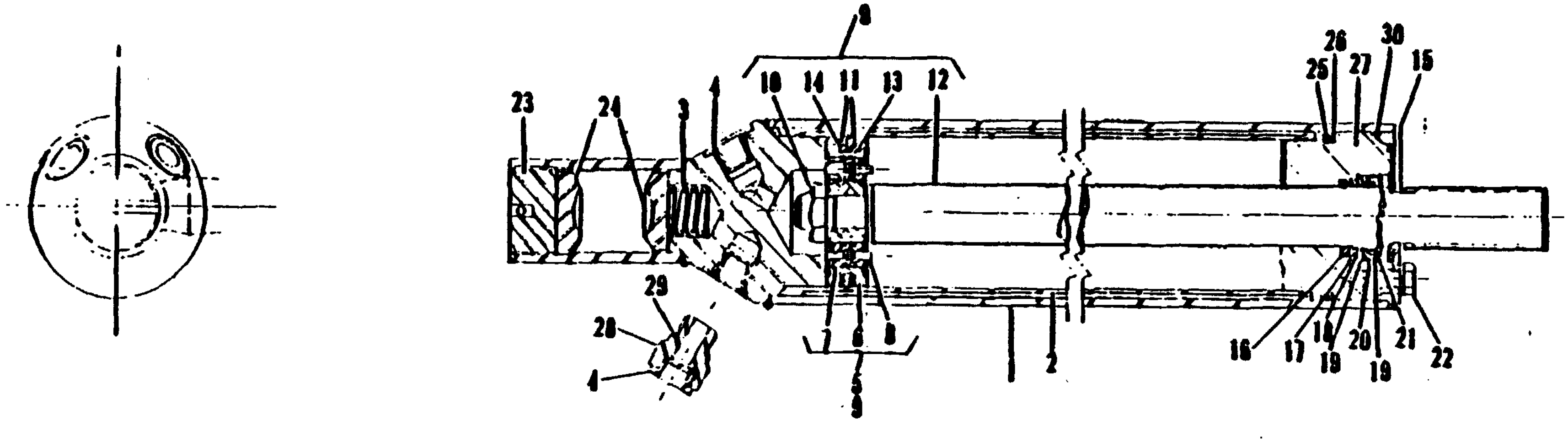


POWER STEERING PUMP
VICXERS INC. PART NO. VT-16-100-40-95-40-10
REX PART NO. 298-47-53

Item No.	Part No.	Description	No. Req'd
1	102-8518-10	Screw (Reservoir Tank Cover) (*146835)	1
2	102-8518-11	Lock Washer (For Tank Cover Screw) (*99784)	1
3	102-8518-12	Washer (for Tank Cover Screw) (*43321)	1
4	102-8518-13	Guide (for Tank Cover Screw) (*143119)	1
5	102-8518-14	Gasket (For Guide) (*144569)	1
6	102-8518-15	Cover (For Reservoir Tank) (*146241)	1
7	102-8518-16	Gasket (For Reservoir Cover) (*142521)	1
8	102-8518-17	Screws (Tank to Body) (*161314)	2
9	102-8518-18	Reservoir Tank (*142526)	1
10	102-8518-19	Spacer (Tank to Body) (*161288)	2
11	102-8518-20	Cover (Valve Body) (*151016)	2
12	102-8518-21	Screws (Cover to Valve Body)(*146333)	2
13	102-8518-22	Spring (For Control Valve) (*155086)	1
14	102-8518-23	Control Valve Sub-Assembly (*157137)	1
15	102-8518-24	Pressure Plate (*155109)	1
16	102-8518-25	"O" Ring (Pressure Plate to Ring) (**143216)	1
17	102-8518-26	Ring (**141395)	1
18	102-8518-27	Rotor (**141393)	1
19	102.8518-28	Pins (*156841)	-
20	102-8518-29	Vanes for Rotor (**912008)	12
21	102-8518-25	"O" Ring (**143216)	1
22	102-8518-31	Pump Body (*154770)	1
23	102-8518.32	Small Bearing for Rotor Shaft (*1701)	1
24	102-8518.33	Oil Seal (Rotor Shaft) (*161170)	1
25	1028518.34	Rotor Shaft (*166506)	1
26	102.8518.35	Woodruff Key (*1602)	1
27	102-8518.36	Large Bearing for Rotor Shaft(*154787)	1
28	102-851837	Snap Ring (*153918)	

* Vickers Incorporated, Mobile Hydraulics Division, Detroit, Michigan 48084 part numbers.

FIG. 35. POWER STEERING PUMP



POWER STEERING CYLINDER ASSEMBLY
ROSS GEAR DIVISION PART NO. C36531-A4-650
REX PART NO. 102-8404-1

FIG. 36. POWER STEERING CYLINDER

POWER STEERING CYLINDER ASSEMBLY
ROSS GEAR DIVISION PART NO. C36531-A4-50
REX PART NO. 102-8404-1

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	102-8404-10	Head, Socket & Tube Assembly		16	102-1948-39	"O" Ring (*032200-17)	1
		(*C363833-A6)	1	17	102-1948-40	Back Up Ring (*032249)	1
2	102-8404-11	Inner Cylinder Tube (*098502 -		18	102-1948-53	Retaining Ring (*028272)	1
		Specify required length on order)	1	19	102-1948-54	Retaining Ring (*028271)	2
3	102-8404-12	Spring (*401212)	1	20	102-1948-41	Oil Seal (*032205)	1
4	— — — —	Shipping Plug (*036098)	2	21	102-1948-55	Retaining Ring (*401233)	1
5	102-1631-73	Piston Assembly - Consisting of		22	102-8404-13	Hex Head Cop Screw 4-20 x 5/8"	
		items 6 thru 8 (*C364004-A1)				w/Lock Washer (*G9409107)	3
6	102-1631-50	Piston (*C364004)	1	23	102-8404-14	Ball Seat Lock ('403652)	1
7	102-1631-51	Poppet Seat ('415344)	4	24	102-8404-15	Ball Seat (*403651)	2
8	102-1631-52	Poppet (*040067)	2	25	102-1948-42	"'0" Ring ('032201-6)	1
9	102-1948-51	Piston and Red Assembly - Consisting		26	102-1948-43	Beck Up Ring (*032272)	1
		of Item 5 and Items 10 thru 14)		27	102-1631-46	Gland (*C365508)	1
		(*C364004-A2)	1	28	102-1631-68	Adopter Assembly - Includes Item 29	
10	102-1631-47	Hex Nut ½-20 (*G941592)	1			(*415371A1)	2
11	102-1631-48	Piston Ring ('C366002)	2	29	102-1948-44	"0" Ring (*032229)	2
12	102-1631-49	Piston Rod (*C334101-1118)	1	30	102-1948-56	Retaining Ring (*401264)	1
13	102-1948-37	Seal (*032503)	1				
14		Seal Ring (*033145)				* Ross Gear & Tool Co. part numbers.	
15	102-1631-57	End Plate (402230)	1				

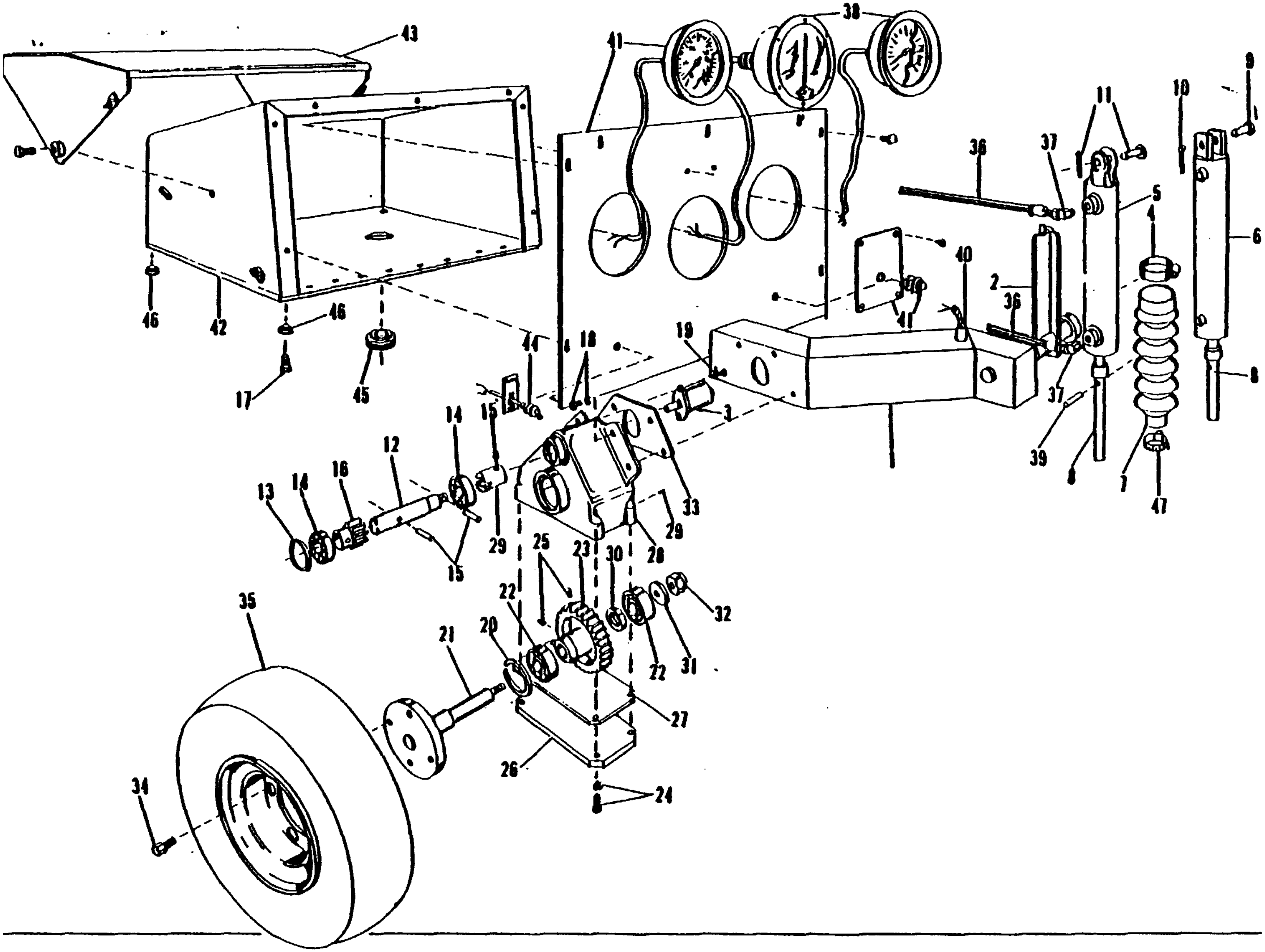


FIG. 37. FIFTH WHEEL - TACH DRIVE
3-64-64

FIFTH WHEEL -- GEARCASE - GENERATOR
VISUAL PERFORMANCE INDICATOR

Item No.	Part Number	Description	No. Req'd
1	502-4587-80	Axle Bracket Arm	1
2	502-4586-80	Support-Tachrometer Wheel	1
3	102-8533-1	Generator-Tachrometer- 6 Volt at 1000 RPM-(Static Torque ½ to 1 inch oz.) Amperage (Maximum 8.6 M.A. At 120 RPM with 50 Ohms-1.6 M.A. at 1200 RPM with 5000 Ohms-) Normal Operating Temperature +40°F. to +110°F-Impedance Approx. 40 Ohms-Bearings, Oil Impregnated Self Aligning Bronze 7 Bar Commutator	1
4	298-9005-86	Hose Clamp- (Wittek No. 28H) 1 5/16" to 2 ¼"	1
5	102-7818-1	Hydraulic Cylinder (with Cast Clevis-Alternate to Item 6) Double Acting, 1 ½" Dia.- 5" Stroke- ¾" Diameter Rod Clevis Mounted Head End with 49/64" Diameter Hole-Rod End Threaded ¾ - 16 UNF-2A (Without Clevis) ¼" N.P.T.F. Ports to be in lane with Clevis Pin Hole (Cross No. 2-15-050-NW-B-C)- See Separate Illustration	
6	102-9751-1	Hydraulic Cylinder (with Fabricated Clevis-Alternate to Item 5) 5" Stroke - 11 5/16" Retracted, 16 5/16" Retracted, 16 5/16" Extended- (T.J. Brooks)-See Separate Illustration	1
7	102-7819-1	Boot-Hydraulic Cylinder	1
8	502-2938-80	Rod-Cylinder Extension	1
9	502-2051-80	Pin	1
10	398-3000-22	Cotter Pin 3/16 X 1 ¼"	1

Item No.	Part Number	Description	No. Req'd
11	— — — —	Included in Item No. 5	
12	102-3891-1	Shaft-Tachrometer Drive	
13	298-7520-34	Retaining Ring-Internal- (Truare #N5000-125)	1
14	298-287-2	Bearing (Fafnir #201NPP)	2
15	298-6027-34	Roll Pin 3/8 X 1 ¼"	2
16	102-8536-1	Gear-12 Tooth	1
17	398-2002-21	Cap Screw ½ X 1 ½" with L.W. & Nut	4
18	— — — —	Socket Head Set Screw #10- 32 X ¼"	1
19	398-10000-33	Round Head Machine Screw #6 - 32 X ½" with #6 Lock Washer	2
20	298-7521-34	Retaining Ring Internal (Truare #N5000-206)	1
21	502-2935-80	Axle Shaft	1
22	298-231-2	Bearing (Fafnir #205NPP)	2
23	102-8537-1	Spur Gear-48 Tooth	1
24	398-2001-60	Hex Head Cap Screw 5/16" X 1" with Lock Washer	4
25	398-17000-60	Set Screw ¼ - 20 U.N.C. X ½"	2
26	102-8539-1	Cover	1
27	102-8538-1	Gasket	1
28	402-2614-2	Gear Case	1
29	398-14005-67	Pipe Plug ¼" N.P.T.	1
30	102-8540-1	Spacer	1
31	398-20000-25	Cut Washer ½"	1
32	298-2010-71	Nut - Conelock	1
33	102-8546-1	Gasket	1
34	298-4057-47	Wheel Bolt ¾" Hex - 60° Taper, ½ - 20 UNF - 1 ½" Overall (Geneva #S61)	4
35	102-8534-1	Wheel Assembly - 4.80/4.00 X 8 Two Ply Super Tread Tubeless Tire Mounted on Rim, Less Hub 2 ½" Pilot Dia. (Geneva #DC1650-R)	1

FIFTH WHEEL - GEARCASE - GENERATOR
VISUAL PERFORMANCE INDICATOR
(Continued)

Item No.	Part No.	Description	No. Req'd
36	102-2700-7	Hydraulic Hose - 3/8" I.D. X 25/32" O.D. One Wire Braid Hose, Synthetic Tube and Cover, Oil and Weather Resistant, Working Temperature - 40° to +200° F with 3/8" Male Fittings	2
37	298-2052-62	Union - 90° Adapter- ¼" Male N.P.T. X 3/8" Female N.P.T.	4
38	— — — —	Instruments (See Item 41)	—
39	298-6027-34	Roll Pin 3/8" X 1 ¼"	1
40	298-48-17	Cord Grip	1
41	102-8577-1	V.I.P. Instrument Panel (#602-7288)	1
42	502-6158-81	Console - For Instruments	1
43	502-6159-80	Console Cover	1
44	X202617	Toggle Switch	1
45	298-5525-68	Grommet 1" I.D. - 7/8" Groove Dia. (Goshen #2808)	2
	298-5577-68	(Atlantic India Rubber Works #2764)	2
46	298-5535-68	Cushion Connector - Krenz & Co. Inc. # DA1062	4
47	298-9018-86	Clamp - Boot Cylinder	1

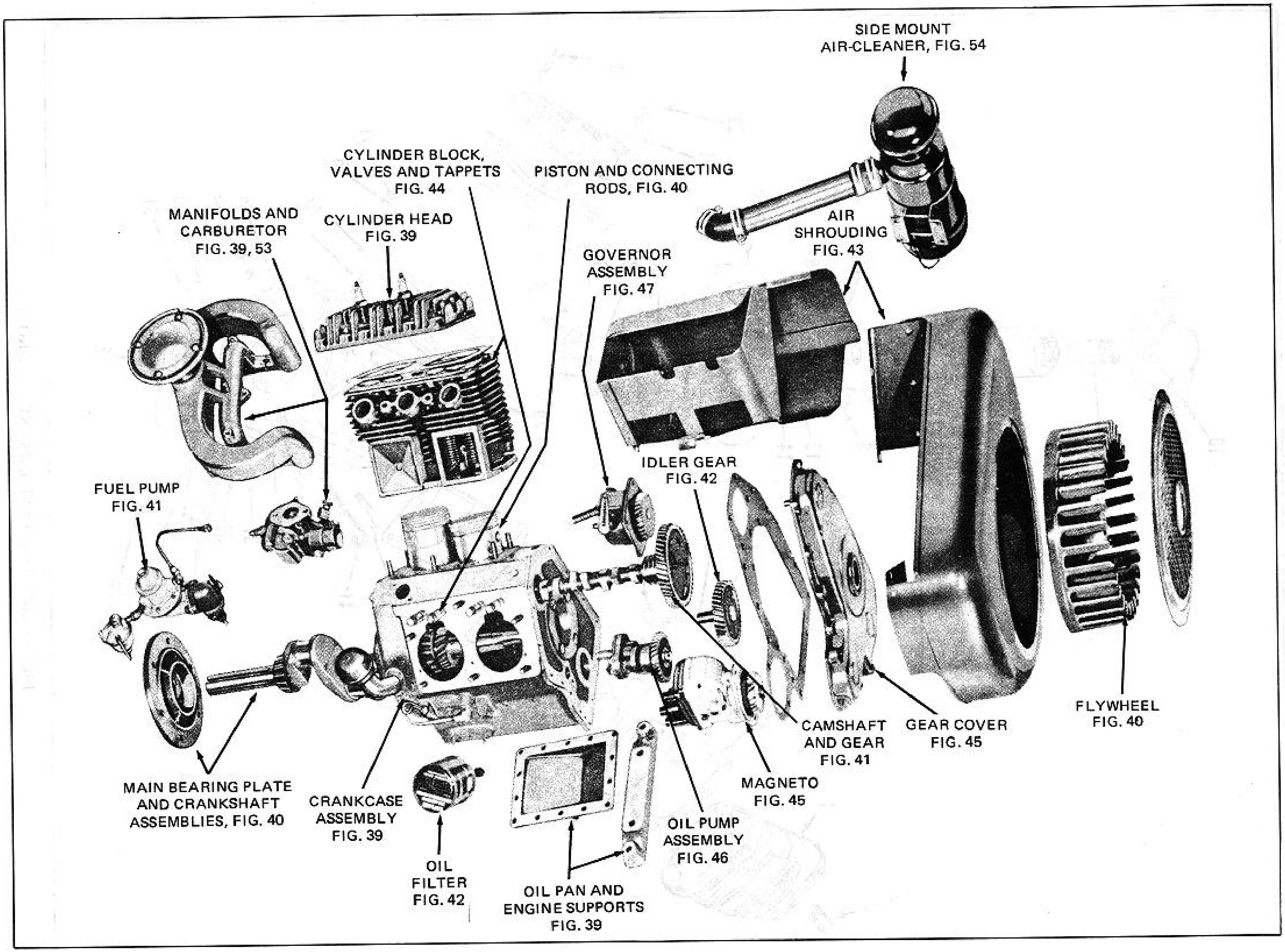


FIG. 38. EXPLODED VIEW OF ENGINE

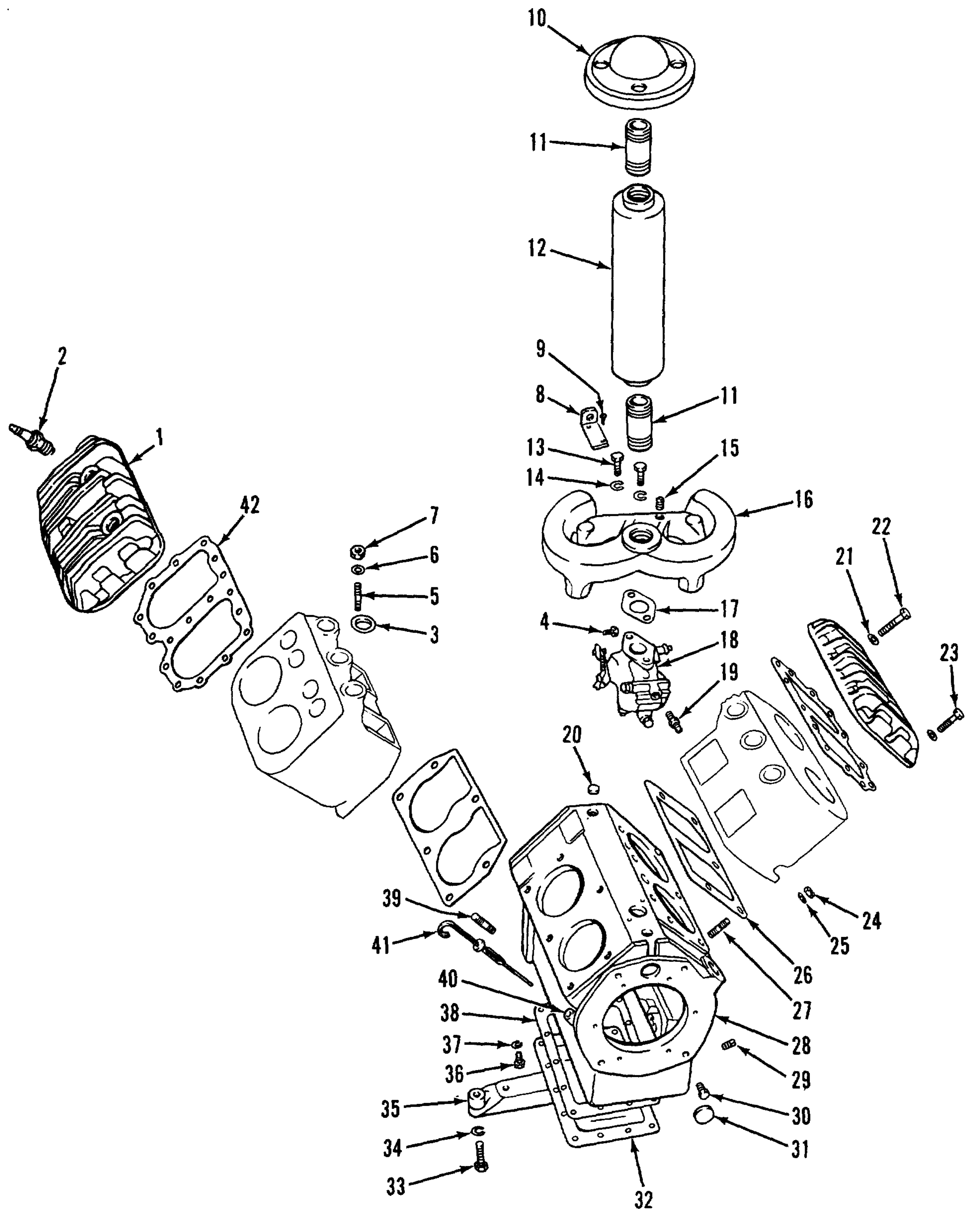


FIG. 39. MANIFOLD AND CRANKCASE GROUP

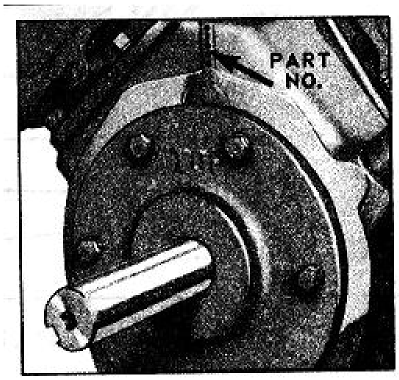
MANIFOLD AND CRANKCASE GROUP

Item No.	Part Number	Description	No. Req'd
1	AB 100	CYLINDER HEAD	2
2	YD311 S1	SPARK PLUG	4
3	QB 75	GASKET, for manifold to cylinder block	6
4	XA 33	SCREW, 1/4 - 20 x 1/2" hex hd	1
5	PC 406	STUD, manifold to cylinder block	4
6	PH 22 A	WASHER, PLAIN, manifold to cylinder block	4
7	PD 206	NUT, 3/8"- 24 hex	4
8	PG 475	BRACKET, for choke control	1
9	XA 65	SCREW, # 8 x 1/2" lg.	2
10	WD 98 S5	MUFFLER CAP	1
11	LJ 184	NIPPLE, 1-1/4 x 2-1/2" lg.	2
12	102-1424-2	MUFFLER	1
13	XD17	SCREW, 5/16- 18 x 1" g. hex hd.	2
14	PE 4	LOCKWASHER, 5/16"	2
15	XK1	PLUG, 1/8" pipe, sq. hd	1
16	LD 253	INLET and EXHAUST MANIFOLD	1
17	QC 71 A	GASKET, for carburetor flange	3
18	L108	CARBURETOR, Walbro No. LUB-1	1
19	RF269	STRAIGHT FITTING, in carburetor	1
20	SA 26	PLUG, 5/8" expansion	2
21	PH 77 A	WASHER, PLAIN, 5/16"	34
22	XD 20	SCREW, 5/16 - 18 x 1-3/8" lg. hex hd	4
23	XD 19	SCREW, 5/16 - 18 x 1-1/4" lg. hex hd	30
24	PD 12	NUT, 7/16- 20, hex	12
25	PE 63	LOCKWASHER, 7/16" external tooth	12
26	QD 617	GASKET, for cylinder base	2
27	PC 615	STUD	12
28	BA 48 C	*CRANKCASE ASSEMBLY	1
29	XK 3	PLUG, 3/8" pipe, sq. hd	1
30	PK 144	PLUG	4
31	SA 58	PLUG, 1-3/8" expansion	1
32	BH 141 A	BOTTOM COVER for CRANKCASE	1
33	XD43	SCREW, 1/2-13x1-1/2" lg. hex hd	4
34	PE 7	LOCKWASHER, 1/2"	4
35	BK 65	ENGINE SUPPORT	2
36	XD 14	SCREW, 5/16- 18 x 5/8" lg. hex hd.	14
37	PE 4	LOCKWASHER, 5/16"	14
38	QD 610 A	GASKET, crankcase bottom cover	1
39	PC 396	STUD, starter bracket	2
40	RF 1495 F	ADAPTOR TUBE, dip stick	1
41	RJ 173 A	DIP STICK	1
42	QD 613 C	GASKET, cylinder head	2

*CRANKCASE ASSEMBLY - Includes:

1 LJ 300P	Tube	4 RF 1143	Nozzles
12 PC 615	Studs	1 RF	Tube
2 PC 396	Studs	1 RJ	Dip stick
7 PF 18	Plugs	2 SA 26	Plugs
4 PF 144	Plugs	1 SA 28	Plug
1 RC 91	Screen	2 XD 17	Screws

NOTE: The basic standard crankcase part number is BA 48 C. Any special machining is indicated by a number stamped in the location shown at right. Add this number to BA 48 C. Order by complete number and by giving the Model, Spec and Serial Number of the engine.



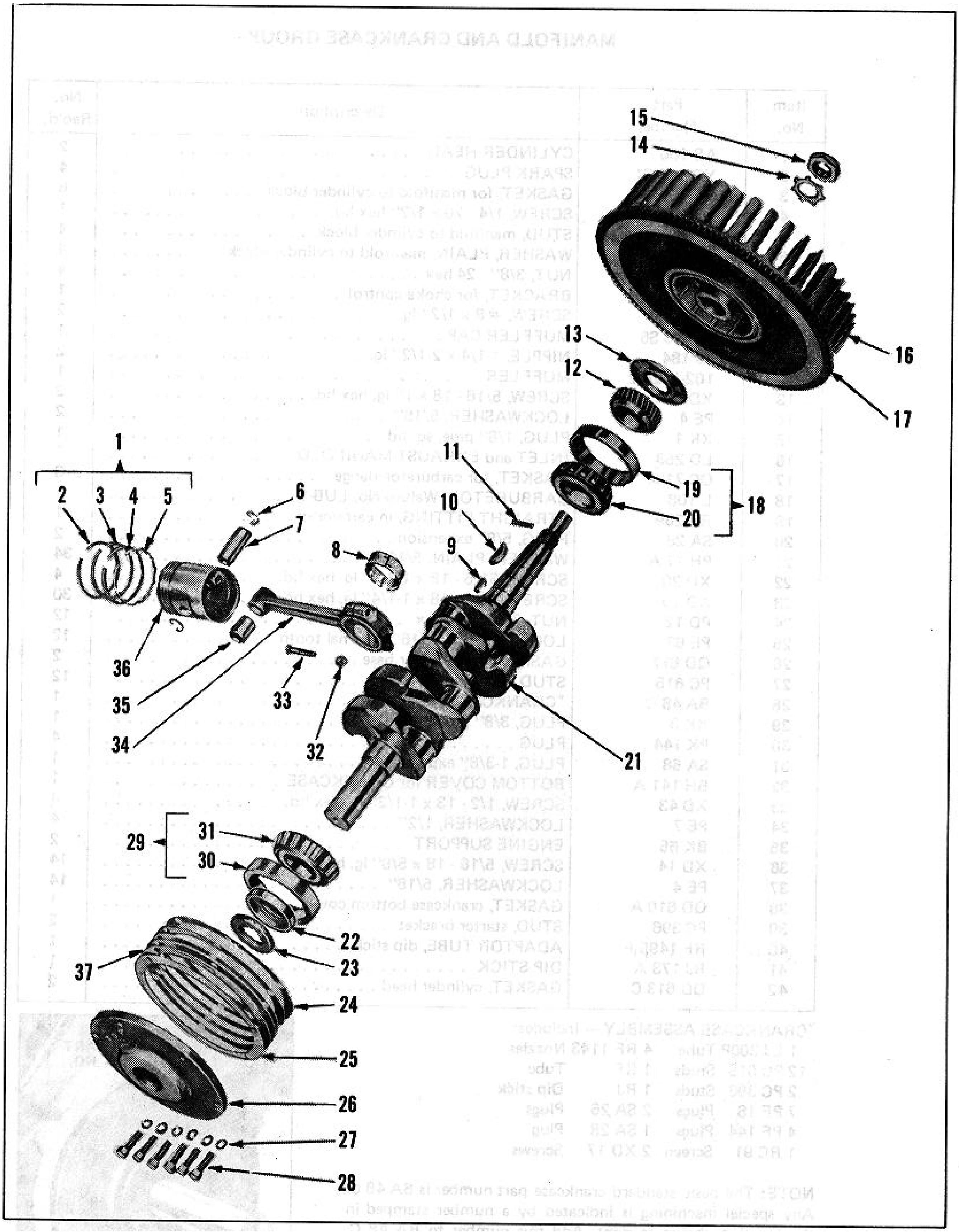


FIG. 40. CRANKSHAFT, PISTON AND CONNECTING ROD GROUP

CRANKSHAFT, PISTON AND CONNECTING ROD GROUP

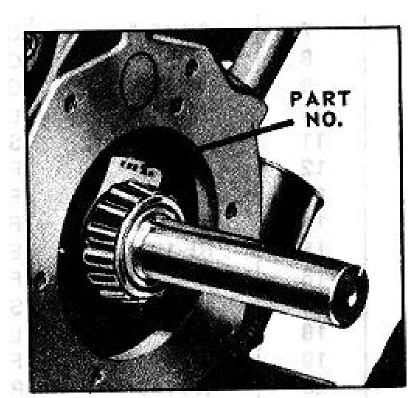
Item No.	Part Number	Description	No. Req'd
1	DR 64	RING SET, std. size (3 ring piston)	1
2	DC 363	COMPRESSION RING, top groove	4
3	DC 364	SCRAPER RING, 2nd groove	4
4	DC 211	OIL RING, 3rd groove	4
5	DC 365	EXPANDER, for oil ring	4
6	PK 52	RETAINING RING, for piston pin	8
7	DE 65	PISTON PIN, std. size	4
8	HA 134-S	SHELL BEARING, (2 halves) std. size	4
9	PL 53	KEY, No. 8 woodruff	1
10	PL 83	KEY, No. 23 woodruff	1
11	PA 333	PIN	1
12	GA 36 A	CRANKSHAFT GEAR	1
13	RK170	OIL SLING, on crankshaft	1
14	PE 66	LOCKWASHER, for flywheel nut	1
15	PD 123	NUT, for flywheel mounting	1
16	N 101 A	FLYWHEEL	1
17	GH 44	RING GEAR	1
18	ME 71	MAIN BEARING ASSEMBLY, flywheel end	1
19	ME 691	BEARING CUP — NOT SOLD SEPARATELY	1
20	ME 71-1	BEARING CONE — NOT SOLD SEPARATELY	1
21	CA71 A	*CRANKSHAFT ASSEMBLY	1
22	SD 43	RETAINER, oil seal cork	1
23	HF 261	OIL SEAL, cork, for main bearing	1
24	QD 527 D	GASKET, 0.003" thick	3
25	QD 527 C	GASKET, 0.006" thick	3
26	BG-210 C-52	MAIN BEARING PLATE ASSEMBLY	1
27	PE 5	LOCKWASHER, 3/8"	6
28	XD29	SCREW, 3/8-16x1.1/4" lg. hex hd.	6
29	ME 114	MAIN BEARING ASSEMBLY, take-off end	1
30	ME 114-2	BEARING CUP — NOT SOLD SEPARATELY	1
31	ME 114-1	BEARING CONE — NOT SOLD SEPARATELY	1
32	PD 246	LOCKNUT, 5/16" - 24	8
33	PB 148S1	CONNECTING ROD BOLT ASSEMBLY	8
34	DA 68A-S1	CONNECTING ROD, shell bearing type	4
35	HG 157 A	PISTON PIN BUSHING	4
36	DB 210-4	PISTON, std. size (3 ring piston)	4
37	QF 33 C	**SHIM, 0.013" thick	

*CRANKSHAFT ASSEMBLY, includes ..

1 GA	Gear	1 ME 114	Bearing
1 ME 71	Bearing	1 PL 53	Key

NOTE: The basic crankshaft part number is CA 71 A. Dash numbers are added to the basic part number to identify special machining at the take-off end. The dash (-) number will be found stamped on the cheek facing the take-off end of the shaft, as illustrated at right. Order by complete part number, (dash No. added to basic No.) and by giving the model, spec and serial numbers of engine.

**NOTE: Use same quantity of shims and gaskets as were removed to give 0.002" to 0.005" end play.



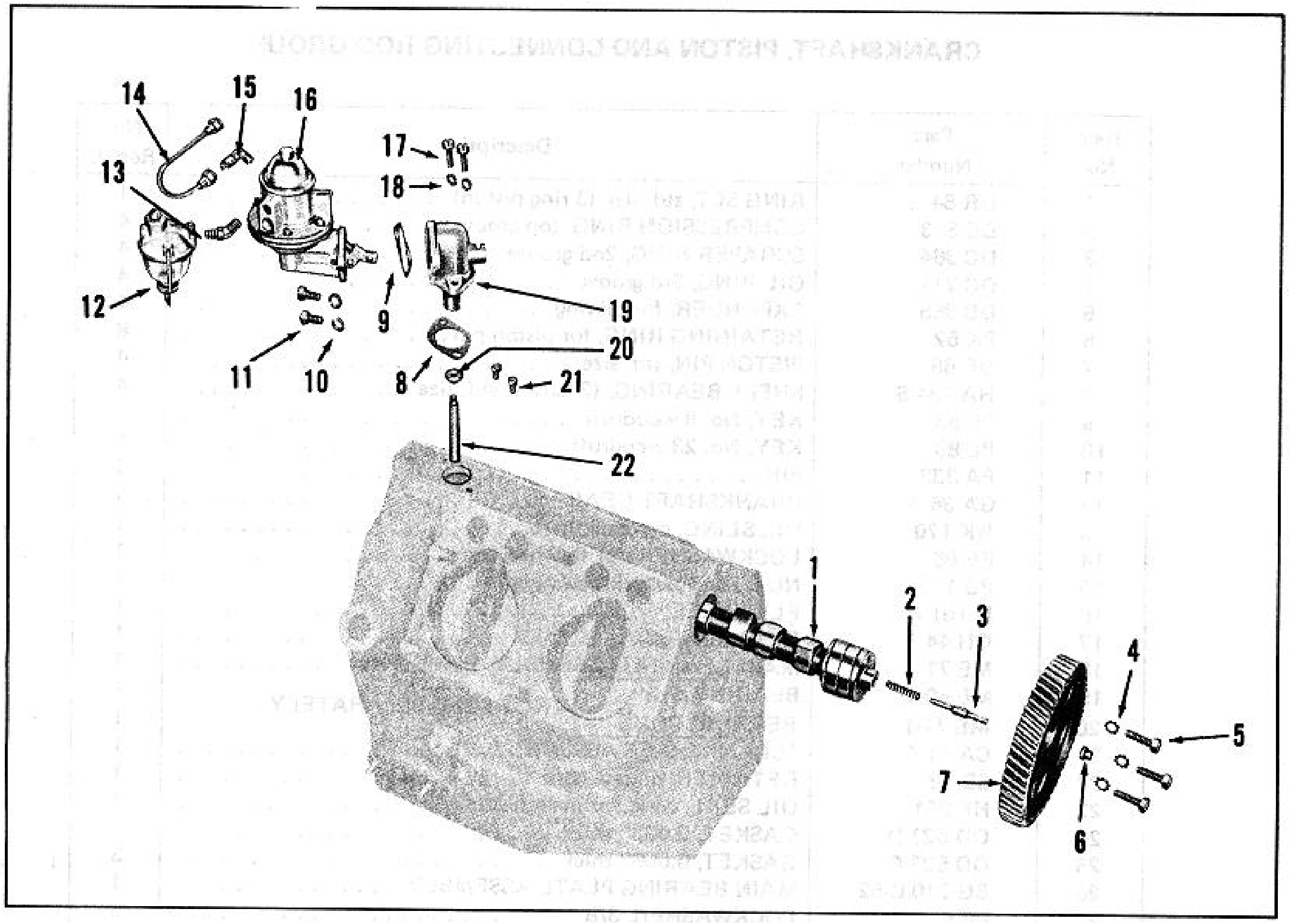


FIG. 41. CAMSHAFT AND FUEL PUMP MOUNTING GROUP

Item No.	Part Number	Description	No. Req'd
1	EA 113	CAMSHAFT	1
2	PM 108	SPRING	1
3	PF 101	THRUST PLUNGER..	1
4	PE 46	LOCKWASHER, 5/16", external tooth	3
5	XD17	SCREW, 5/16- 18x 1" lg. hex hd	3
6	PF 52 A	BUTTON, 11/16" lg.	1
7	GB 45 A	CAMSHAFT GEAR	1
8	QD 67	GASKET, for fuel pump adaptor..................................	1
9	QD 538 A	GASKET, for fuel pump mounting	1
10	PE 4	LOCKWASHER, 5/16"...	2
11	XD15	SCREW, 5/16- 18x3/4" lg. hex hd.	2
12	LP 43	FUEL STRAINER (LQ 31 REPAIR KIT)........................	1
13	RF 1397	ELBOW, 450 male for mounting fuel strainer	1
14	RM 1122 C	FUEL LINE, pump to carburetor	1
15	RF 1225	ELBOW, for fuel line	1
16	LP 38E-S1	FUEL PUMP (LQ 46 REPAIR KIT)	1
17	XA 36	SCREW, 1/4 - 20 x 3/4" lg. hex hd	2
18	PE 3	LOCKWASHER, 1/4"	2
19	TF 96-18	FUEL PUMP ADAPTOR...	1
20	TA 116	PLUNGER CAP..	1
21	XA 34	SCREW, 1/4 - 20 x 1/2"19. hex hd.	2
22	TA 111 B1	PLUNGER, for fuel pump..	1

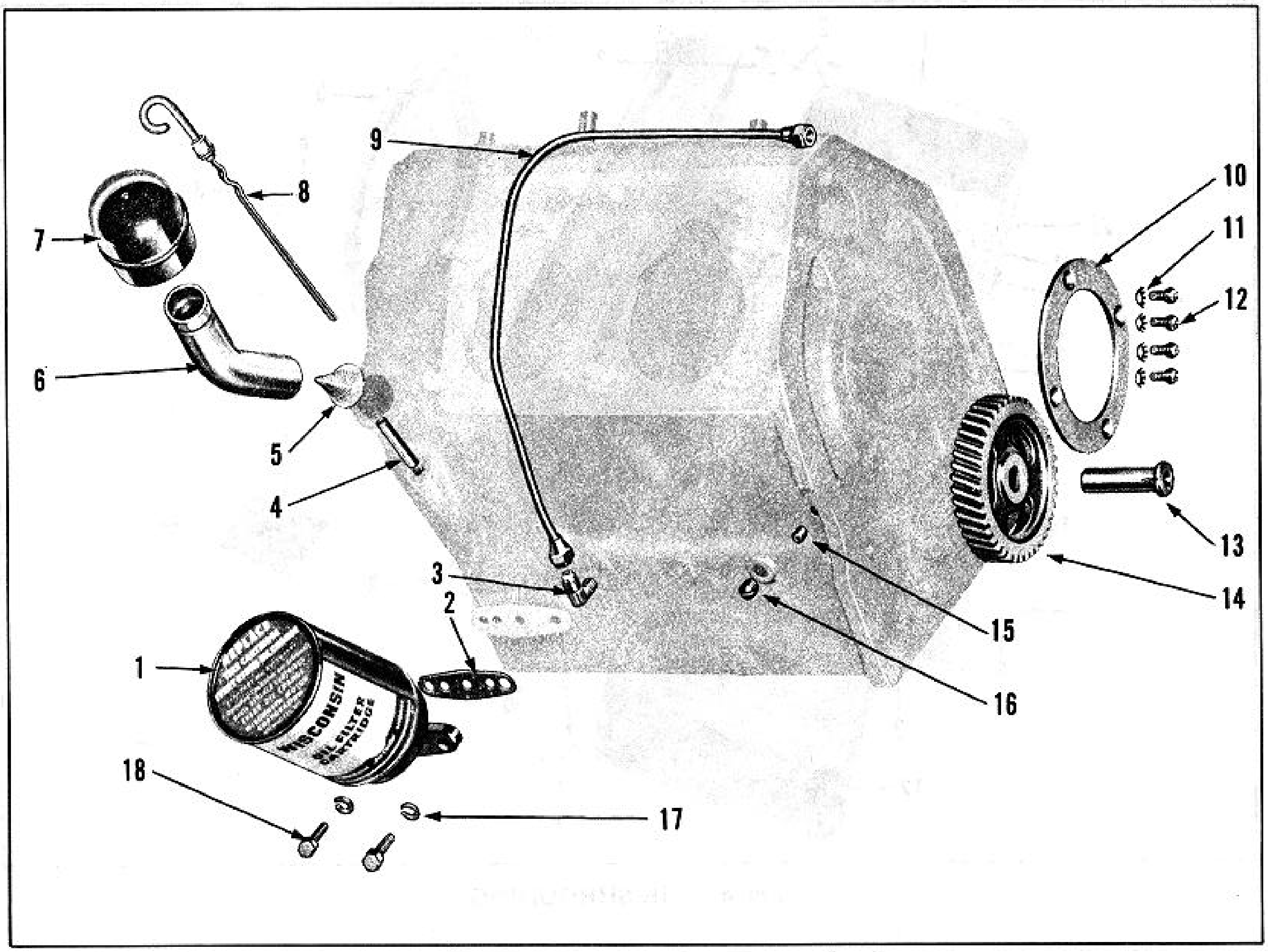


FIG. 42. OIL FILTER AND OIL FILLER MOUNTING GROUP

Item No.	Part Number	Description	No. Req'd
1		OIL FILTER, consisting of:	
	RV40-S4	CARTRIDGES (4 pack) with QD 685 gaskets	1
	RV40-A1	BASE ASSEMBLY	1
2	QD 595 A	GASKET, oil filter mounting	1
3	RF 1225	ELBOW, for fuel line	1
4	RF 1495 F	ADAPTOR TUBE, (curved) dip stick	1
5	RC 91	SCREEN, for oil filter	1
6	LJ 300 P	OIL FILLER TUBE	1
7	LO 60	OIL FILLER and BREATHER CAP	1
8	RJ 173 A	DIP STICK	1
9	RM 675	OIL LINE, crankcase to governor	1
10	BG 209	PLATE, bearing retainer, flywheel end	1
11	PE 49	LOCKWASHER, 5/16"	4
12	XC 68	SCREW, 5/16 - 18 x 3/4" lg. flat soc. hd.	4
13	PJ 105	STUD, for idler gear	1
14	GC 27 B1	IDLER GEAR	1
15	XE 55	SCREW, 5/16 - 18 x 3/8" lg. allen hd. set	1
16	PF 18	PIPE PLUG, 1/8" slotted, for oil header	1
17	PE 4	LOCKWASHER, 5/16"	2
18	XD17	SCREW, 5/16- 18 x 1" lg. hex hd	2

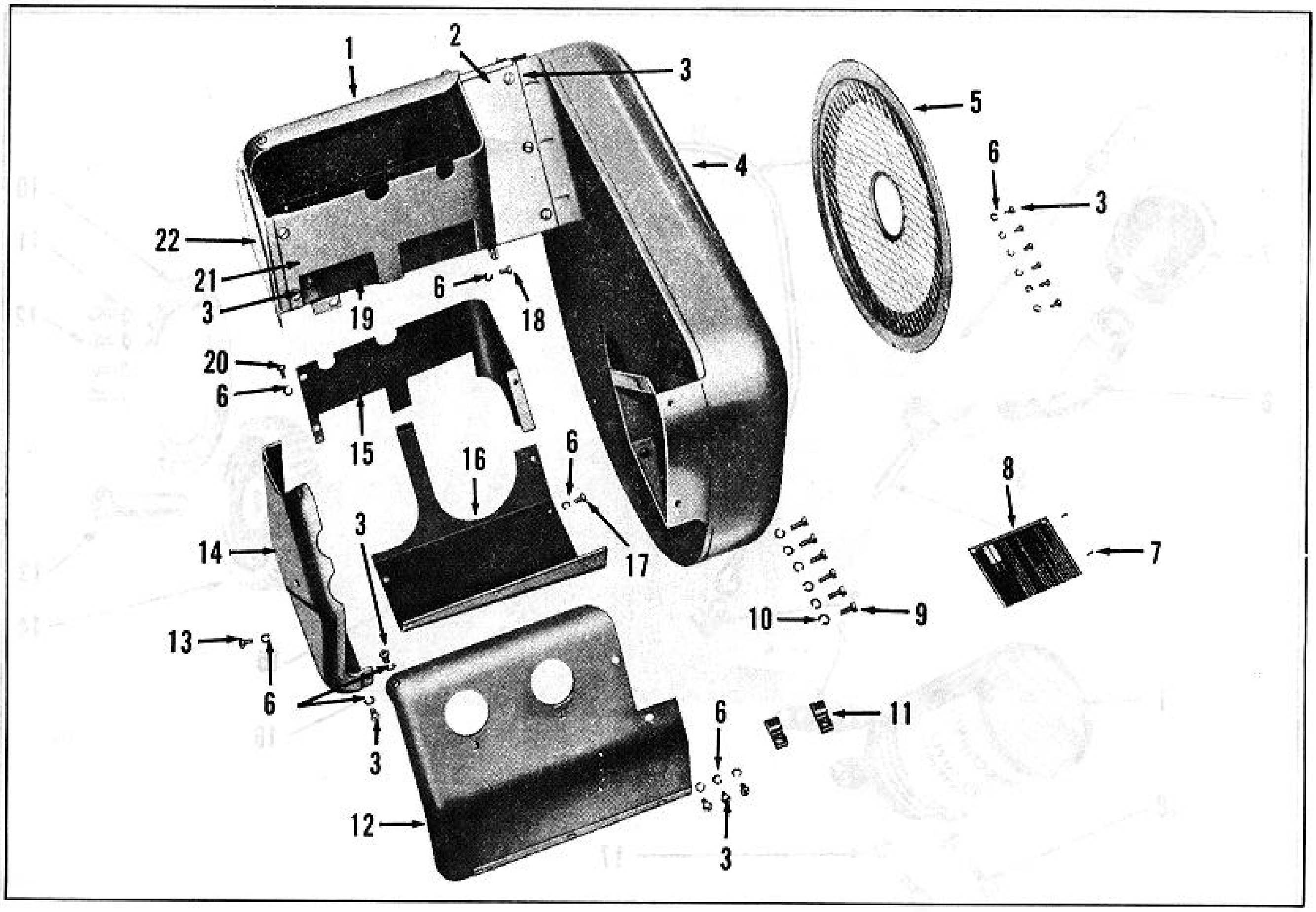


FIG. 43. AIR SHROUDING

Item No.	Part Number	Description	No. Req'd
1	SE 78C	CYLINDER HEAD SHROUD, right hand side	1
2	SE 80	SIDE COVER, for flywheel shroud................................	1
3	XA 33	SCREW, 1/4 - 20 x 3/8" lg. hex hd	29
4	SE 74 YC	FLYWHEEL SHROUD	12
	XD 172	SCREW, 5/16" - 18 x 1/2" lg. hex hd. for flywheel shroud.....	2
5	SE 20 B3	SCREEN, for flywheel shroud.......................................	1
6	PE 3	LOCKWASHER, 1/4"	39
7	XA 67	SCREW, #4 x 1/4" lg. for mounting nameplate............	4
8	SD 312 A	ENGINE NAMEPLATE..	1
9	XD 13	SCREW, 5/16"- 18 x 1/2" lg. hex hd.	4
10	PE 4	LOCKWASHER, 5/16..	6
11	PG 314	CLIP, for spark plug ignition cables	2
12	SE 79 C	CYLINDER HEAD SHROUD, left hand side	1
13	XA 36	SCREW, 1/4 - 20 x 3/4" lg. hex hd	2
14	SE 82 C	REAR SHROUD COVER, left hand side.......................	1
15	SE 77 C	HEAT DEFLECTOR, left hand side	1
16	SE 76 B	LOWER CYLINDER SHROUD, left hand side	1
17	XA 33	SCREW, 1/4 - 20 x 1/2" lg. hex hd	4
18	XA 34	SCREW, 1/4 - 20 x 1/2" lg. hex hd	4
19	SE 75 B	LOWER CYLINDER SHROUD, right hand side	1
20	XD 6	SCREW, 1/4 - 20 x 3/4" lg. hex hd	2
21	SE 77 D	HEAT DEFLECTOR, right hand side	1
22	SE 83 C	REAR SHROUD COVER, right hand side.....................	1

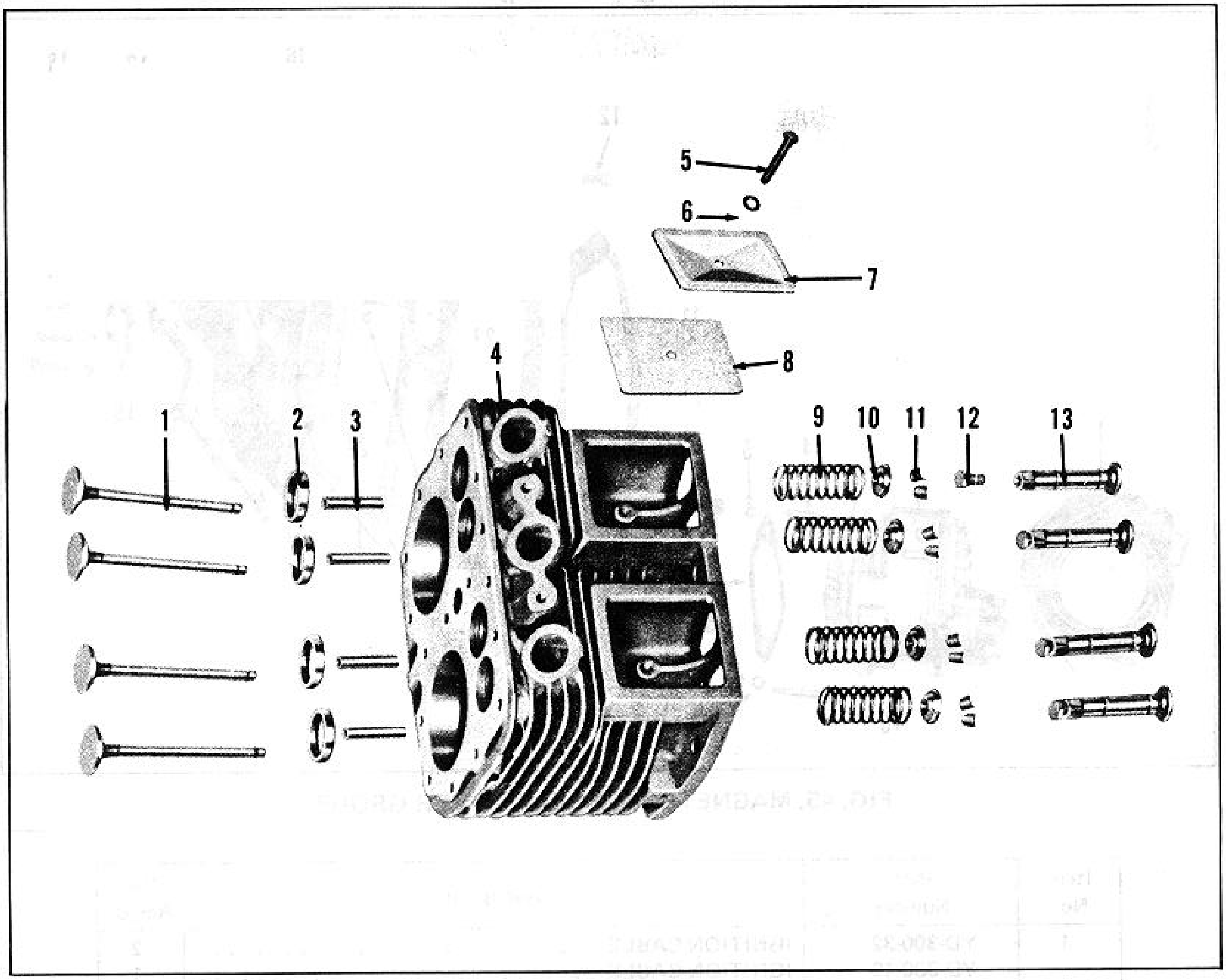


FIG. 44. CYLINDER BLOCK ASSEMBLY

Item No.	Part Number	Description	No. Req'd
1	AE 75 B	VALVE, inlet	4
	AE 75 D	VALVE, exhaust, stellite faced	4
2	HG 201	VALVE SEAT INSERT, inlet	4
	HG 201 D	VALVE SEAT INSERT, stellite exhaust	4
3	AD 41 E	VALVE STEM GUIDE	8
4	AA 98 S7	CYLINDER BLOCK ASSEMBLY	1
5	XD 21	SCREW, 5/16 - 18 x 1-1/2" lg. hex hd	4
6	PH 14	WASHER, PLAIN, 5/16" copper	4
7	SA 68	COVER PLATE	4
8	QD 612 A	GASKET	4
9	AF 49 A	VALVE SPRING, inlet	4
	AF 54	VALVE SPRING, exhaust, for stellite valves and rotators	4
	AF 51	VALVE SPRING, exhaust, for stellite valves less rotators	
10	AG 26	SEAT	4
	AG 31	VALVE ROTATOR	4
11	AH 9	LOCK	16
12	PB 169 A	TAPPET ADJUSTING SCREW	8
13	F 61	VALVE TAPPET	8

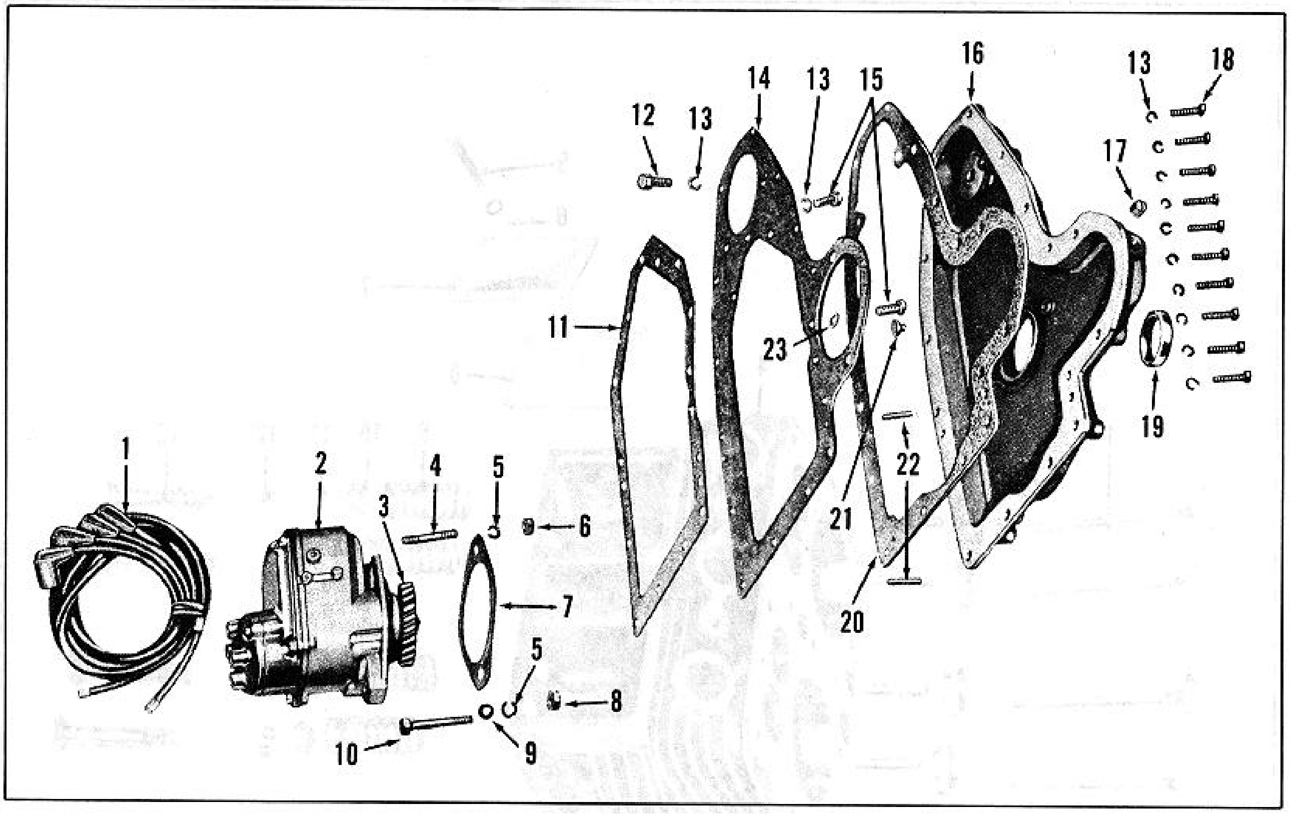


FIG. 45. MAGNETO AND GEAR COVER GROUP

Item No.	Part Number	Description	No. Req'd
1	YD-300-32	IGNITION CABLE	2
	YD-300-40	IGNITION CABLE	1
	YD-300-23	IGNITION CABLE	1
2	Y-98-C-S4	MAGNETO	1
	YQ 8	POINTS AND CONDENSER KIT	
3	GD 93 C 4	MAGNETO GEAR	1
4	PC 110	STUD, for magneto mounting	1
5	PE 5	LOCKWASHER, 3/8"	2
6	PD 11	NUT, 3/8 - 24, hex steel, for magneto stud	1
7	QD 616	GASKET, for magneto flange	1
8	PD 79	NUT, 3/8 - 16, hex steel	1
9	PH 22 A	WASHER, PLAIN, 3/8"	1
10	XD 33	SCREW, 3/8 - 16 x 2-1/4" lg. hex hd	1
11	QD 614	GASKET, gear cover spacer to case	1
12	XD 15	SCREW, 5/16 - 18 x 3/4" lg. hex hd.	2
13	PE 4	LOCKWASHER, 5/16"	15
14	WE 182 A	SPACER, for gear cover	1
15	XD 14	SCREW, 5/16 - 18 x 5/8" lg. hex hd.	5
16	BD 100K4-S1	GEAR COVER ASSEMBLY	1
17	XK 3	PIPE PLUG, 3/8" sq. hd	1
18	XD 19	SCREW, 5/16- 18x 1-1/4" lg. hex hd	10
19	PH 299	OIL SEAL	1
20	QD 611	GASKET, for gear cover	1
21	PF 52 A	BUTTON	1
22	PA 291	DOWEL PIN, for gear cover	2
23	PH 14	WASHER, PLAIN, 5/16" copper	2

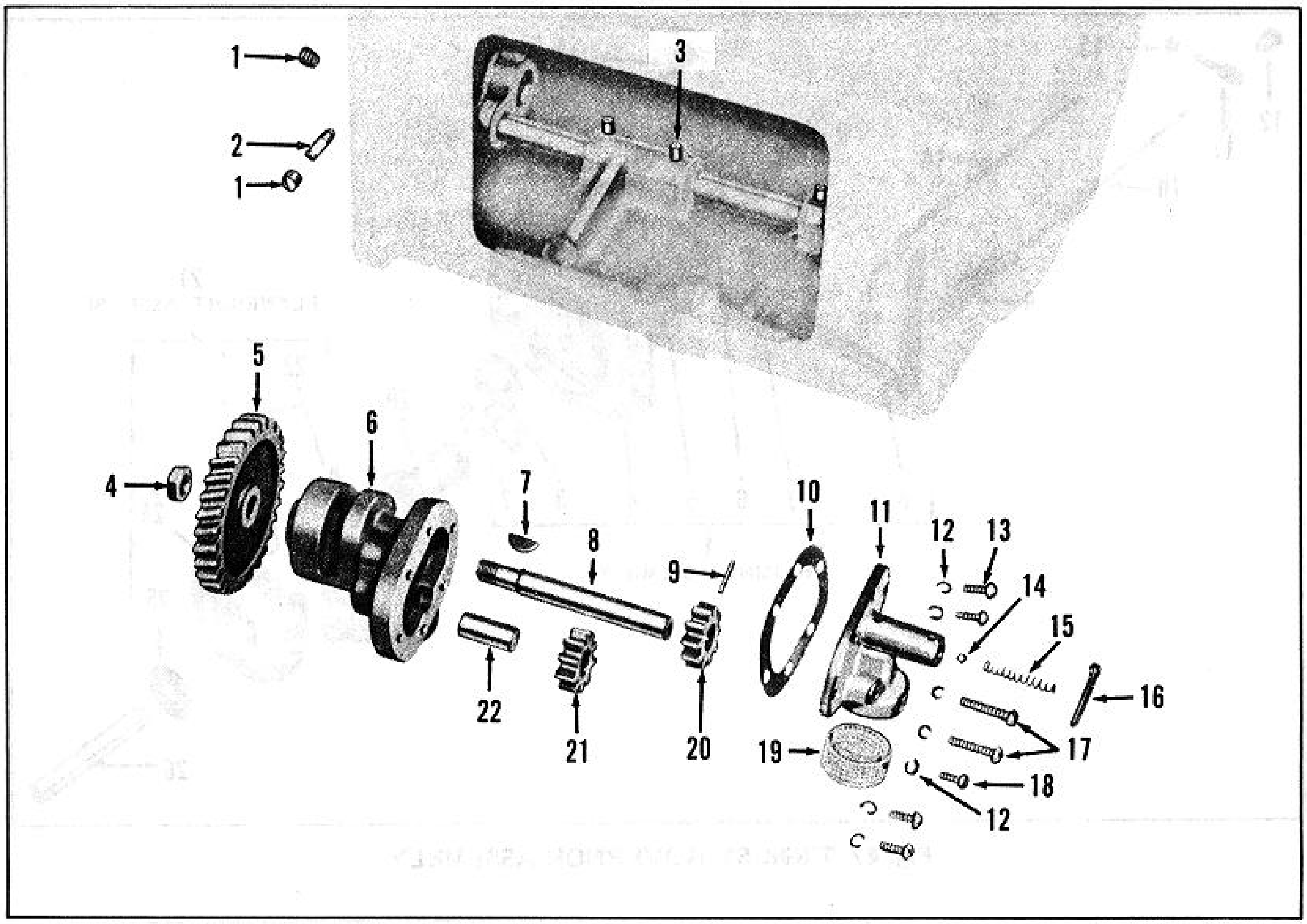


FIG. 46. K 95 L Oil Pump Assembly

Item No.	Part Number	Description	No. Req'd
1	PF 18	PIPE PLUG, 1/8" slotted	6
2	PI 143 B	OIL PUMP LOCKSCREW	1
3	RF 1143	OIL SPRAY NOZZLE	4
4	PD 195	NUT, for mounting oil pump gear	1
5	GD 94 C	OIL PUMP GEAR	1
6	KA 61 D-S1	PUMP BODY	1
7	PL 137	KEY, No. 1 woodruff	1
8	KD 121-S1	DRIVE SHAFT	1
9	PA 64	PIN, 1/8 x 3/4" lg.	1
10	QD 535 A	GASKET, 0.003, for oil pump cover	1
11	KB 42-S2	COVER ASSEMBLY	1
12	PE 14	LOCKWASHER, No. 10	7
13	XA 8	SCREW, 10-32 x 1/2" g. rd. hd.	4
14	ME 60	STEEL BALL, 1/4" dia	1
15	PM 111	SPRING, for oil pump relief valve	1
16	XI 16	COTTER PIN, 1/8 x 1" lg.	1
17	XA 56	SCREW, 10 - 32 x 1-1/4" lg. ind. hex hd.	2
18	XA 7	SCREW, 10 - 32 x 3/8" lg. rd. hd.	1
19	RD 112	OIL PUMP SCREEN	1
20	KC 56 A	DRIVER GEAR	1
21	KC 56 A	DRIVEN GEAR, 0.499 - 0.4A98 I.D	1
22	KD 122 A	STUB SHAFT	1

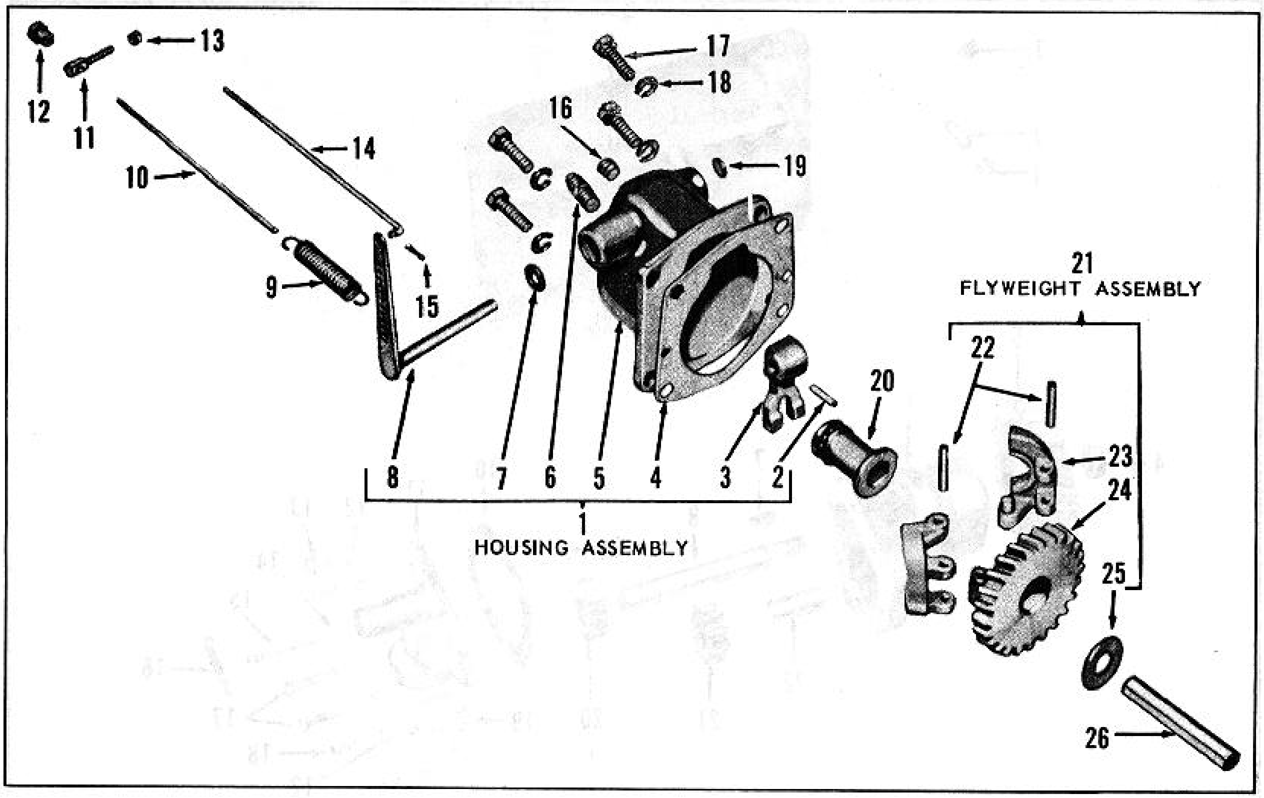


FIG. 47. T 89K-S1, GOVERNOR ASSEMBLY

Item No.	Part Number	Description	No. Req'd
1	TC 395-S1	GOVERNOR HOUSING ASSEMBLY	1
2	PA 367	ROLL PIN, 1/8" x 3/4" lg	1
3	VB 151	GOVERNOR YOKE	1
4	QD 615 A	GASKET, for governor housing	1
5	TC 395	GOVERNOR HOUSING, not serviced separately	1
6	RF 269-2	FITTING, for oil line	1
7	PH 571	OIL SEAL	1
8	TC 398	CROSS SHAFT and LEVER	1
9	PM 76	GOVERNOR SPRING	1
10	PI 115F	ADJUSTING SCREW	1
11	TC 367	ADJUSTING SCREW PIN	1
12	PD 173 A	NUT, for governor adjusting screw	1
13	PD 77	NUT, 1/4 - 20 hex steel	1
14	VE 464	CONTROL ROD, to carburetor	1
15	XI 32	COTTER PIN, 3/64" x 3/8" lg	1
16	PF 18	PIPE PLUG, 1/8" slotted	1
17	XD 16	SCREW, 5/16"- 18 x 7/8" lg. hex hd.	4
18	PE 4	LOCKWASHER, 5/16"	4
19	SA 52	PLUG, 1/2" expansion	1
20	TC 391 D	THRUST SLEEVE and BEARING	1
21	TC 405 J	GOVERNOR FLYWEIGHT ASSEMBLY	1
22	PA 340	ROLL PIN	2
23	TC 322D-S1	GOVERNOR FLYWEIGHT ASSEMBLY	2
24		GOVERNOR GEAR, included in Ref. No. 21	1
25	PH 313 A	WASHER, for governor gear bushing	1
26	TC 388-1	GOVERNOR SHAFT	1

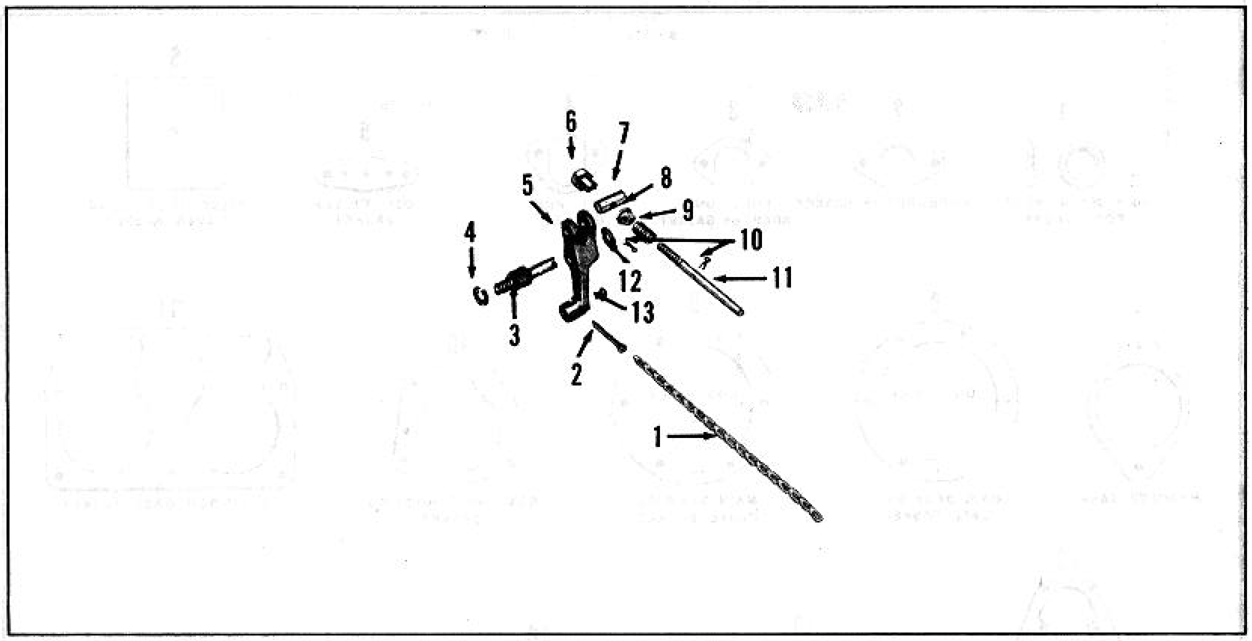


FIG. 48. TT-45-L AND TT-45L-1
GOVERNOR CONTROL ASSEMBLIES

Item No.	Part Number	Description	No. Req'd
1		NO. 1/0 GALVANIZED SAFETY CHAIN, 8-3/4" lg.	1 pc.
2	XI-11	COTTER PIN, 3/32 x 1-1/4" lg.	1
3	TC-365	PIN, variable speed lever support................................	1
4	PE-3	LOCKWASHER, 1/4"	1
5	VB-134-A	VARIABLE SPEED LEVER	1
6	PD-1 73-A	LOCKNUT, for adjusting screw....................................	1
7	TC-368-A	PIN, for adjusting screw swivel	1
8	PK-121	RETAINER, for adjusting screw spring	1
9	PM-111-1	SPRING, for adjusting screw.......................................	1
10	XI-1	COTTER PIN	3
11	PI-115-E	ADJUSTING SCREW..	1
12	PH-77	WASHER, PLAIN, 5/16" I.D. x 5/8" O.D. x 1/16" thick .	1
13	XA-62	SCREW, 8 - 32 x 1/4" 19 lg. rd. hd	1

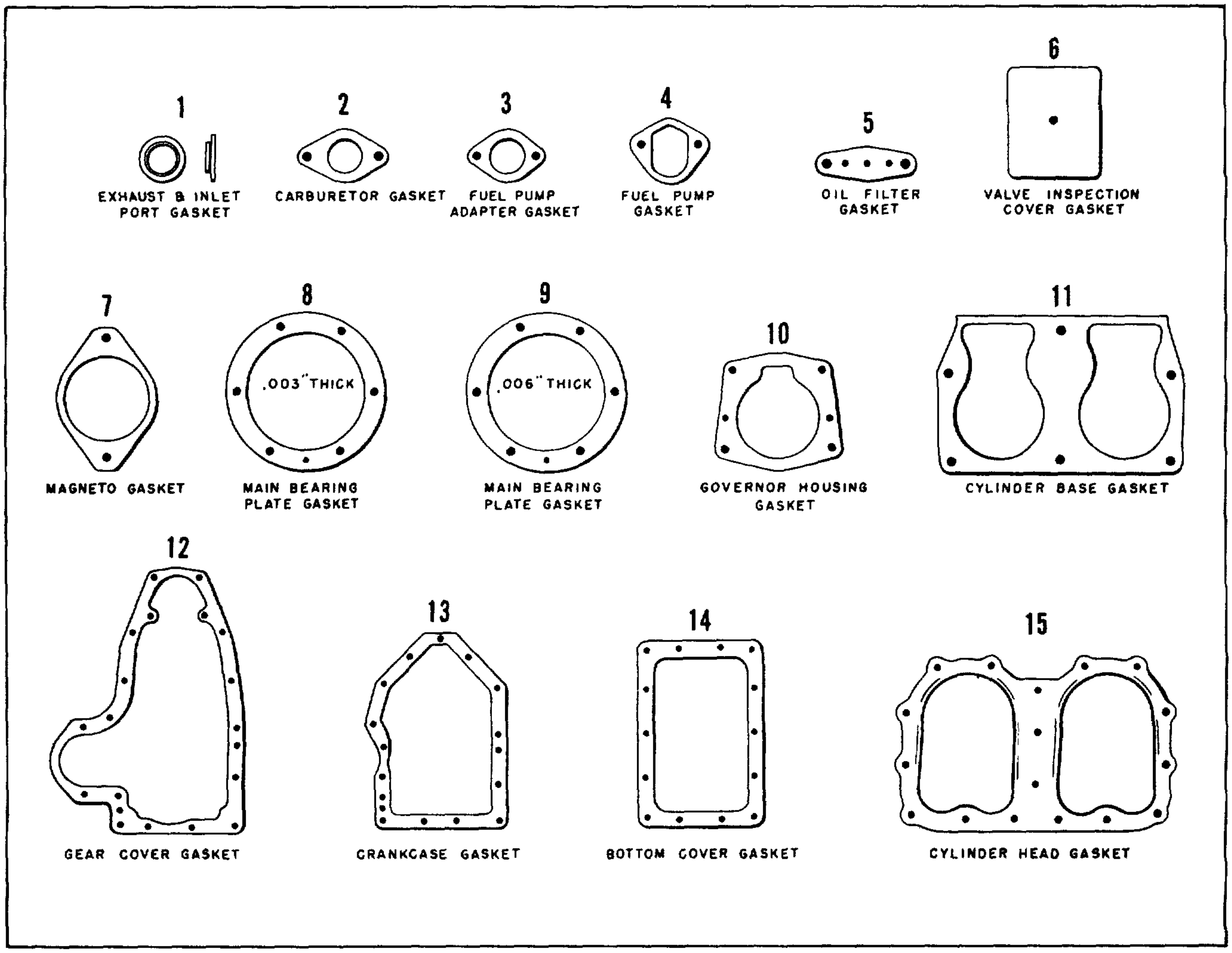


FIG. 50. Q12J GASKET SET

Item No.	Part Number	Description	No. Req'd
1	QB 75	EXHAUST and INLET PORT GASKET	6
2	QC 71 A	CARBURETOR GASKET	3
3	QD 67	FUEL PUMP ADAPTER GASKET	1
4	QD 538 A	FUEL PUMP GASKET	1
5	QD 595 A	OIL FILTER GASKET	1
6	QD 612 A	VALVE INSPECTION COVER GASKET	4
7	QD 616	MAGNETO GASKET	1
8	QD 527 D	MAIN BEARING PLATE GASKET	3
9	QD 527 C	MAIN BEARING PLATE GASKET	3
10	QD 615A	GOVERNOR HOUSING GASKET	1
11	QD 617	CYLINDER BASE GASKET	2
12	QD 611	GEAR COVER GASKET	1
13	QD 614	CRANKCASE GASKET	1
14	QD 610 A	BOTTOM COVER GASKET	1
15	QD 613 C	CYLINDER HEAD GASKET	2
	Q 28	VALVE GRINDING GASKET SET, consisting of:	1
	QB 75	EXHAUST and INLET PORT GASKET	6
	QD 612 A	VALVE INSPECTION COVER GASKET	4
	QD 613 A	CYLINDER HEAD GASKET	2

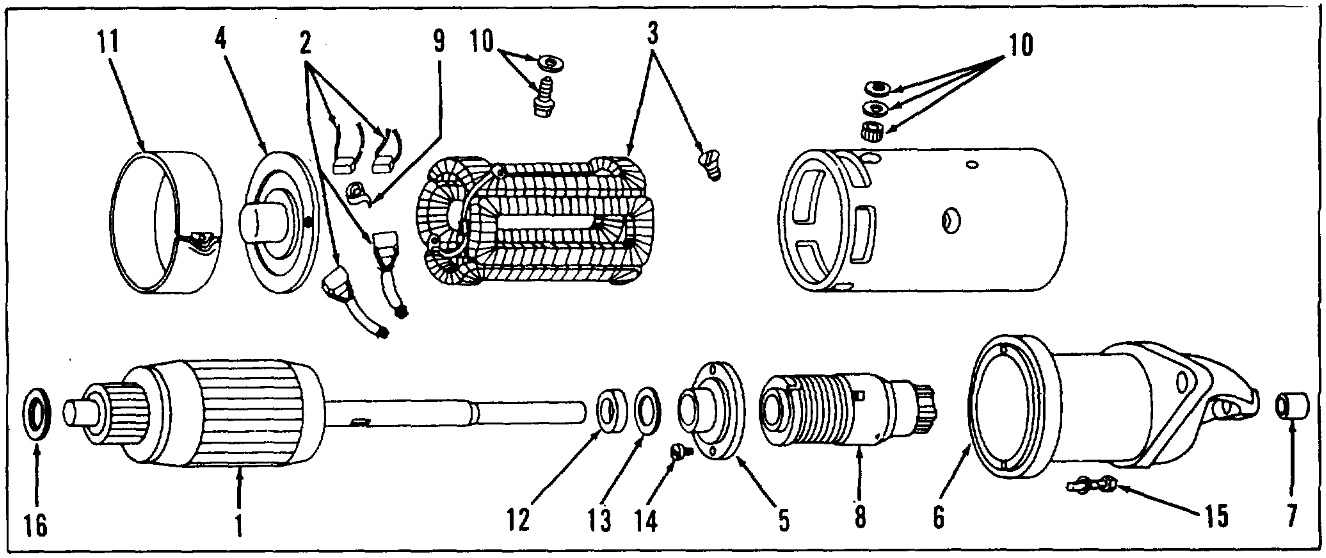


FIG. 50. STARTING MOTOR ASSEMBLY
WITH FOLO-THRU BENDIX
YA-54-A (12 VOLT) - PRESTOLITE NO. MBG-4141

Item No.	Part Number	Description	No. Req'd
1	28-MBG-2411	ARMATURE	1
2	28-MBG-2012S	*BRUSH SET	1
3	28-MBG-3005AS	FIELD COIL PACKAGE - Includes:	1
		MZ-38C SCREW, for pole shoe	
4	28-MZ-2002Q	COMMUTATOR END HEAD ASSEMBLY - Includes:	1
		*MBG-1021S BRUSH, grounded	2
		MAD-110 FELT	1
		MZ-19S BRUSH SPRING SET	1
5	28-MZ-1360	BEARING PLATE ASSEMBLY	1
6	28-PS2330BS	PINION HOUSING ASSEMBLY- Includes:	1
		MZ-364 BRONZE BEARING	1
		MZ-358 BEARING CAP	1
		XA-832 OIL SEAL	1
		28PS1330B, replaced by 28-PS2330BS.	
7	28-MZ-364	BRONZE BEARING	1
8	28-EBB-137A	BENDIX DRIVE (Eclipse #480187)	1
9	28-MZ-19S	BRUSH SPRING SET	1
10	28-P90-743	TERMINAL STUD PACKAGE - Includes:	1
		TERMINAL	1
		INSULATING BUSHING, stud	1
		TERMINAL STUD	1
		INS. WASHER, terminal stud, in	1
		INS WASHER, terminal stud, out	1
		PLAIN WASHER, terminal stud	1
11	28-MZ-1024U	COVER BAND	1
12	28-XA-832	OIL SEAL	1
13	28-MZ-359	GASKET, for interm. bearing	1
14	28-P90-822	MOUNTING SCREW PACKAGE - Includes:	1
		8X-3649 SCREW, interm. bearing, flat head # 8 - 32 x 3/8	4
15	28-MZ-52	SCREW, pinion housing, hex head # 10 - 32 x 31/32	4
16	28P90-448	** THRUST WASHER PACKAGE	1

* Brush Set for Service (Ref. 2)
** Contains additional parts to service other applications.

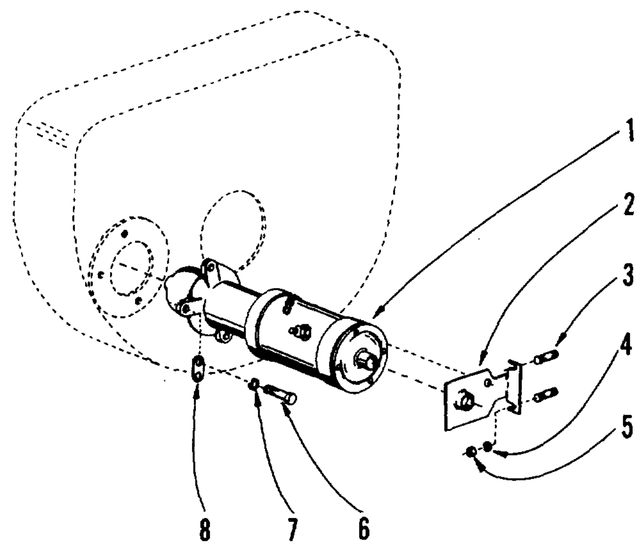


FIG. 51. STARTER MOUNTING

Item No.	Part Number	Description	No. Req'd
1	YA-54-A	STARTING MOTOR..	1
2	PG-514-A-1	BRACKET, for starter support.....................................	1
3	PC-396	STUD, for starter bracket..	2
4	PE-4	LOCKWASHER, 5/16"..	2
5	PD-10	NUT, 5/16- 24 hex steel..	2
6	PB-187	SCREW, 3/8 - 24 x 1" lg. hex hd	3
7	PE-5	LOCKWASHER, 3/8"	3
8	YD-296	TERMINAL CONNECTOR, for ground	1

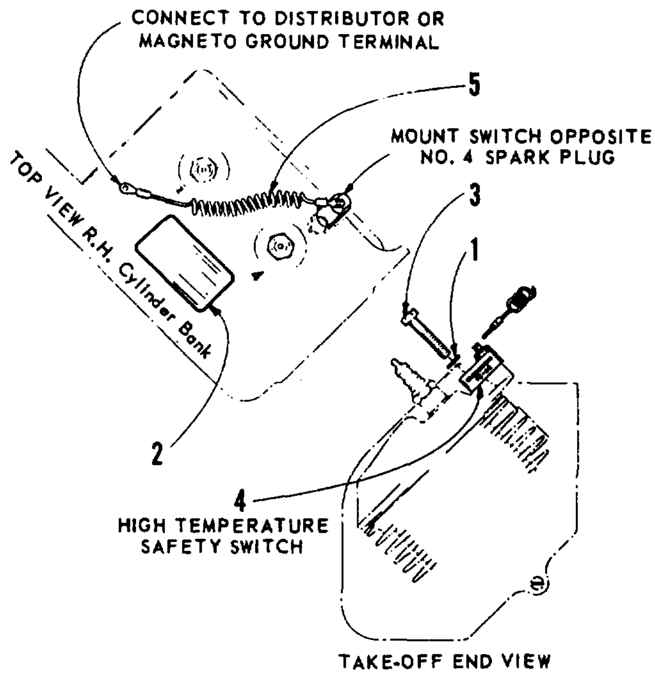


Fig. 52. YC66D-S1 HIGH TEMP. SAFETY SWITCH KIT.

Item No.	Part Number	Description	No. Req'd.
	YC-66-D-S1	HIGH TEMPERATURE SAFETY SWITCH KIT, complete ... consisting of:	1
1	PH-77	WASHER, 5/16" I.D., plain steel .... For switch to cylinder head mounting.	1
2	SD-233	INSTRUCTION DECAL	1
3	XD-22	CAPSCREW, 5/16" - 18 thread x 1-3/4" long, hexagon head (special hardness) .... For switch to cylinder head mounting.	1
4	YC66-D	HIGH TEMPERATURE SAFETY SWITCH .... For replacement, order YC-66-D-S1 Kit.	1
5	YL-357-42	WIRE ASSEMBLY, 42" long, with terminals .... (Wire coiled to suit all models.)	1

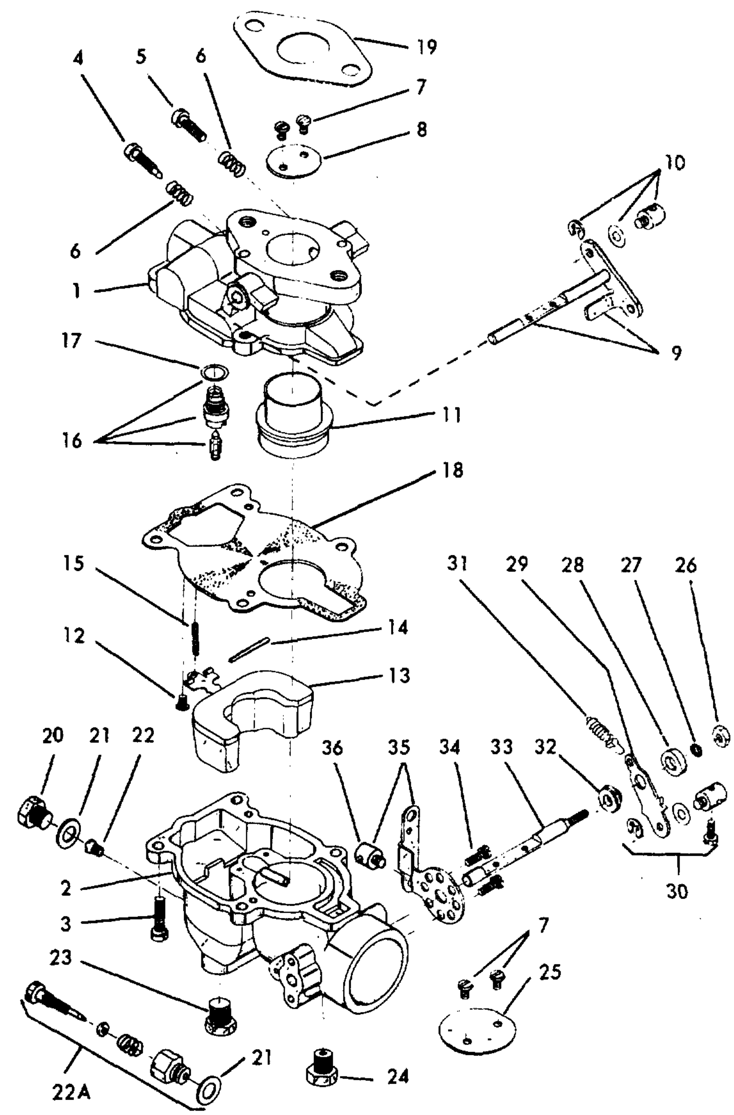


Fig. 53. WALBRO CARBURETOR MODEL LUB.

WALBRO CARBURETOR

Item No.	Part Number	Description	No. Req'd.
1		THROTTLE BODY - not serviced separately	
2	83-20-566	FUEL BOWL ASSEMBLY	1
3	83-96-570	SCREW-WASHER, fuel bowl .... # 10 - 32 x 3/4" Philips head with L.W.	4
4	†	NEEDLE, idle adjusting	1
5	83-96-262	SCREW, idle speed adjustment .... # 10 - 32 x 3/4" Fillister head.	1
6	83-98-14	SPRING, idle and throttle stop	2
7	83-96-185	SCREW-WASHER, choke and throttle valves .... # 6 - 40 x 1/4" pan head.	4
8	83-34-113	VALVE, throttle	1
9	83-30-827	THROTTLE SHAFT ASSEMBLY	1
10	83-52-515	SWIVEL ASSEMBLY, throttle lever	1
11	83-46-28	VENTURI (50)	1
12	†	SCREW, float lever pin .... #6- 32 x 3/16" pan head.	1
13	83-75-545	F LOAT ASSEMBLY	1
14	†	PIN, float assembly	1
15	†	SPRING, float buoyancy	1
16	†	FUEL VALVE and SEAT ASSEMBLY	1
17	*	GASKET, valve seat	1
18	*	GASKET, bowl to body	1
19	*	GASKET, mounting flange	1
20	83-96-155	SCREW, main jet plug .... 5/16 - 24 x 1/2" hex head.	1
21	*	GASKET, main jet plug screw	1
22	83-114-0560	MAIN JET (.056)	1
22A		NEEDLE ASSEMBLY, main jet adjustment	
23	83-88-109	PLUG, bowl drain, 1/8- 27 pipe	1
24	83-125-515	DRIP PLUG ASSEMBLY	1
25	83-62-73	VALVE, choke	1
26	83-134-51	NUT, choke shaft, # 6 - 32 hex	1
27	83-136-162	LOCKWASHER, shaft nut, #6	1
28	83-10889	RETAINER, choke lever	1
29	83-42-520	CHOKE LEVER ASSEMBLY	1
30	83-52-501	SWIVEL ASSEMBLY, choke lever	1
31	83-98-349	SPRING, choke return	1
32	83-148-68	BUSHING, choke lever retainer	1
33	83-44-235	CHOKE SHAFT	1
34	83-96-551	SCREW-WASHER, choke bracket .... # 8 - 32 x 7/16" pan head.	2
35	83-167-518	BRACKET ASSEMBLY, choke	1
36	83-52-521	SWIVEL ASSEMBLY, choke cable support	1
	LQ 55	REPAIR KIT † Parts included in LO 55 Repair Kit	
	Q 47 †	GASKET SET (also included in Repair Kit) * Parts included in Q47 Gasket Set	

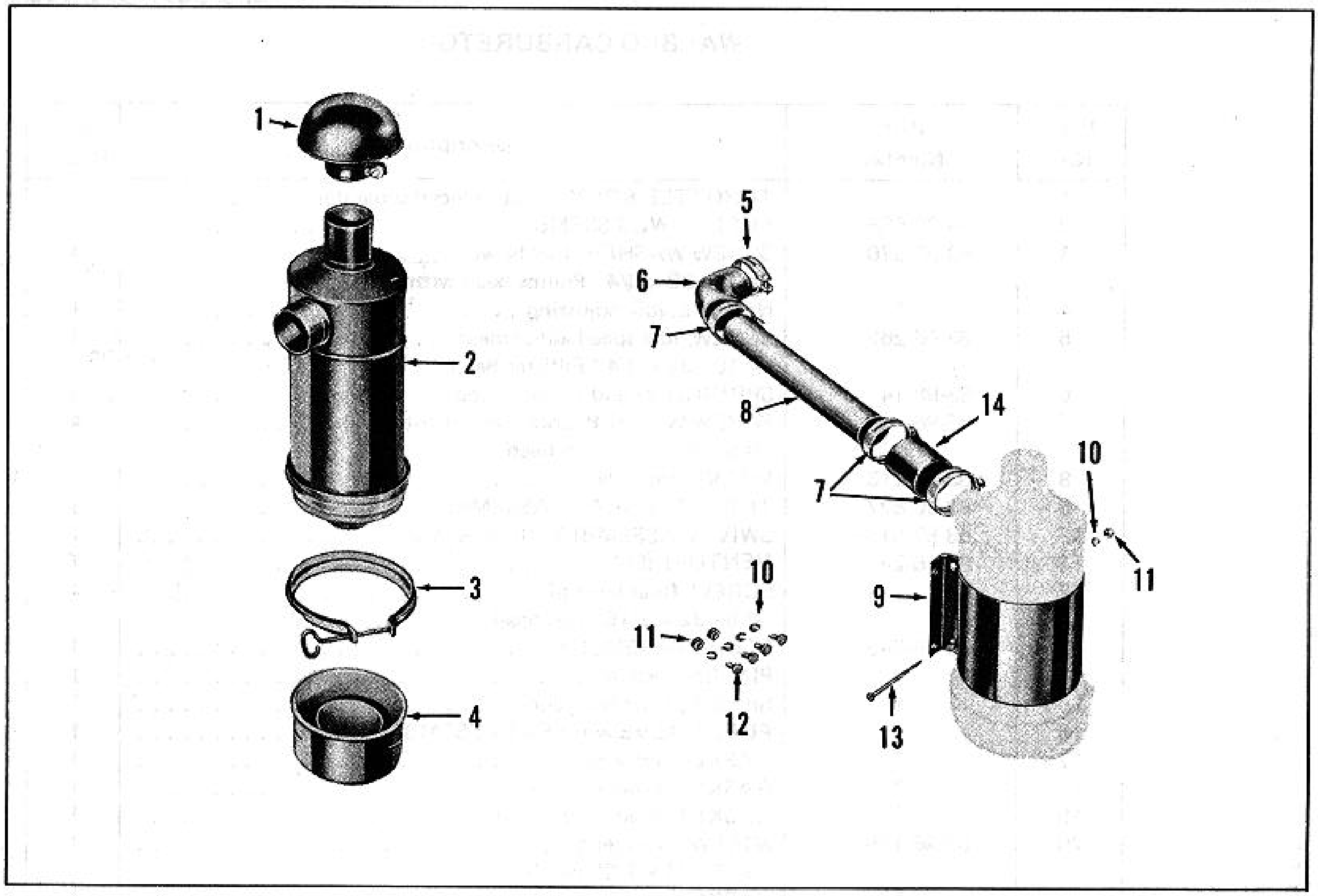


Fig. 54. LO-64 SIDE MOUNT AIR CLEARNER ASSEMBLY.

Item No.	Part Number	Description	No. Req'd.
1	LO-86	STACK CAP	1
2		BODY (order LO-64, complete assembly)	1
3	22-P2846	CLAMP ASSEMBLY	1
4	22-P15463	INNER OIL CUP	1
	22-P14889	OUTER OIL CUP	1
5	LK-10	HOSE CLAMP, 2" I.D.	1
6	LL-67	RUBBER ELBOW	1
7	LK-8	HOSE CLAMP, 2-1/8" I.D	3
8	LJ-120	TUBE	1
9	PG-291	STRAP, for mounting air cleaner	1
10	PE-3	LOCKWASHER, 1/4"	6
11	PD-77	NUT, 1/4 - 20 hex steel	4
12	XD-4	SCREW, 1/4 - 20 x 1/2" lg. hex hd.	4
13	XA-74	SCREW, 1/4 - 20 x 2-1/4" lg. rd. hd.	2
14	LL-27	RUBBER HOSE	1

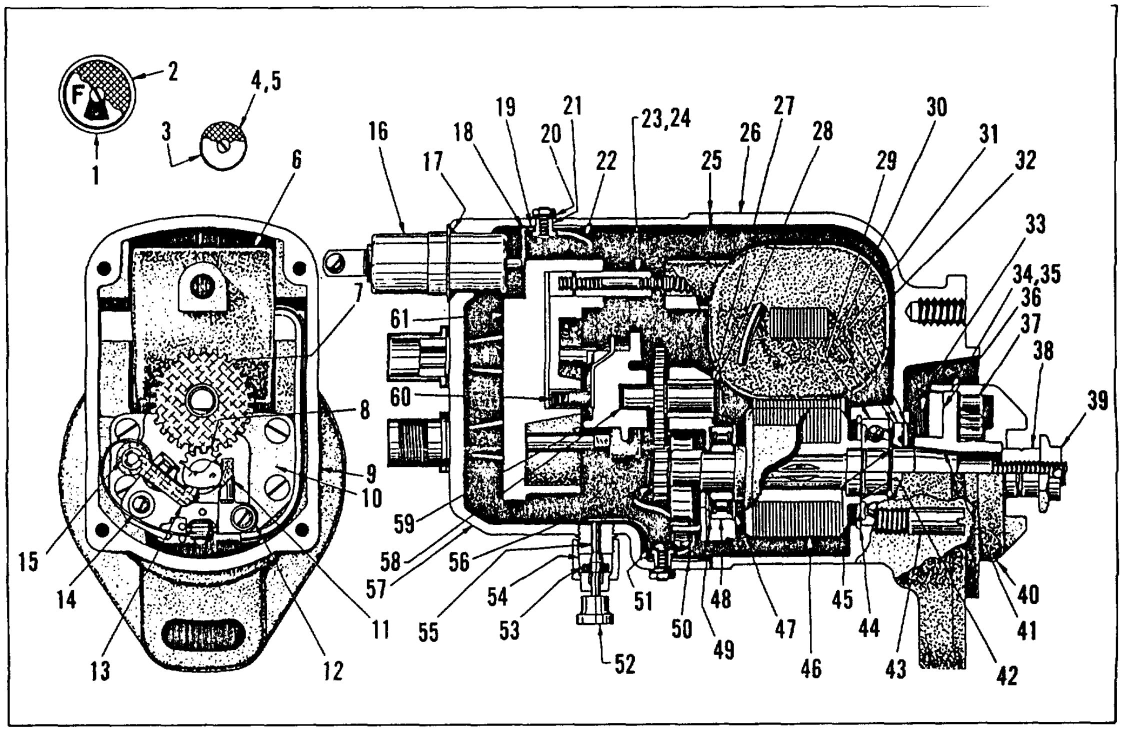


Fig. 55. MAGNETO - Fairbanks-Morse No. FM-XZE4B7-4, Wisconsin Motor No. Y-98-C-S2 per MIL-E-11275-C Specifications.

Item No.	Part Number	Description	No. Req'd.
1	A 1232	VENTCOVER	2
2	A 6032	VENT COVER SCREEN	2
3	B 6030 A	VENT COVER	2
4	C 6032 B	VENT COVER SCREEN	2
5	A 1233	VENT COVER COPPER WOOL	4
6	RS 2477 C	COI L	1
7	Q 5939	DISTRIBUTOR GEAR ASSEMBLY	1
8	Q 5852	ROTOR GEAR	1
9	B 1498 D	ROTOR DRIVE END SHAFT SNAP RING	1
10	UX 4631	BEARING SUPPORT	1
11	G 2788	CAM WICK and HOLDER	1
12	B 5969	CONTACT SUPPORT LOCKING SCREW PLATE WASHER	1
13	A 2437 A *	BREAKER ARM SUPPORT BRACKET and POINTS	1
14	D 2458	CONTACT SUPPORT LOCKING SCREW PLATE WASHER	1
15	C 1498 G	FULCRUM PIN SNAP RING	1
16	MX 2433 *	FEED-THRU CONDENSER	1
17	H 2473 *	CONDENSER "O" RING SEAL	1
18	K 2513	CONDENSER CONTACT	1
19	B 1355	GROUND STRIP GUIDE	1
20	D 2458	GROUND SWITCH SCREW PLATE WASHER	1
21	G 2457 A	GROUND SWITCH INSULATING BUSHING	1
22	K 2499 A	GROUND SWITCH WIRE ASSEMBLY	1
23	F 983 B	HIGH TENSION LEAD	1
24	D 1182	SUPPRESSOR INSULATOR	1
25	K 2498	END CAP to FRAME GASKET	

Fig. 55. MAGNETO (Cont.)

Item No.	Part Number	Description	No. Req'd.
26	WW 2425	HOUSING	1
27	D 5950 C	DISTRIBUTOR BEARING	1
28	G 1498	DISTRIBUTOR SHAFT SNAP RING	1
29	C 5949	ROTOR DRIVE END BEARING	1
30	A 2492 C	ROTOR DRIVE END SEAL INNER WASHER	1
31	G 3861	ROTOR DRIVE END SEAL	1
32	A 2492 A	ROTOR DRIVE END SEAL OUTER WASHER	1
33	S 5963	IMPULSE COUPLING PAWL SPRING	2
34	CZ 2563	COUPLING HUB ASSEMBLY	1
35	BW 2563 C	IMPULSE COUPLING, complete	1
36	Q 2566	COUPLING PAWL	2
37	E 2565	IMPULSE COUPLING DRIVE SPRING	1
38	F 2572	IMPULSE COUPLING BUSHING	1
39	M 2570	IMPULSE COUPLING NUT	1
40	Y 5957	IMPULSE COUPLING SHELL	1
41	3 K 1	KEY (ROTOR to IMPULSE COUPLING)	1
42	C 2723	ROTOR DRIVE END BEARING SHIM	2
43	S 2568	IMPULSE COUPLING PAWL STOP PIN	1
44	B 1498 B	ROTOR DRIVE END BEARING SNAP RING	1
45	B 1498 D	ROTOR DRIVE END SHAFT SNAP RING	1
46	TS 2480	MAGNETIC ROTOR	1
47	A 2492 C	ROTOR BEARING GREASE RETAINING WASHER	1
48	D 5949 A	ROTOR CAM END BEARING	1
49	E 2493	GREASE RETAINING WASHER	1
50	W 2514	GROUND SWITCH to CONTACT SUPPORT	1
51	H 2514	PRIMARY GROUND TERMINAL STRIP	1
52	LX 2514 C	GROUND SWITCH ASSEMBLY, complete	1
53	E 2513 A	GROUND SWITCH BUTTON SPRING	1
54	F 4373	GROUND SWITCH SPACER	1
55	HW 2514	GROUND SWITCH PLUNGER, NUT and BUTTON ASSY..................	1
56	D 1498	ROTOR GEAR SNAP RING	1
57	LY 2430 A	END CAP ASSEMBLY	1
58	A 2766	DISTRIBUTOR ROTOR SPRING CLIP	1
59	X 2765	DISTRIBUTOR ROTOR	1
60	E 2460 B	BRUSH and SPRING ASSEMBLY	1
61	L 2474 E *	DISTRIBUTOR BLOCK	1
		ITEMS NOT SHOWN	
	6S6N	VENTCOVERSCREW,6-32 x3/8	2
	10 S10 D	END CAP SCREW, 10 - 24 x 5/8	2
	10 S18 D	END CAP SCREW, 10 - 24 x 1-1/8	2
	6 S6 D	CONDENSER MTG. SCREW, 6 - 32 x 3/8..	2
	6 S6 Z	BEARING TERMINAL SCREW and LOCKWASHER, 6- 32 x3/8	1
	6 S6 U	CONTACT SUPPORT LOCKING SCREW and LOCK-WASHER, 6 - 32 x 3/8	1

Fig. 55. MAGNETO (Cont.)

Item No.	Part Number	Description	No. Req'd.
		ITEMS NOT SHOWN (Cont.)	
	8 S6 U	CONTACT SUPPORT LOCKING SCREW and LOCK- .... WASHER, 8- 32 x 3/8	1
	31 SS14 A	COIL BRIDGE SET SCREW, 5/16 - 24 x 7/8	2
	8 S8 D	DISTR IBUTOR BLOCK SCREW, 8 - 32 x 1/2	4
	6 S8 N	GROUND SWITCH TERMINAL SCREW LOCKWASHER	2
	6 LW 1	GROUND SWITCH TERMINAL SCREW LOCKWASHER	2
	6 N 1	GROUND SWITCH TERMINAL SCREW-NUT	2
	29-45	PAWL SNAP RING	2
	8 S6 G	BEAR ING SUPPORT SCREW, 8 - 32 x 3/8	4
	6 S4L	VENTCOVER SCREW, 6 - 32x 1/4	2
	SK 90	SERVICE KIT	1

* PARTS INCLUDED IN SERVICE KIT

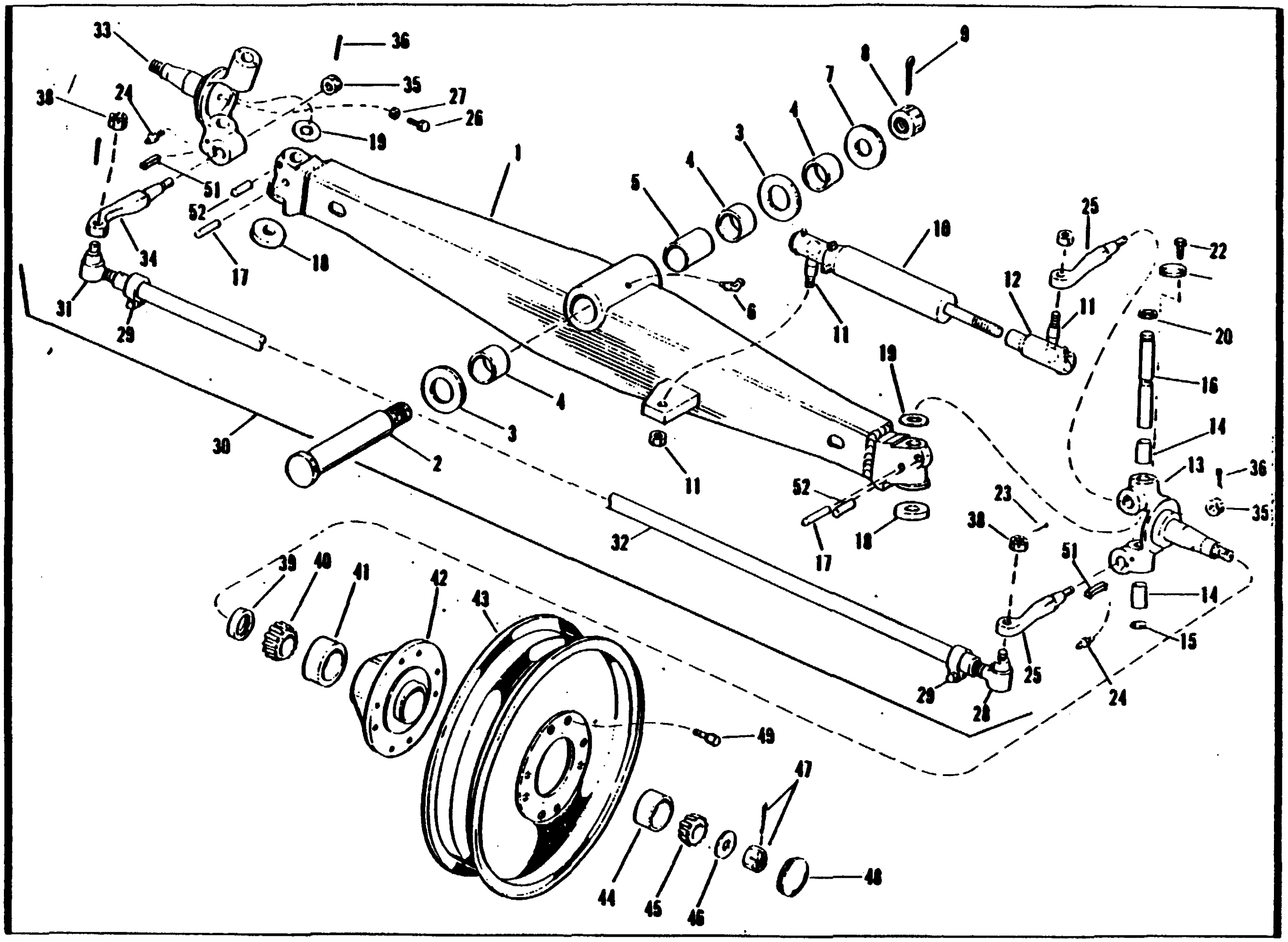


FIG. 56. FRONT AXLE ASEMBLY.

FRONT AXLE
FRONT AXLE KIT 102-9438-1 - ROCKWELL STANDARD #FC-901

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	502.6333-80	Front Axle	1	29	102-9438-32	End Clamp	2
2	102-3847-1	Pivot Pin		30	102-9438-28	Steering Cress & Tube Assy.	
3	102-8401-1	Thrust Washer	2			(includes Items 28-32, 37 and 38)	1
4	298-278-2	Inner Bushing	3	31	102-943-29	Rod End (L.H.)	1
5	102-8402-1	Spacer	1	32	102-9438-31	Cross Tube & Clamp	1
6	398-8000-11	Lube Fitting 1/8" - 90° - 11613B	1	33	102-9438-2	Steering Knuckle (L.H.) & Bushing	
7	398-20000-31	Cut Washer	1	I		(item 14)	1
8	398-11001-89	Slotted Nut IK-12	1	34	102-9438-24	Steering Arm (L.H.)	1
9	398-3000-33	Cotter Key 5/16" x 3"	1	35	102-9438-26	Steering Arm Nut	3
10	102-8404-1	Hyd. Cylinder (Ross IC36553-A2-650)	1	36	102-9438-27	Steering Am Key	3
11	102-1948-50	Ball Stud with 5/ -1a Slotted Nut,		37	- - - - -	Not Used	--
		1.25" Boll (Ross 142060-E-102649)	1	38	- - - - -	Nut 2	
12	102-1948-33	Socket Assy. w/Clamp for 1.25" Boll			298-3109-68	Oil Seal	2
		(Ross 1403572-A1-425)	2		298-3110-68	Wiper., O11 Seal	2
13	102-9438-3	Steering Knuckle (R.H.) & Bushing	1	39	298-3040-68	Retainer - Inner, Felt Oil Seal	2
14	102-9438-33	Bushing	4		298-3041-68	Retainer - Outer, Fell Oil Seal	2
15	102-9438-5	Pin Plug	2	40	298-338-2	Bearing Cone	2
16	102-9438-4	Steering Knuckle Pin	2	41	298-337-2	Bearing Cup	2
	102-9438-13	Pin Draw Key - Lower	2	42	402-1756-2	Hub, Front Wheel	2
17	102-9438-14	Pin Draw Key - Lower	2		602-4589-1	Wheel & Tire 9.00 x 24 - Includes	2
	102-9438- 15	Pin Draw Key - Lower	2	43	298-4019-47	Wheel 18-24	1
18	298-336-2	Thrust Bearing	2		298-6012-68	Tire - 8 Ply - 9.00 x 24	1
	102-9438-6	Shim	2		298-6013-68	Tube 9.00 x 24	1
	102-9438-7	Shim	2	44	298-126-2	Bearing Cup	2
19	102-1503.29	Shim	2	45	298-340-2	Bearing Cane	2
	102-9438-8	Shim	2	46	102-9438-21	Wheel Bearing Washer	2
20	102-9438-10	Dust Cop Gasket	2	47	102-1503-11	Nut, Wheel Bearing w/102-9438-22	
21	102-9438-9	Dust Cop	2			Cotter Pin	2
22	102-9438-11	Dust Cop Screw	4	48	298-4006-47	Hub Cap	2
23	102-1574 10	Cotter Pin, Boll Nut	2	49	298-4018-47	Wheel Bolt 5/8" (U.N.F.)	16
24	- - - - -	Lub. Fitting 1/8" - 11610	2	50	- - - - -	Not Used	--
25	102-9438-23	Steering Arm (R.H.)	2	51	102-9438-25	Key, Steeting Arm	2
26	102-9438-19	Slop Screw	2		102-9438-16	Pin Draw Key - Upper	2
27	102-9438-20	Nut 2		52	102-9438-17	Pin Draw Key - Upper	2
28	102-9438-30	Rod End (R.H.)	1		102-9438- 18	Pin Drew Key - Upper	2
				53	502-6114-80	Axle Support & Pivot (Not Illustrated)	1

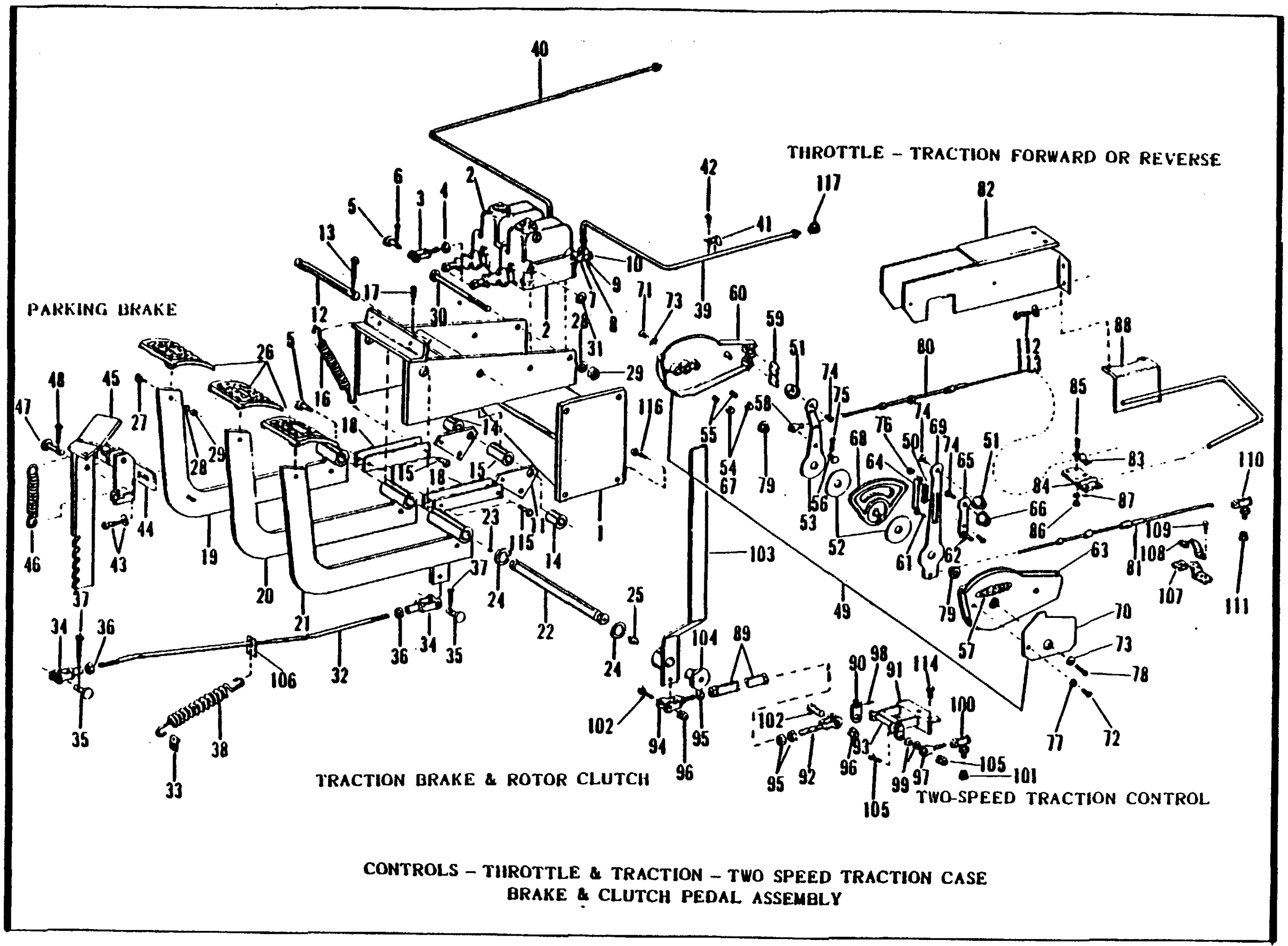


FIG. 57. CONTROLS.

CONTROLS - THROTTLE & TRACTION - TWO-SPEED TRACTION CASE
BRAKE & CLUTCH PEDAL ASSEMBLY

Item No.	Part Number	Description	No. Req'd	Item No.	Part Number	Description	No. Req'd
1	502-5622-80	Mounting Bracket	1	32	102-2960-1	Rod, Clutch Control	1
2	102-6228-1	Master Cylinder	2	33	102-1338-1	Spring Clip	1
3	102-1991-1	Male Yoke End	2	34	298-81-47	Yoke End	2
4	398-11000-40	Hex Nut 7/16" U.N.F.	2	35	298-80-47	Pin, Yoke End	2
S	298-80-47	Clovis Pin	4	36	- - - - -	Hex Nut, 7/16" U.N.F.	2
6	398-3000-8	Cotter Pin 3/32" x ¼"	6	37	- - - - -	Cotter Pin 3/32" x i"	2
7	298-5017-92	Copper Gasket	2	38	102-1411-1	Spring	1
8	298-5020-92	Connector	2	39	502-2089-81	Short Brake Line	1
9	298-5018-92	Copper Gasket	2	40	502-2089-80	Long Brake Line	1
10	298-5019-92	Connector Boll	2	41	298-59-47	Tube Clamp	4
11	102-1485-1	Bell Crank	2	42	398-10000-46	Rd. Hd. Machine Screw 110-24 x 5/8"	
12	102-1552-1	Drilled Pin	1			w/Nut & Lock Washer U.N.C.	4
13	398-13000-32	Cotter Pin 1/8" x 11/"	2	43	398-2001-79	Cap Screw 3/8" x 1/4" w/Nut, Cut	
14	102-1557-1	Spacer	2			Washer & Lock Washer U.N.C.	2
15	102-1557-2	Spacer	1	44	502-1744-80	Bracket	1
16	102-1891-1	Spring (Broke Pedals)	2	45	502-1745-80	Pedal	1
17	398-95003-51	Sot Screw 5/16" x 2" UN.C.	2	46	102-1891-1	Spring	1
	398-11000-18	Hex Nut 5/16" U.N.C.	2	47	102-1450-1	Rivet Pin	1
18	102-6246-1	Link, Bell Crank	4	48	398-3000-14	Cotter Pin 1/8" x I"	1
19	502-3880-81	Broke Lover (R.H.)	1	49	1024206-1	Control Assy., Engine & Hydrostatic	
20	502-3880-80	Broke Lever (L.H.)	1			Pump (Consists of Items 50 thru 79	
21	502-3880-82	Clutch Lover	1			Incl.)	1
22	102-1465-1	Pin, Broke & Clutch	1	50	1024206-11	Spring, Detent A1I4527	1
23	398-14005-67	Pipe Plug 1/4" N.P.T.	1	51	1026206-12	Knob, Black *A31812.1	2
24	298-8506-34	Retaining Ring	2	52	10246206-13	Broke Disc *A31984	2
25	398-8000-13	Grease Fitting #1627B	1	53	1024206-14	Shift Lever, Offset *A31994	1
26	402-1596-2	Foot Pedal	3	54	1024206-15	Broke Shoo *A32005	4
27	398-2001-82	Cap Screw 3/8" x 1I" U.N.C.	3	55	1026206-16	Broke Spring *A32006	4
28	398-20000-37	Lock Washer 3/8"	5	56	1024-206-17	Pin, Lover *A32023	2
29	398-11000-19	Hex Nut 3/8"	5	57	102-6206-18	Name Plate, Morse *A32724	2
30	398-2002-3	Cop Screw 3/8" x 6" U.N.C.	2	58	1024206-19	Throttle Pivot *A37639	2
31	61922-30	Shim, .030" Thick	2	59	102-6206-20	Clip, Cable Casing *A37953	2

CONTROLS - THROTTLE & TRACTION - TWO-SPEED TRACTION CASE BRAKIE CLUTCH PEDAL ASSEMBLY (Continued)

Item No.	Part Number	Description	No. Req'd
60	102-6206-21	Housing (R.H.) *A37954-1	1
61	1024206-22	Bushing *A392S7	2
62	1024206-23	Detent Bar *A39299	1
63	102-6206-24	Housing (L.H.) *A39301	1
64	1024206-25	Spring Guide *A39309	1
65	1024206.26	Plate, Tripper *A39316	1
66	1024206-27	Modified Knob *A39318	1
67	102-6206-28	Pressure Disc, Brake *A39319	2
68	102-6206-29	Separator Segment *B31813	1
69	102-6206-30	Lever, Modified *B39302	1
70	102-6206-31	Detent Plate *B39303	1
71	*- - - - -	Rd. id. Slot. Mach. Screw .-20 x 5/8" lg. (SST 18-8)	1
72	*- - - - -	Rd. Hd. Slot. Mach. Screw 1/4-20 x 5/8" lg. (SST 18-8)	
73	*- - - - -	Lock Washer , Internal Tooth ¼" (SST Type 430)	2
74	*- - - - -	Screw, Truss Hd. Slotted #10-24 x 5/8" lg. (SST 18-8)	3
75	*- - - - -	Cotter Pin 3/32" Dia. 1/2" lg.	2
76	*- - - - -	Rd. Hd. Much. Screw 310-24 x 5/8" (SST 18-8)	2
77	*- - - - -	Hex Nut #10-32 (SST 118-8)	2
78	*- - - - -	Rd. Hd. Much. Screw #10-32 x 1/2" lg. (SST 18-8)	2
79	102-6206-32	Bearing 5/8" I.D. Snap * 10L2-FF	1
80	298-155-47	Push Pull Cable Control 5' lg. (Throttle) (Morse Model 43C) Clamp Type Mounting, I/8" Core, .450" Flex Casing O.D., 3" Travel, 1/2-28 U.N.F. Threaded Ends	1

Item No.	Part Number	Description	No. Req'd
81	291-156-47"	Cable Control, Push Pull, Model 43C, 11' lg., Clamp Type Mig., 1/8" Core, .450" Flex. Casing O.D., 3" Travel 1/4-28NF2 Threaded Ends	1
	502-2065-80	Control Bracket	1
82	398-2001-54	C.S. 1/4" x 2-1/2" w/Nut & L.W. U.N.C.	2
	- - - - -	C.S. 5/16" x 1" w/Nut & L.W. U.N.C.	6
83	298-158-47	Cable Clamp	2
84	298-157-47	Bracket, Cable Clamp	1
85	398-1000-48	Rd. Hd. Mach. Screw #10-24 x 1/4' U.N.C.	10
86	- - - - -	Hex Nut #10-24 U.N.C.	10
87	- - - - -	Lock Washer #10	10
88	502-3869-80	Support, Throttle Cable	1
89	502-2235.80	Rod, Two-Speed Shifter (Traction)	1
90	102-6541-1	Lever	1
91	502-2234-80	Pivot Bracket	1
92	102-1970-1	End Yoke 1/2-13 U.N.C.	2
93	502-2248-80	Lever Assembly	1
94	102-1970-1	End Yoke -13 U.N.C.	1
95	- - - - -	Nut - 13 N.C.	1
96	298-2010-17	Conelock Hut ½-13 N.C.	2
97	102-6572-1	Rod End, Male	1
98	8-6002-34	Roll Pin 1/4" x 1-1/4"	1
99	Cut Washer	3/8"	2
100	X7887	Ball Joint Assembly 3/8" U.N.F.	1
101	298-2011-71	Conelock 3/8-24 U.N.F.	1
102	- - - - -	Cap Screw 1/2-13 x I-1/4"	2

CONTROLS - THROTTLE & TRACTION - TWO-SPEED TRACTION CASE BRAKE & CLUTCH PEDAL ASSEMBLY (Continued)

Item No.	Part Number	Description	No. Req'd
103	502-2060-80	Gear Shift Lever	1
104	102-6204-1	Special Nut	1
105	- - - - -	Cap Screw 3/8" x 1-1/2" U.N.C.	1
	298-2012-71	Conelock Nut 3/8-16 U.N.C.	1
106	102-1564-1	Stop - Clutch Pedal	1
107	298-2506-68	Asbestos Cloth (Cables)	2
108	298-30-47	Clamp	2
109	- - - - -	Cap Screw 1/4" U.N.C. x 1" w/ Nut & Lock Washer	4
110	X202821	Ball Joint 1/4" U.N.F.	1
111	- - - - -	Hex Nut 1/4" U.N.F.	1
112	- - - - -	Cap Screw 5/16" N.C. x 3/4" w/Lock Washer	10
113	12987-71	Lock Nut 5/16" N.C.	5
	- - - - -	Hex Nut 5/16" N.C.	5
114	- - - - -	Cap Screw 5/8" x 1-1/4" U.N.C.	2
115	102-6938-1	Pin - Clevis & Spring Anchor	2
116	- - - - -	Cap Screw 1/2" x 1-1/2" U.N.C. w/Nut, Lock Washer and Cut Washer	4
117	298-205362	Reducer Adapter	2

* Morse Instrument Co., Hudson, Ohio part numbers.

** Other end of Item 81 - use 298-276-2 rod end 1/4-28 N.F. female x 1/4" hole.

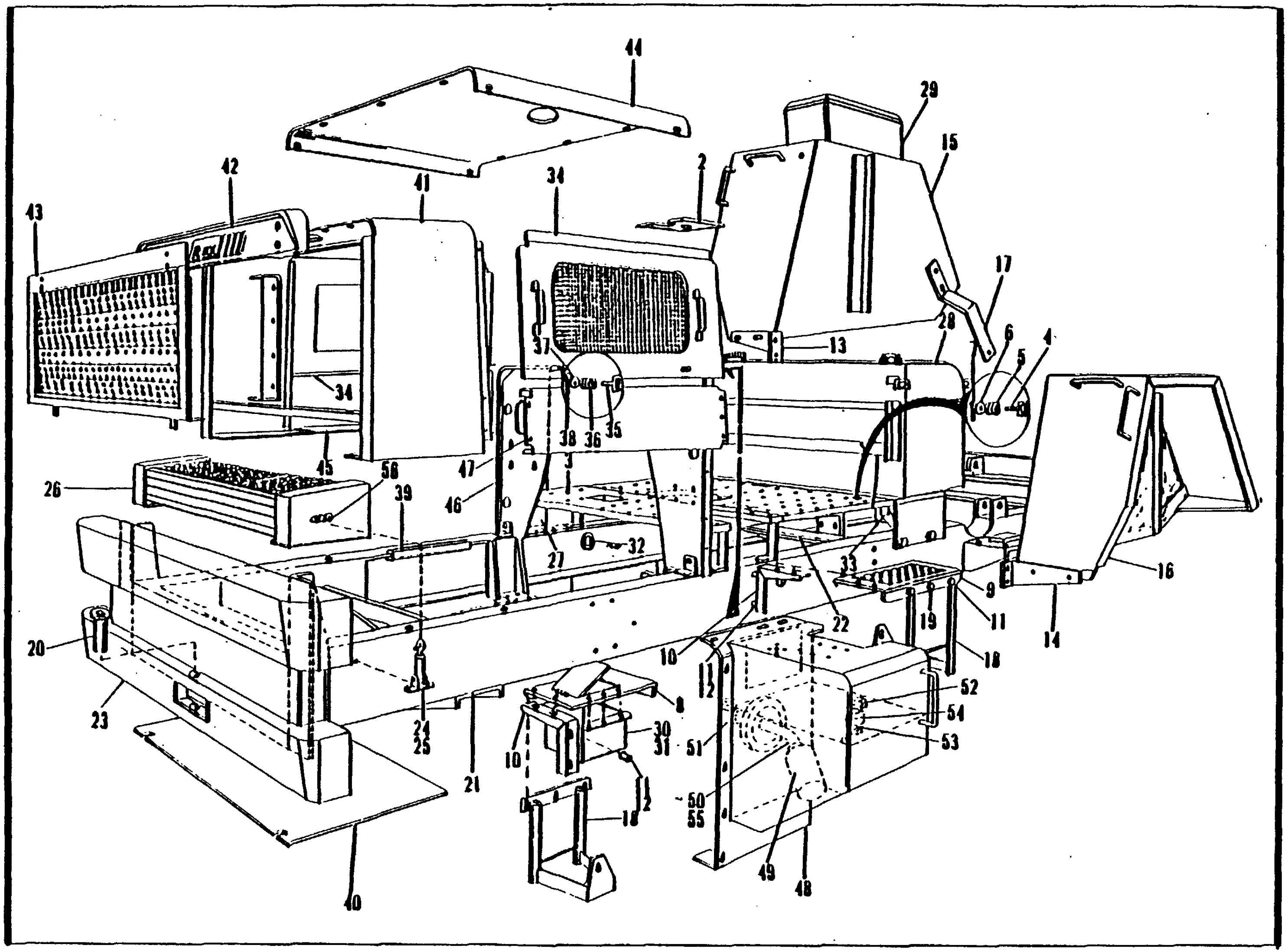


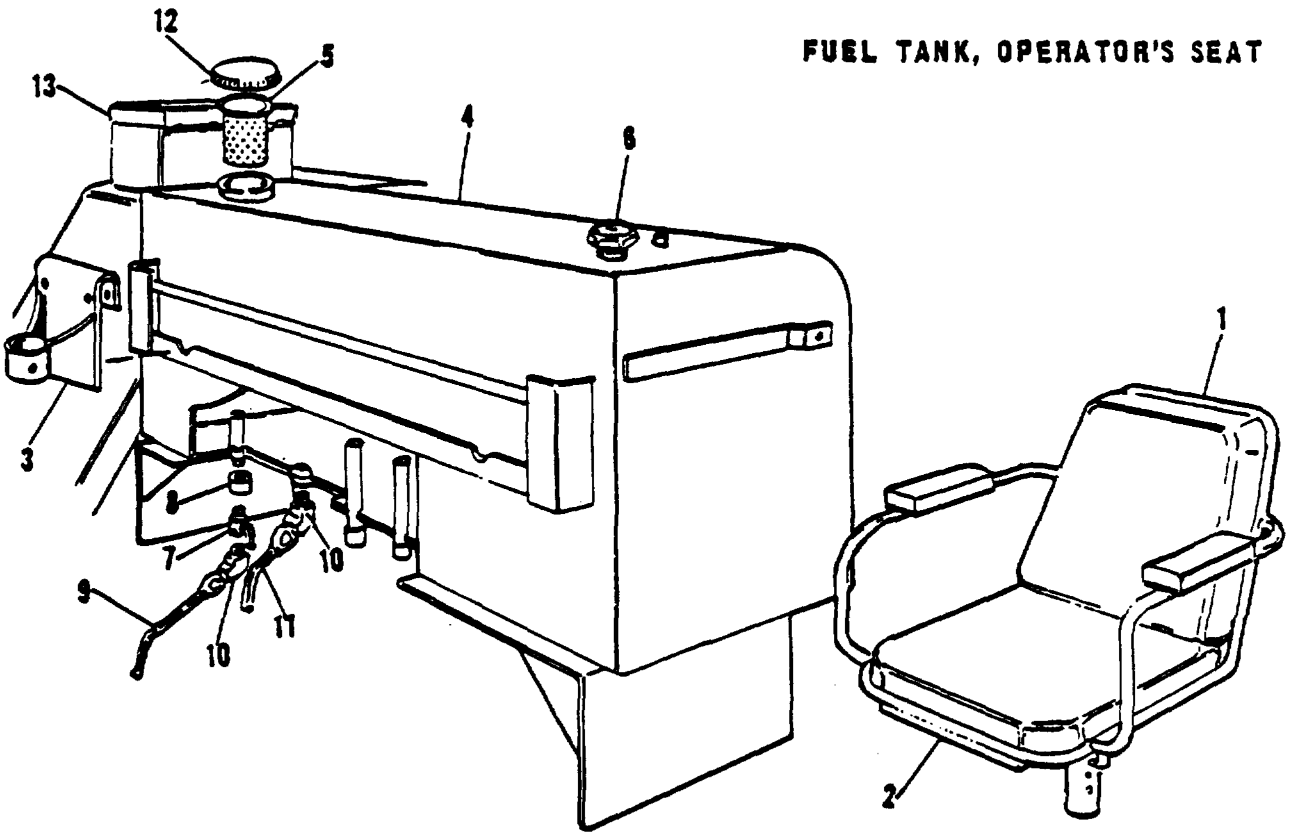
FIG. 58. MAIN FRAME, ENGINE HOUSE, FLOORBOARD AND FENDERS.

MAIN FRAME - ENGINE HOUSE - FLOORBOARD-
FENDERS

Item No.	Part Number	Description	No. Req'd
1	502-4672-80	Floorboard - Rear	1
2	102-3976-1	Door - Rear Floorboard	1
3	502-3858-80	Floorboard - Front	1
4	102-9607-2	Fastener	2
5	X6860	Spring	2
6	398-20000-88	Cut Washer 1/4'	2
7	398-3000-12	Cotter Pin 1/8 x 34"	2
8	502-4385-80	Running Board-(R.H.)	1
9	502-3672-80	Running Board - (L.H.)	1
10	102-30046-1	Support - Running Board	2
11	59591-5	Spacer	6
	398-2002-59	Capscrew 5/8 x 2"	4
12	398-20000-41	Lock Washer 5/8"	4
	398-11000-23	Hex Nut 5/8"	4
13	102-30045-1	Bracket -- Rear - Fender (R.H.)	1
14	102-30045-2	Bracket - Rear - Fender (L.H.)	1
15	502-6199-80	Fender (R.H.)-- Opposite Operator's Side	1
16	502-6199-81	Fender (L.H.) - Operator's Side	1
17	102-2673-1	Brace - Fender	2
18	502-4686-80	Ladder	1
19	398-2002-18	Capscrew 1/2 x 1½"	8
20	502-108-80	Hitch Pin - (Used on all Pulvi Mixer options - is in hole provided in pumping unit main frame on all fluid handling units)	
21	502-6115-80	Main Frame	1
22	502-3865-80	Bracket - Drive Axle & Pillow Block Support	1
23	398-2002-98	Cup Screw 3/4 x 2" NOT SHOWN	4
	398-20000-42	Lock Washer 3/4"Y	4
24	102-7742-1	Latch - Grille	2
	398-2001-58	Capscrew 5/16 x 3/4"	2
25	398-20000-64	Lock Washer 5/16"	2
	398-11000-18	Hex Nut 5/16"	2
26	502-5606-80	Grille- Hydrostatic Pump	1
27	502-4692-80	Hood Extension (R.H.)	1
28	502-6239-80	Fuel Tank - (Reference only - see separate illustration for Fuel Tank - Fuel Lines and Operator's Seat)	1
29	102-4222-1	Tool Box	1
30	502-3684-80	Battery Box	1
	398-2001-58	Capscrew 5/16 x 3/4"	6
31	398-20000-64	Lock Washer 1/16"	6
	398-1100018	Hex Nut 5/16"	6
32	298-5525-68	Grommet	
33	102-6197-1	Angle Bracket - (on fuel tank - for front floor board fastener)	2
34	502-3845-80	Hood Side Cover	2
35	102-9607-2	Fastener	4
36	X6860	Spring	4
37	398-20000-88	Cut Washer 1"	4
38	398-3000-12	Cotter Pin 1/8 x 3/4"	4
39	102-340-1	Channel Rubber	1
40	102-4596-1	Dust Shield	1
41	502-5603-80	Radiator Shell	1
42	402-2571-2	Top - Radiator Grill	1
43	502-3844-80	Radiator Grill	1
44	102-4654-1	Hood Top	1
45	102-2778-1	Panel - Hood Side (R.H.)	1

MAIN FRAME - ENGINE HOUSE - FLOORBOARD - FENDERS (Continued)

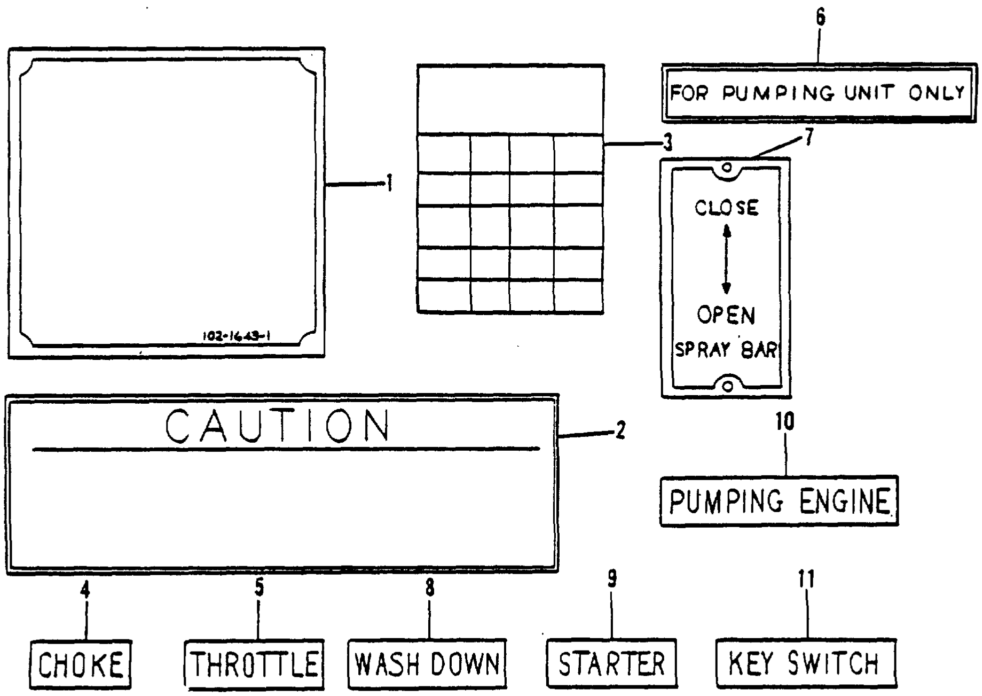
Item No.	Part Number	Description	No. Req'd
	502-3868-80	Firewall (used only on machines without fluid handling options -- HDS only)	
46	502-3868-82	firewall (used only on machines with fluid handling options)	1
47	102-2704-1	Panel -- Hood Side -- (L.H..)	1
48	502-5613-80	Oil Reservoir and Hood Extension	1
49	298-151-53	Sump Strainer -- 60 Mesh Monel -- (C.O. Jelliff Mfg. Corp. JI0-170-60) 1" N.P.T.F.	1
	502-3867-80	Inlet Flange and Pipe	1
	102-2864-1	Gasket -- Inlet Pipe Flange	1
50	298-23-93	Cap Screw	6
	398-20000-23	Cut Washer 3/8	6
51	298-2103-62	Union - Swivel Adapter - 90° Female 1 NPT' x Female 3/4” NPT (Imperial Eastman Corp. 60UG -- 16 x 12)	1
52	298-13014-86	Oil Level View Gauge: 3/4” NPT Threaded Type (Gits Bros. Mfg. Co. BW-20-4053)	1
53	398-14002--90	Close Nipple 3/4”	1
54	X7258	Breather (Air Maze FBOHS- 3/4” Pipe thread female)	1
55	398-20000-51	Copper Cut Washer 3/8" -- for Inlet Flange and Pipe	6
	X7176	Fastener Catch	2
	398-10000-39	Rd. Hd. Mach. Screw #10-32 x 1/2"	4
56	39811-11000-36	Nut #10-32	4
	398-2000-35	Lock Washer 3/16"	4
58	102-10801-1	Holder Manual	1
	398-10000-46	Machine Screw, #10-24 x 5/8" Lg. Rd. Hd.	4
	298-2026-71	Lock Nut #10-24	4
	102-10802-1	Label, Manual	1



FUEL TANK - SUCTION & RETURN FUEL LINES
OPERATOR'S SEAT - TOOL BOX

Item No.	Part Number	Description	No. Req'd
1	102-9189-1	Operator's Seat	1
2	102-9190-1	Slide - Operator's Seat	1
3	502-4735-80	support Operator's Seat ·	1
4	502-6239-80	Fuel Tank	1
5	298-5010-92	Strainer - Fuel	1
6	102-9217-1	Fuel Gauge	1
7	298-5010-92	Two Way Cock	1
8	102-9217-1	Pipe Coupling	1
9	102-2759-1	Hose Assembly - Section - Fuel Line	1
10	298-2069-62	Adapter Union	2
11	102-2759-1	Hose Assembly - Return Fuel Line	1
12	2989-34-47	Gas Tank Cap	1
13	102-4222-1	Tool Box	1

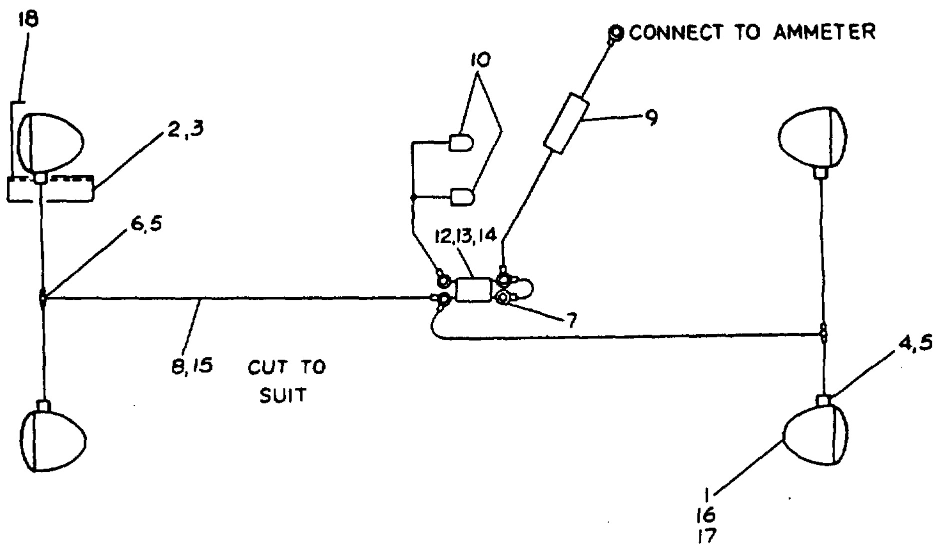
FIG. 59. FUEL TANK FOR DIESEL ENGINE AND OPERATOR'S SEAT.



DECALS AND LABELS
REX SELF PROPELLED PULVI MIXER

Item No.	Part Number	Description	No. Req'd
1	102-1643-1	Instruction Plate - Pump Engine Shifting	1
2	102-30088-1	Caution Label for Meter Lines	1
3	102-8901-1	Application Reference Chart - HD.S.-A	1
4	102-8905-1	Decal Label "Choke"	1
5	102-8904-1	Decal Label "Throttle"	1
6	102-8813-1	Decal Label "For Pumping Unit Only"	1
7	102-65 14-1	Spray Bar Control Plate	1
8	102-8903-1	Decal Label "-Wash Down"	1
9	102-8906-1	Decal Label "Starter"	1
10	102-8902-t	Decal Label "Pumping Engine"	1
11	102-8907-1	Decal Label "Key Switch"	1

FIG. 60.



WIRING SCHEMATIC - LIGHTING

Item No.	Part Number	Description	No. Req'd
1	298-1205-17	Lamp	4
2	102-31147-1	Bracket	1
3	102-31147-2	Bracket	1
4	298-26086-17	2-Way Bullet Splice	2
5	298-26085-17	Bullet Terminal	14
6	298-26087-17	3-Way Bullet Splice	2
7	- - - - -	Ring Terminal, #5 Stud, # 14 Wire	6
8	398-95002-93	#14 Plastic Coated Wire, Orange	50 ft.
9	602-10238-1	Fuse Assy., 10OA	1
10	298-12113-17	Dash Light	2
11	2984518-68	Nylon Tie Strap	16
12	298-6123-17	Switch	1
13	102-9220-1	Label	1
14	298-52-17	Toggle Seal	1
15	398-95002-94	Loom 1/4"	50 ft.
16	398-11000-4	Nut 1/2", Plated	4
17	398-20000-39	Lock Washer 1/2"	4
18	298-356-47	Light Protector	4

FIG. 61. WIRING SCHEMATIC - LIGHTING.

SECTION 3 PARTS INDEX

SECTION 4

SUPPLEMENTAL OPERATING, MAINTENANCE AND REPAIR PARTS INSTRUCTIONS

FOR

MIXER, ROTARY TILLER, SOIL STABILIZATION: MODEL HDS-E

TABLE OF CONTENTS

Table of Contents (Continued)

SUBSECTION I

GENERAL

1-1. Purpose. To provide user and support personnel supplemental maintenance and repair parts instructions that have special application to commercial construction equipment items.

1-2. Scope. This publication applies to Department of the Army units, organizations and activities that use and/or support the Mixer, Rotary Tiller; Model HDS-E, NSN 3895-01-141-0882.

1-3. Description. The Self-Propelled Rotary Tiller consists of a 4-71 Detroit Diesel Engine, Hydrostatic Drive Transmission, and a 4 Cylinder Air-Cooled gasoline engine driven emulsion/asphalt pump, mounted on a pneumatic tired tractor frame.

1-4. Operational Concept. The Hydrostatic Self-Propelled Stabilizer is a heavy duty machine designed specifically for use in pulverizing the subgrade prior to addition of a suitable binder, or blending in the case of purely mechanical stabilization.

1-5. Procurement Status. The procurement contract number is DAAEO7-82-C-6328 and was awarded on 20 Aug 82 for a total of 14 units.

1-6. Equipment Publications.

a. Initially two sets of manufacturer's commercial publications will be overpacked and shipped with each Mixer, Rotary Tiller (reference Appendix A).

b. The overpacked publications are located in the tool box attached to the Mixer, Rotary Tiller.

c. Additional commercial manuals may be obtained by requisitioning from Defense Construction Supply Center, DCSC. Requisitions to DCSC should be prepared in the same manner as for part numbered repaired parts, using the Federal Supply Code for manufacturer's FSCM and manual numbers listed in Appendix A. If DD Form 1348-6 is used, mail it directly to Commander, DCSC, ATTN: DCSC-OSR, Columbus, OH 43215.

d. If additional assistance is required, contact the address in paragraph 1-11 of this publication.

1-7. Personnel and Training.

a. MOS Requirements:

(1) Operator: 62J General Construction Equipment Operator

(2) Organizational Maintenance: 62B, Construction Equipment Repairman.

(3) Direct and General Support Maintenance: 62B, Construction Equipment Repairman; 63G, Fuel and Electrical Systems Repairman, 44B Metal Body Repairman.

1-7. Personnel and Training. (cont'd)

b. New Equipment Training: New Equipment Training Teams (NETTs) are available to major field commands. Requests for NETTs should be forwarded to: Commander, US Army Tank-Automotive Command (TACOM) ATTN: AMSTA-MLT, Warren, MI 48090. Training teams should be requested only when trained personnel are not available in the command to operate and/or maintain the Rotary Tiller.

1-8. Load Classification. The Military Load Classification (MLC) of the Self-Propelled Mixer Rotary Tiller is MLC 9 for both highway and cross-country modes.

1-9. Logistics Assistance.

a. Tank-Automotive Command's Field Maintenance Technicians (FMTs) stationed at CONUS and OCONUS installations will be fully qualified and available to furnish on-site training and/or assistance concurrent with receipt of the Rotary Tiller.

b. Assistance can be obtained by contacting the Logistics Assistance Office listed in AR 700-4.

1-10. Warranty. The Rotary Tiller contractor warrants the products furnished under this contract according to the terms and conditions described in the equipment publications and Appendix B of this publication. All warranties furnished to the Rotary Tiller contractor by subcontractors of assemblies or components utilized in the manufacture of the end item will be extended to the Government. See Appendix B for warranty guidelines.

1-11. Reporting. You can improve this publication by recommending improvements, using DA Form 2028 (Recommend Changes to Publications and Blank Forms) and mail direct to: Commander, US Army Tank-Automotive Command, ATTN: AMSTA-MBS, Warren, MI 48090.

SUBSECTION II

MAINTENANCE

2-1. Maintenance Concept. The Rotary Tiller will not require any new or special maintenance considerations. All maintenance functions can be accomplished within the current maintenance concepts established for construction equipment.

a. Operator/Crew Maintenance: Operator and crew maintenance is limited to daily preventive maintenance checks and services.

b. Organizational Maintenance: Organizational maintenance consists of scheduled preventive maintenance services, minor repairs and adjustments.

c. Direct Support Maintenance: Direct support maintenance consists of repairs on-site or in a direct support unit's shops. Repairs are accomplished with a minimum of tools and test equipment. Upon completion of repairs to an end item or component, they are returned to the user.

d. General Support Maintenance: General support maintenance overhauls selected assemblies and repairs items designated by the area support Command for return to stock.

e. Depot Maintenance: Depot maintenance overhauls end items and selected major assemblies when they are required to satisfy overall Army requirements. Overhaul of the end item may also be performed by contract with the manufacturer.

2-2. Maintenance Allocation Chart. Maintenance will be performed as necessary by the category indicated in the Maintenance Allocation Chart (MAC) (Appendix C) to retain or restore serviceability. All authorized maintenance within the capability of a using organization will be accomplished before referring the item to support maintenance. Higher categories will perform the maintenance functions of lower categories when required or directed by the appropriate Commanders. Using and support units may exceed their authorized scope and functions in the MAC when approval is granted by the next higher support maintenance Commander.

2-3. Modifications. Modifications will be accomplished by the end item manufacturer after TACOM's approval of the field campaign or modification plan. See Appendix D.

2-4. Equipment Improvement Recommendations (EIR). Equipment Improvement Recommendations will be submitted in accordance with TM 38-750.

2-5. Equipment Readiness Reporting. Readiness Reporting will be accomplished in accordance with TM 38-750.

2-6. Maintenance Expenditure Limits. The average life expectancy for the Mixer, Rotary Tiller is 14 years.

PERCENT OF REPAIR	YEAR
65%	1987
55x	1988
50%	1990
35%	1992
30%	1993
20%	1994
10%	1995

2-7. Shipment and Storage.

a. Shipment and Storage: Refer to TB 740-97-2 for procedures covering preservation of equipment for shipment and storage.

b. Administrative Storage: Refer to TM 740-90-1 for instructions covering administrative storage of equipment.

2-8. Destruction to Prevent Enemy Use. Refer to TM 750-244-3 for procedures covering destruction of equipment to prevent enemy use.

2-9. Fire Protection.

a. A hand operated fire extinguisher may be installed by the using unit.

b. Approved hand-portable fire extinguishers are listed in TB 5-4200-200-10.

2-10. Basic Issue Items List (BIIL). See Appendixes E and F for a list of items which accompany the end item or are required for operation and/or operator's maintenance.

2-11. Maintenance and Operating Supply List. See Appendix H for a list of maintenance and operating supplies required for initial operation.

2-12. Special Tools and Equipment. See Appendix C, Section III for the special tools or equipment that are required for operation and maintenance of the Mixer, Rotary Tiller.

2-13. Maintenance Forms and Records. Operational, maintenance, and historical records will be maintained as required by the current TM 38-750.

SUBSECTION III

REPAIR PARTS SUPPLY

3-1. General.

a. The basic policies and procedures in AR 710-2, AR 725-50, FM 38-725-50, and DACIR 700-81-1 are applicable to repair parts management for construction equipment.

b. Manufacturer's part manuals are initially furnished for the Rotary Tiller instead of Department of the Army Repair Parts and Special Tool List (RPSTL). The RPSTL will be available approximately one year after the equipment fielding date.

c. National Stock Number (NSNs) are initially assigned only to PLL/ASL parts and major assemblies, i.e., engine, transmissions, etc. Additional NSNs will be assigned by the supply support activities for inclusion into the RPSTL.

d. Automated Processing (AUTODIN) of Federal Supply Code Manufacturer (FSCM) part number requisitions, without edit for matching NSNs and exception data, is authorized.

e. Proper use of project codes and weapons systems designator codes on parts requisitions is essential.

f. Repair parts are available from commercial sources and may be purchased locally in accordance with AR 710-2 and AR 735-110.

g. Initial Prescribed Load List (PLL) and Authorized Stock List (ASL) will be distributed by US Army Tank-Automotive Command (TACOM), ATTN: AMSTA-FH.

3-2. Prescribed Load List (PLL). The PLL distributed by TACOM is an estimated 15 days supply recommended for initial stockage at organizational maintenance. Management of PLL items will be governed by the provisions of AR 710-2 and local command procedures. Selection of PLL parts for shipment to CONUS/OCONUS units is based upon the receiving command's recommendation after their review of the TACOM prepared list. Organizations and activities in CONUS/OCONUS will establish PLL stocks through normal requisitioning process.

3-3. Authorized Stockage List (ASL). The ASL distributed by TACOM is an estimated 45 days supply of repair parts for support units and activities. The ASL parts will be shipped according to the recommendations of the receiving commands, after they have reviewed the initial list distributed by TACOM. Support units and activities in CONUS/OCONUS will establish ASL stocks through normal requisitioning process.

3-4. Requisitioning Repair Parts.

a. Using Units/Organization: Requisitions (DA Form 2765 Series) will be prepared according to AR 710-2 and local command directives. Units in CONUS will use Project Code "BGW" in block 19. Units OCONUS will enter in block 19 Project Code "JZC", see Appendix I.

b. Support Units and Activities:

(1) General: All MILSTRIP requisitions (DD Form 1348 Series) prepared for repair parts support will include distribution and Project Codes, see Appendix I.

(2) Distribution Code: Supply customers in CONUS will use code "F" in card column 54. Customers OCONUS will use the appropriate code from Appendix P, paragraph P-3, AR 725.50.

(3) Project Codes: The applicable Project Code will be entered in card columns 57-59 of requisitions for NSN parts, whether CONUS or OCONUS customers. Project Code "BGW" will be used by CONUS customers when requisitioning part numbered parts. Supply customers OCONUS will use Project Code "JZC" for part numbered parts.

3-5. Submitting Requisitions.

a. Using Units and Organizations will submit DA Form 2765 Series requisitions to designated support units or activities in accordance with local procedures.

b. Support units and activities will forward MILSTRIP requisitions for NSN parts through the Defense Automated Addressing System (DAAS) to the managing Supply Support Activity. Requisitions for part numbered parts will be forwarded through DAAS to the Defense Construction Supply Center (DCSC).

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 A05/AOE requisitions (DD Form 1348-6) and mail it to : Commander, Defense Construction Supply Center, ATTN: DCSC-OSR, Columbus, OH 43215.

APPENDIX A

EQUIPMENT PUBLICATIONS

DA EQUIPMENT PUBLICATIONS		
NOMENCLATURE	EQUIPMENT PUBLICATION NUMBER	DATE
Utilization of Engineer Construction Equipment: Volume A	TM5-331A NOTE Supervisors and operators should refer to TM5- 331A to get the most use from this equipment.	Aug 67

OTHER THAN OFFICIAL DA EQUIPMENT PUBLICATIONS			
NOMENCLATURE	EQUIPMENT PUBLICATION NUMBER OR TYPE	DATE	SOURCE OF SUPPLY
Instruction manual Rotary Tiller Mixer (Operation and Maint-enance)	(FSCM 61361) SP 358	Apr 83	DCSC
Supplemental Operating Maintenance and Repair Parts Instructions	SOMARPI 5-3895-359	Apr 83	TACOM

APPENDIX B

WARRANTY GUIDELINES

1. A warranty period of 15 months applies to the Rotary Tiller, Model HDS-E, manufactured by Rexworks Inc., after delivery to the Government. This warranty applies to the end item, components and all supplies furnished under the contract.

2. Using units may not contact their local dealer. You must mail DA Form 2407 to the Maintenance Directorate, TACOM, at the following address: US Army Tank-Automotive Command, ATTN: AMSTA -MVB, Warren, MI 48090. To expedite actions you may call the information to AUTOVON 786-7439, 7358, or 8297, with the information from your DA 2407, section 1, block 1 through 11 and blocks 16, 17, 18
and 20.

3. General Information:

a. DA Form 2407 (prepared in accordance with warranty claim action 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 and/or warranty statement included in the operator's and maintenance manual for the end item. <u>All warranty actions</u> settled or unsettled <u>will be reported to the National Maintenance Point(NMP)</u> on DA Form 2407. For warranties settled locally the DA Form 2407 will contain a statement "For Information Only" in block 16a.

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(NMP) (US Army Tank-Automotive Command, ATTN: AMSTA-MVB, AUTOVON 786-7439, 786-7358, 786-8297, 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.

APPENDIX B (Cont'd)

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 changes, 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, 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 pick up 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 problem trend evaluation by the NMP and must be identified upon completion of warranty services.

f. Telephone the NMP at TACOM, AUTOVON 786-7439, 786-7358 and/or 786-8297, 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 dealer's 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. During the Warranty Period: Quality Deficiency Report (EIR/QDR) SF 368, will be limited to the reporting of "equipment failure in design" which poses a threat to operator safety or which detracts from the operational capability and for reporting of "delays exceeding 20 days" (from contractor notification) in completing requested warranty service or "unsatisfactory workmanship" resulting in user dissatisfaction with such service.

APPENDIX C

MAINTENANCE ALLOCATION CHART
FOR
MIXER, ROTARY TILLER, SELF-PROPELLED
REXWORKS MODEL HDS-E
COMMERCIAL CONSTRUCTION EQUIPMENT (CCE)

Section I Introduction

1. General: This Maintenance Allocation Chart (MAC) designates responsibility for performance of maintenance functions to specific maintenance categories.

2. Maintenance Functions: Maintenance functions will be limited to and defined as follows:

a. Inspect: To determine the serviceability of an item and detect incipient failure by comparing its physical, mechanical and/or electrical characteristics with established standards through examination.

b. Test: To verify serviceability and detect incipient failure by measuring the 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 comparison of two instruments, one 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 replacing, 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 subassembly) for an unserviceable counterpart.

e. Repair: The application of maintenance services (inspect, test, service, adjust, align, calibrate, or replace) or other maintenance actions (welding, grinding, riveting, straightening, facing, remachining, or resurfacing) 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.

k. Rebuild: consists of those services/actions necessary for the restoration of unserviceable equipment to a like new condition in accordance with original manufacturing standards. Rebuild is the highest degree of material maintenance applied to Army equipment. The rebuild operation includes the act of returning to zero those age measurements (hours/miles, etc.) considered in classifying Army equipment/components.

3. Column Entries: Columns used in the Maintenance Allocation Chart and-entries for these columns are explained below:

a. Column 1; Group Number: Column 1 lists group numbers, the purpose of which is to identify components, assemblies, subassemblies, and modules with the next higher assembly.

b. Column 2; Component/Assembly: 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 formed 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 the 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, troubleshooting 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 alphabetical code which leads to the remark in Section IV, Remarks, which are pertinent to the item opposite the particular code.

Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
01	ENGINE								
0100	Engine Assembly Diesel	Inspect	.5					1,2,3	G
	Service			2.					
	Replace				16.				
	Repair				21.				
	Overhaul					48.			
	Engine Mounts	Inspect		.5					
		Replace			3.				
0101	Crankcase, Block Cylinder Head								
	Crankcase	Replace	15.	1,2					
	Cylinder Head	Replace			4.				
		Repair			4.				
		Overhaul				8.			
	Cylinder Liner	Replace				3.			
0102	Crankshaft	Replace				5.	1,2		
		Repair				2.			
	Bearings and Seals	Replace				4.			
	Dampers and Pulleys	Replace			2.				
0103	Flywheel Assembly	Replace			3.	1,2			
	Housing Flywheel	Replace			1.				
	Repair					2.			
0104	Pistons, Connecting Rods							1,2	
	Rings, Pins	Replace				3.			
	Retainers, Bearings, Connecting Rods	Replace				.5			
0105	Valves, Camshafts & Timing System							1,2	

*The subcolumns are as follows:

C--operator/crew F--direct support D-depot
O--organizational H--general support

Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0105	(Cont'd)								
	Valves and Seats	Adjust		2.0					
		Replace			1.0				
		Repair			2.0				
	Springs	Replace			.3				
	Rocker arms, Tappets	Adjust		.5					
		Replace			.5				
	R6ds, Push	Replace			.5				
	Lifter Assembly	Replace				1.0			
	Cover	Replace		.5					
		Repair			.5				
	Camshaft and Bearings	Replace				4.0			
	Timing Gear, Idler Gear	Replace				4.0			
0106	Engine Lubrication System							1,2	
	Oil Pump Assembly	Replace				.8			
		Repair				2.0			
	Oil Filter Element	Replace		.5					
	Oil Cooler	Replace			1.0				
		Repair				2.0			
	Pressure Regulator	Adjust			.2				
		Replace				1.0			
	Relief Valve	Replace			.5				
	Breather Crankcase	Inspect		.1					
		Replace		.2					
	Oil Pan	Replace			1.5				
		Repair				1.0			
	Lines and Fittings (ext)	Replace		.5					
	Gage Level	Replace		.1					
	Lines and Fittings (int)	Replace			1.0				

*The subcolumns are as follows:
C--operator/crew F--direct support D--depot
O--organizational H--general support

Section II MAINTENANCE LOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0108	Manifolds							1,2	
	Exhaust	Replace		1.0					
	Heat Control & Gaskets	Inspect		.2					
		Replace		1.0					
0109	Accessory Drive	Replace-			1.5				
0110	Diesel Starting Controls & Conversion Units							1.2	
	Valves, Guides, Levers,	Inspect		.2					
	Seals, Controls, Fit- tings, Lines, Devices	Replace			1.0				
02	CLUTCH								
0200	Clutch Assembly							1,2	
	Disk, Pressure & Drive	Adjust		.5					
	Plates	Replace			4.0				
	Facing, Lining, Hubs, Shafts	Replace			2.5				
	Bearings	Replace			1.0				
03	FUEL SYSTEM								
0301	Fuel Injector	Replace			1.0			1,2,5	
		Repair				2.5			
		Adjust			.7				
0302	Fuel Pumps								
	Fuel Transfer Pump	Replace		1.0					
		Repair				1.0			
	Lines, Fittings (Low	Inspect		.1					
	Pressure)	Replace		.5					
0304	Air Cleaner							1	
	Pipe, Hose, Clamps	Inspect	.1						
		Replace		.5					

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C--operator/crew F--direct support D-depot
O--organizational H--general support

Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0304	Air Cleaner (cond't)								
	Filter Element	Inspect	.4						
		Replace		.5					
0305	Turbocharger or Blower	Replace			2.5			1,3	
		Repair				3.0			
	Piping, Rotor, Bearings Shafts	Replace				2.5			
0306	Tanks, Lines, Fittings							1,2	
	Manifold Fuel Tank,	Inspect		.2					
	Fuel Manifolds	Replace			1.5				
		Repair				2.0			
	Hose, Valves, Fittings	Replace		1.0					
	Cap	Inspect	.1						
		Replace		.2					
0308	Engine Speed Governor and Controls							1,2	
	Governor Assembly &	Adjust			.5				
	Drive	Replace			1.0				
		Repair				2.0			
	Linkage, Rods and	Adjust		.5					
	Controls	Replace		.5					
0309	Fuel Filters							1	
	Filters, Strainers	Inspect	.2						
		Replace		.5					
		Repair			.5				
	Filter Elements	Inspect	.2						
		Replace		.5					
0311	Engine Starting Aid							1	
	Discharger Assembly	Replace		.5					
	Lines, Sleeves, Nozzle	Inspect		.2					
	Fittings	Replace		1.0					

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0312	Accelerator, Throttle								
	or Choke Control	1							
	Accelerator & Hand	Adjust		.5					
	Control	Replace		1.0					
04	<u>EXHAUST SYSTEM</u>							1	
0401	Muffler and Pipes								
	Muffler, Pipe, Cap,	Inspect	.2						
	Gasket	Replace		1.5					
05	<u>COOLING SYSTEM</u>							1,2	
0501	Radiator, Evaporative								
	Cooler or Heat								
	Exchanger								
	Radiator and Core	Inspect	.2						
		Replace		2.0					
		Repair			2.0				
	Guard, Grille, Frame	Replace		1.0					
		Repair			1.0				
	Cap	Inspect	.1						
		Replace		.3					
0502	Cowling, Deflectors, Air	Replace		1.0				1	
	Ducts, Shrouds & Plates	Repair			1.5				
Q503	Water Manifolds, Headers								
	Thermostats							1,2	
	Manifold-	Replace		1.0					
	Thermostat	Replace		1.0					
	Lines, Fittings, Hoses	Inspect	.2						
	and Clamps	Replace		.5					
0504	Water Pump							1,2	
	Pump, Water	Replace		2.0					
		Repair				1.0			

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0504	Water Pump (Cond't)								
	Hoses, Clamps	Replace		.5					
0505	Fan Assembly							1	
	Fan	Replace		1.0					
	Belt	Inspect	.1						
		Adjust		.5					
		Replace		1.0					
	Pulley	Replace			2.0				
06	<u>ELECTRICAL SYSTEM (ENGINE AND VEHICULAR)</u>								
0601	Generator, Alternator	Test		.5				1,2,4	
		Replace		.6					
		Repair			1.5				
	Belt	Inspect	.1						
		Adjust	.5						
		Replace			1.0				
0602	Generator Regulator (Voltage)							1,2,4	
	Regulator, Generator	Test		.5					
		Replace		.6					
		Repair			1.0				
0603	Starting Motor							1,2,4	
	Starter	Test		.5					
		Replace		1.0					
		Repair			1.5				
	Brushes	Replace			.3				
0607	Instrument or Engine Control Panel							1,4	
	Instruments, Switches, Circuit Breakers	Replace		.5					
	Gages, Electrical	Replace		.3					
	Lamps								

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0607	Instrument or Engine Control Panel (Cond't)								
	Hourmeter	Replace		1.5					
	Wiring	Replace			1.0				
		Repair	.	5					
0609	Light							1,4	
	Headlight	Replace		.3					
	Floodlight	Replace		.3					
	Stop & Taillight	Replace		.3					
	Turn Signal	Replace		1.0					
		Repair		1.5					
0610	Sending Units and Warning Switches							1,4	
	Temperature & Pressure Type	Replace		.5					
0612	Batteries, Storage (Wet or Dry)							1,4	
	Batteries, Cables	Service	.2						
		Replace		.5					
	Boxes, Bars, Nuts, Bolts	Replace		.5					
0615	Radio Interference Suppression Components	Replace		.5				1,4	
07	<u>TRANSMISSION</u>							1,2	
	Transmission 2-Speed	Service		.5					
	Travel & Motor Drive	' -Replace			4.				
		Repair				20.			
	Transmission Shafts	Replace				1.0			
	Bearings, Gears and Shafts	Replace				2.5			

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0703	Transmission Clutch and Clutch Controls	Adjust		.5	1,2				
		Replace		1.0					
		Repair			1.5				
07Q4	Transmission Top Cover Assembly	Replace			4.0	1,2			
09	PROPELLER AND PROPELLER SHAFTS								
0900	Propeller Shafts	Replace		1.0	1.0			1	
	Universal Joints	Replace		2.5	2.5				
	Shafts	Replace		2.0	2.0				
10	FRONT AXLE								
1000	Front Axle Assembly							1,2	
	Axle Assembly	Replace				4.5			
		Repair				2.0			
11	REAR AXLE								
1100	Rear Axle Assembly	Service		1.0				1,2	
		Replace				12.5			
		Repair				3.0			
1102	Differential							1,2	
	Differential Assembly								
	Gears	Replace				5.0			
	Pinions, Shafts, Carriers	Replace				2.0			
1103	Planetary or Final Drive							1,2	
	Bearings, Shafts, Seals, Gears, Cap	Replace			3.0				

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
12	BRAKES								
1202	Service Brakes	Replace			5.0			1,2	
		Repair			3.0				
1204	Hydraulic Brake System							1,2	
	Master Cylinder	Service		.5					
		Replace		2.0					
		Repair			1.0				
	Wheel Cylinder	Replace			3.0				
		Repair			1.0				
	Lines, Fittings, Hose	Replace			2.0				
		Repair		1.0					
1206	Mechanical Brake System								
	Pedals, Shaft Rods	Replace		1.0					
		Repair		1.0					
13	WHEELS AND TRACKS							1	
1311	Wheel Assembly								
	Wheel Assy, Bearings	Replace		1.0					
	Hub and Drum	Replace		1.5					
1313	Tires and Tubes	Replace		1.0				1	
		Repair			2.0				
14	STEERING								
1401	Steering Assembly	Service		.3					
		Replace			2.0				
		Repair				4.0			
	Tie Rod, Linkage	Replace		1.5					
	Wheel	Replace		.5					
1410	Hydraulic Pump or Fluid Mtr Assembly							1,2,3	

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
1410	Hydraulic Pump or Fluid								
	Mtr Assembly (Cond't)							1,2,3	
	Pump Assembly	Replace			2.0				
		Repair				4.0			
	Belt	Inspect	.1						
		Adjust		.5					
		Replace		.8					
1411	Hoses, Lines, Fittings	Replace		2.0					
		Repair			3.0				
1412	Hydraulic Cylinder							1,2,3	
	Booster Cylinder	Replace			1.0				
	Clamps, Plugs, Socket	Repair				3.0			
	Spring Seat	Replace			1.0				
1413	Tanks, Reservoirs							1,2	
	Reservoir	Service		.5					
		Replace			2.0				
		Repair				2.0			
15	<u>FRAME, TOWING ATTACHMENTS DRAWBARS</u>								
1501	Frame Assembly	Repair				2.0		1,2	
16	<u>SPRINGS AND SHOCK ABSORB-ERS</u>								
1601	Springs							1	
	Front Springs, Shack-les	Replace			2.5				
		Repair				1.5			
	Bolts, Nuts, Straps	Replace		.5					
18	<u>BODY, CAB, HOOD, HULL</u>								
1801	Body, Cab, Hood, Hull							1,2	

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
1801	(Cond't)								
	Hood, Body, Cab	Repair			4.0				
1805	Floors	Repair			1.5			1,2	
	Seats	Replace		.5					
		Repair			1.0				
1806	Upholstery, Cushions	Replace		1.0				1,2	
		Repair			1.5				
1808	Hose Reel, Boxes							1,2	
	Hose, Boxes	Replace		.5					
		Repair			1.0				
22	<u>BODY, CHASSIS OR HULL AND ACCESSORY ITEMS</u>								
2202	Accessory Items								
	Hose, Transfer	Replace		.5					
29	<u>ENGINE (PUMP)</u>								
2910	Engine Assembly								
	Engine, Gasoline	Inspect	.5					1,2	
		Service		2.0					
		Replace			3.0				
		Repair			12.0				
		Overhaul				18.0			
	Crankcase, Block Cylinder Head							1,2	
	Crankcase, Block	Replace				3.0			
	Head, Cylinder	Replace			4.0				
		Repair			2.5				
2912	Crankshaft	Replace				4.0		1.2	

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
2913	Flywheel Assembly	Replace			3.0			1,2	
		Repair			1.0				
2914	Pistons, Connecting Rods	Replace				3.0		1,2	
2915	Valves, Camshafts and Timing System							1,2	
	Lifter, Valve	Adjust		1.0					
		Replace			2.0				
	Guides, Valves, Seats	Replace			2.0				
		Repair			2.0				
	Springs	Replace			.2				
	Camshaft and Bearings	Replace			2.0				
2916	Engine Lubrication System							1,2	
	Pump, Oil	Replace				.8			
		Repair				1.0			
	Filter Element & Breather	Inspect	.3						
		Replace		.5					
	Dipstick and Filter Cap	'Inspect	.1						
		Replace		.1					
	Lines & Fittings	Replace		.5					
2917	Engine Starting System							1	
	Crank, Hand	Replace	.1						
2918	Manifolds	Replace		2.5				1	
03	FUEL SYSTEM								
2931	Carburetor	Adjust		.5				1	
		Replace		1.0					
2932	Fuel Pumps	Replace		1.0	1				
2933	Air Cleaner	Inspect	.1					1	
		Service		.2					
		Replace		.2					

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
2935	Tanks, Lines, Fittings, Headers							1	
	Tank, Fuel	Inspect	.1						
		Replace		2.0					
		Repair			1.0				
	Lines and Fittings	Replace		.5					
2936	Engine Speed Governor	1							
	Governor	Adjust		.5					
	Controls	Replace		1.0					
		Repair			2.5				
2937	Fuel Filters	Replace		.2					
2939	Choke Controls	Replace		.5				1	
04	<u>EXHAUST SYSTEM</u>								
2941	Muffler and Pipes	Replace		.5				1	
05	<u>COOLING SYSTEM</u>								
2952	Cowling, Deflectors, Air Duct							1	
	Shroud	Replace		1.0					
		Repair			.5				
06	<u>ELECTRICAL SYSTEM</u>								
2963	Starting Motor	Test		.5				1,2,4	
		Replace		1.0					
		Repair			1.5				
2964	Ignition Components								
	Spark Plugs	Clean		1.0					
		Replace		.8					

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	 O	 F	 H	 D	(5) TOOLS AND EQPT	(6) REMARKS
2964	(Cond't)								
	Magneto	Replace		.8				1,2,4	
		Repair			1.0				
2967	Instrument or Engine Control Panel								
	Switches, Lamps, Gages	Replace		.2				1,4	
	Bulbs	Replace		.1					
43	<u>HYDRAULIC, FLUID, AIR AND VACUUM SYSTEM</u>								
4300	Hydraulic System	Service		.3	1,2,3				
		Replace		3.0					
		Repair				3.0			
4301	Strainers, Filters	Inspect	.2					1	
		Replace		.5					
	Hose, Pipe Fittings, Tubing	Replace		.8					
4305	Manifold and/or Control Valves	-.Replace			2.5			1,2	
		Repair			2.0				
4306	Hydraulic, Vacuum or Fluid Mtr	Repair			1.0			1	
4307	Hydraulic Cylinders	Replace		1.0				1,2	
		Repair			3.0				
4308	Liquid Tank or Reservoir	Replace		2.5				1	
		Repair			3.0				
4309	Hydraulic Controls and/ or Manual Controls	Replace		1.0				1,2	
		Repair		.5					
	Linkage	Replace	.3						
47	<u>GAGES (NON-ELECTRICAL, WEIGHING & MEASURING DEVICES</u>								

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
47	(Cond't)								
4701	Instruments (Speed and Distance) Tachometer	Replace		1.0				1,2	
4702	Gages, Mountings, Lines Fittings	Replace		1.5				1	
4705	Flow Meters & Regulators	Replace		1.0				1,2	
		Repair				4.0			
		Calibrate				2.0			
55	<u>PUMPS</u>								
5500	Pump Assembly	Replace			1.5			1,2,3	
		Repair				4.0			
5501	Shafts, Rotors, Impellers	Replace				2.0		1,2	
5507	Pump Drive	Replace			1.0			1,2	
	Shafts, Gears, Clutch	Replace			1.5				
5510	Inlet & Outer Components	Replace		.5				1	
73	CONCRETE AND ASPHALT EQUIPMENT COMPONENTS								
7317	Material Spray Bar							1	
	Valves, Linkage, Pins	Inspect		.2					
		Replace		.5					
		Repair		1.0					
	Mtg Brackets, Hose, Clamps	Replace		.5					
74	<u>CRANES, SHOVELS AND EARTH-MOVING EQUIPMENT</u>								
7465	Rotary Tiller							1,2	

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Section II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
7465	Rotary Tiller (Cond't)								
	Rotor Assembly	Service		.5					
		Replace			2.0				
		Repair				16.0			
	Rotor Adjustment	Replace			.5				
		Repair			.5				
	Tine and Socket	Replace		.5					
		Repair			1.0				
	Chain	Replace		1.0					
	Chain Case	Replace			2.5				
		Repair				6.0			
	Rotor Hoist	Replace			1.5				
		Repair			1.0				
	Hood & Skis	Adjust		.5					
		Replace		1.5					
	Jack Axle	Replace			3.0				
		Repair				6.0			

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C--operator/crew F--direct support D-depot
O--organizational H--general support

APPENDIX C

MAINTENANCE ALLOCATION CHART FOR

MIXER ROTARY TILLER MODEL: HDS-E

SECTION III

SECTION III - TOOL AND TEST EQUIPMENT REQUIREMENTS

TOOL OR TEST EQUIPMENT REFERENCE CODE	MAINTENANCE CATEGORY	NOMENCLATURE	NATIONAL/NATO STOCK NUMBER	TOOL NUMBER
		Unless otherwise noted, All maintenance functions can be accomplished with the tools contained in the following common tool sets		
1	O, F, H	Shop Equip Contact Maint TRK MTD (SC 4940-97-CL-E 05)	4940-00-294-9518	T10138
1	O, F, H	Shop Equip Org Repair Light TRK MTD (SC 4940-97-CL-E04)	4940-00-294-9516	T13152
1	0, F, H	Tool Kit Automotive Maint, Org Maint Common #1 (SC 4910-95-CL-A74)	4910-00-754-0654	W32593
1	0, F, H	Tool Kit Automotive Maint, Org Maint Common #2 (SC 4910-95-CL-A72)	4910-00-754-0650	W32730
1	O, F, H	Tool Kit, Light Weight (SC 5180-90-CL-W26)	5180-00-177-7033	W33004
1	O, F, H	Shop Equip Auto Maint and Repair Org Maint Supp #1 (SC 4910-95-CL-A73)	4910-00-754-0653	W32867
1	0, F, H	Shop Equip Welding Field Maint (SC 3470-95-CL-A08)	3470-00-357-7268	T16714
1	O, F, H	Tool Set, Veh Full Track ed Supp #2 (5C 4940-95-CL-A08)	4940-00-754-0743	W65747
2	F, H	Shop Equip Gen Purp Repair Semitrlr MTD (SC 4940-97-CL-E03)	4940-00-287-4894	T10549

APPENDIX C

MAINTENANCE ALLOCATION CHART FOR
MIXER ROTARY TILLER MODEL: HDS-E

SECTION III

SECTION III - TOOL AND TEST EQUIPMENT REQUIREMENTS

Tool or Test Equipment Ref Code	Maintenance Category	Nomenclature	National/NATO Stock Number	Tool Number
1	F, H	Tool Kit Automotive, Fuel and Elec Sys Repair (SC 4910-95-CL-A50)	4910-00-754-0655	W32456
1	F, H	Tool Kit, Master Mechanic and Equip Maint and Repair (SC 5180-90-CL-EO5)	5180-00-699-5273	W45060

APPENDIX C

Section IV Remarks

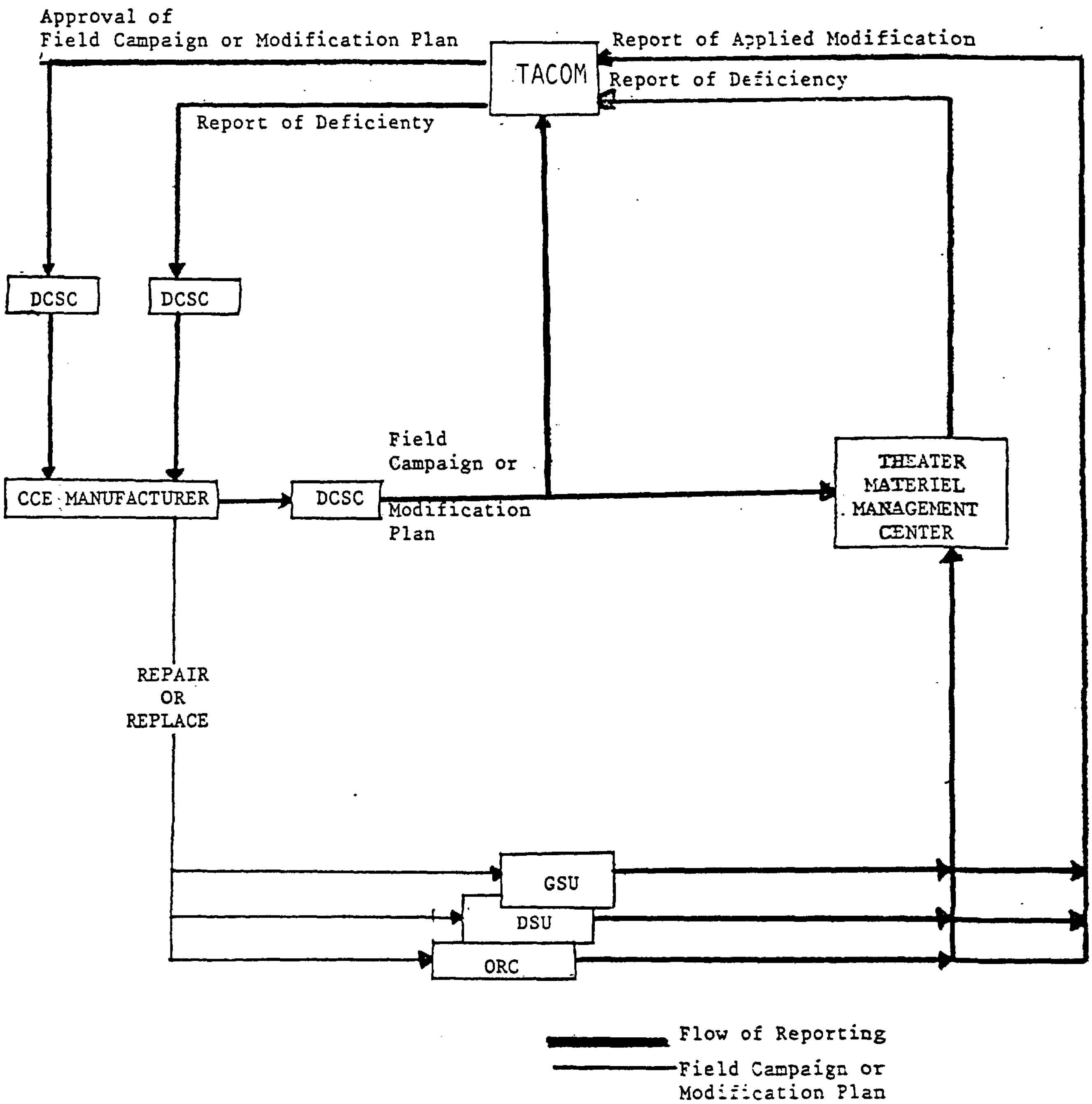
Mixer, Rotary Tiller, Self-Propelled

Reworks Model HDS-E

Reference Code	Remarks
A	Do Not Make Repairs By Welding Which Will Cause Voiding Of The ROPS Certification
B	Water Pump Overhaul Kit Is Available
C	Alternator Repair Kits Are Available
D	Starter Motor Repair Kits Are Available
E	Master Cylinder Repair Kits Are Available
F	Horn Repair Kit Is Available
G	Test Includes Operation And Compression
H	Return To Depot Maintenance When Unserviceable, Economically Repairable
I	Repair Includes Metalizing, Aligning, And Grinding
J	Return to Manufacturer for repair.

APPENDIX D

CCE MANUFACTURER FIELD CAMPAIGNS AND MODIFICA-ION PROCEDURES



APPENDIX E

BASIC ISSUE ITEMS LIST				
NOMENCLATURE: Mixer, Rotary Tiller MANUFACTURER: Reworks SERIAL NUMBER PRANGE: DATE:				
(1) MFR PART NO.	(2) WMR FED CODE	(3) DESCRIPTION	(4) UNIT OF ISSUE	(5) OUANTITY FURINISHED W/EQUIP
402-1591-7	61361	Tine L.H.	Ea	42
402-1591-8	61361	Tine R.H.	Ea	42

APPENDIX F

ITEMS TROOP INSTALLED OR AUTHORIZED LIST					
(1) SMR CODE	(2) NATIONAL STOCK NUMBER	(3) DESCRIPTION REF No & MFR CODE	USABLE ON CODE	(4) UNIT OF MEAS	(5) QTY AUTH
		Note: The following items are authorized but not issued with the Mixer,. Tiller			
PAOZZ	7520-00-559-9618	Case, Cotton Duck: MIL-B-11743 (81349)		Ea	1
PAOZZ	4210-00-889-2221	Extinguisher; Fire Dry Chemical		Ea	1
PAOZZ	5120-00-061-8541	Hammer, Hand		Ea	1'
PAOZZ	5120-00-223-7397	Pliers, Slip Joint		Ea	1
PAOZZ	5120-00-293-0793	Punch, Drive Pin		Ea	1

INITIAL RECOMMENDATION
PRESCRIBED LOAD LIST (PLL)
AUTHORIZED STOCKAGE LIST (ASL)

END ITEM: MIXER, ROTARY TILLER	MAKE: Rexworks	MODEL: HDS-E
MFR PART NO: HDS / NSN: 3895-01-141-0882	SERIAL NUMBER RANGE: 1409 TO 1412 1429 TO 1438	DATE: 6 May 83

SMR CODE	NATIONAL STOCK NO.	PART NUMBER	FSCM	PART DESCRIPTION	U/M	QTY OF PARTS REQ'D FOR NO. OF END ITEMS			
						PLL	ASL		
						1-5	1-5	6-20	21-50
PAOZZ	4330-00-1-165-5905	3634-002	02249	Filter Element	Ea	1	2	2	2
PAOZZ	5930-00-484-5792	9233	13445	Switch Neutral	Ea	0	0	1	1
PAOZZ		95512-A	13445	Switch Rotary	Ea	0	1	1	2
PAOZZ	4310-00930-8170	P10-1240	18265	Filter Element	Ea	1	1	2	3
PAOZZ		D301153-003-120	41625.	Control Assembly, Push-P	Ea	0	0	0	1
PAOZZ	4720-01-151-6319	102-2700-7	61361	Hose, Nonmetalic	Ea	0	0	1	1
PAOZZ	5330-01-155-2587	102-2864-1	61361	Gasket	Ea	1	2	2	3
PAOZZ	5315-01-153-1454 .	102-8740-1	61361	Pin, Grooved, Headless	Ea	3	3	5	8
PAOZZ	6680-01-154-6926	BW-20-4053	24981	Sight Gage Plug	Ea	0	0	1	1
PAOZZ	2910-00-0995639	LP43	66289	Strainer., Sediment	Ea	0	0	1	2
PAOZZ	2940-00-891-9342	RV40	66289	Filter, Element	Ea	1	2	2	3
PAOZZ	2940-01-131-5928	PF-911	70040	Element, Oil Filter	Ea	1	2	3	5
PAOZZ	2910-01-122-9517	25010959	72582.'	Fuel Filter	Ea	1	3	4	6
PAOZZ	2910-01-129-0466	25011011	72582	Filter, Element	Ea	1	2	3	5
PAOZZ	3030-00-865-2702	5133515	72582	Belt V	Ea	1	1	1	2
PAQZZ	4720-01-151-4026	AB101	72781	Hose, Performed	Ea	0	0	1	2
PAOZZ	4720-00-990-1678	812	7278.1	Hose, Radiator Upper	Ea	0	0	1	2
PAOZZ	3030-00-844-3835	8366SX2	24161	Fan Belt Set	Ea	1	1	2	2
PAOZZ.	3020-00-993-3964	100-2-60PL	73433 -	Chain, .Roller	Ea	0	0	2	2

INITIAL RECOMMENDATION
PRESCRIBED LOAD LIST (PLL)
AUTHORIZED STOCKAGE LIST (ASL)

APPENDIX G

END ITEM: MIXER, ROTARY TILLER	MAKE: Rexworks	MODEL: HDS-E

MFR PART NO: HDS	NSN: 3895-01-141-0882	SERIAL NUMBER RANGE: 1409 TO 1412 1429 TO 1438	DATE: 6 May 83

SMR CODE	NATIONAL STOCK NO.	PART NUMBER	FSCM	PART DESCRIPTION	U/M	QTY OF PARTS REQ'D FOR NO. OF END ITEMS			
						PLL	ASL		
						1-5	1-5	6-20	21-50
PAOZZ	5920-00-131-9915	F02A32V20A	81349	Fuse Automotive	Ea	1	1	2	3
PAOZZ	4730-01-152-2795	J5570-H-60	84276	Strainer Element	Ea	0	1	1	2
PAOZZ	2920-00-997-1454	SK90.	82796	Parts Kit	Ea	1	2	2	3
PAOZZ	2920-00-810-7082	MS51009-1	96906	Spark Plug	Ea	4	8	8	12

APPENDIX H

SECTION
MAINTENANCE AND OPERATING SUPPLY LIST

NOMENCLATURE: PULVI-MIXER	MAKE: REXWORKS	MODEL: HDS-E	
MFR PART NO:	NSN: 3895-01-141-0882	SERIAL NO. RANGE: 1409 TO 1412 1429 TO 1438	DATE:

(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
		MIL-L-2104			
MIXER ENGINE	9150-00-188-9858	OIL, LUBRICATING OE/HDO 30	15 qts	*	5 gal
CRANKCASE (DIESEL)	9150-00-186-6668	OIL, LUBRICATING OE/HDO 10	15 qts	*	5 gal
PUMP ENGINE	9150-00-188-9858	OIL, LUBRICATING OE/HDO 30	4 qt	*	5 gal
CRANKCASE (GAS)	9150-00-186-6668	OIL, LUBRICATING OE/HDO 10	4 qt	*	5 gal
		W-F-800			
MIXER ENGINE (FUEL TANK(DIESEL)	9150-00-286-5294	DIESEL FUEL #2	80 gal	60 gal	
		MIL-G-3056			
PUMP ENGINE FUEL TANK(GASOLINE)	9130-00-160-1831	GASOLINE, AUTO COMBAT		12 gal	
HYDRAULIC TANK	9150-00-657-4959	HYDRAULIC OIL	10.5 gal	*	5 gal
BEARINGS, PIVOTS FITTINGS & GENERAL APPLICATION	915 00-190-0905	GAA GREASE	*	*	5 gal

*AS REQUIRED

APPENDIX
SECTION
MAINTENANCE AND OPERATING SUPPLY LIST

NOMENCLATURE: MIXER ROTARY TILLER	MAKE: REXWORKS	MODEL: HDS-E

MFR PART NO: HDS	NSN: 3895-01-141-0882	SERIAL NO. RANGE: 1409 TO 1412 1429 TO 1438	DATE:

(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
Brake Master Cylinder	9150-01-102-9455	MIL-B-46176 Silicone Brake Fluid	*	*	(Gal)
Hydraulic Tank, Power Steering	9150-00-657-4959	(Type A) Automatic Transmission Fluid	11 Gal	*	5 Gal
Cooling System	6850-00-181-7933	MIL-A-46153 Anti-Freeze Permanent	1 34 Gal	*	50-50 solution (5 gal)

APPENDIX I

REQUISITION PROCESSING
GENERAL INSTRUCTIONS

1. Preparation and Transmittal.

a. Requisitions will be prepared in the normal MILSTRIP format.

b. Requisitions transmitted by AUTODIN for NSN repair parts will be automatically routed by the Defense Automated Addressing System (DAAS) to the responsible Federal Supply Class Manager.

c. Requisitions for non-NSN repair parts may be locally procured or requisitioned from the Defense Construction Supply Center (DCSC), Columbus, Ohio. These requisitions, when properly coded, will be forwarded by the DAAS to DCSC. When the Manufacturer's Part Number and the Federal Supply Code for the Manufacturer (FSCM) exceed columns 8-22 of the requisition format (DD Form 1348-1), prepare an AOE/A05 requisition (DD Form 1348-6) and mail to

Commander
Defense Construction Supply Center
ATTN: DCSC-OSR
Columbus, OH 43215

2. Project Codes (Cols 57-59).

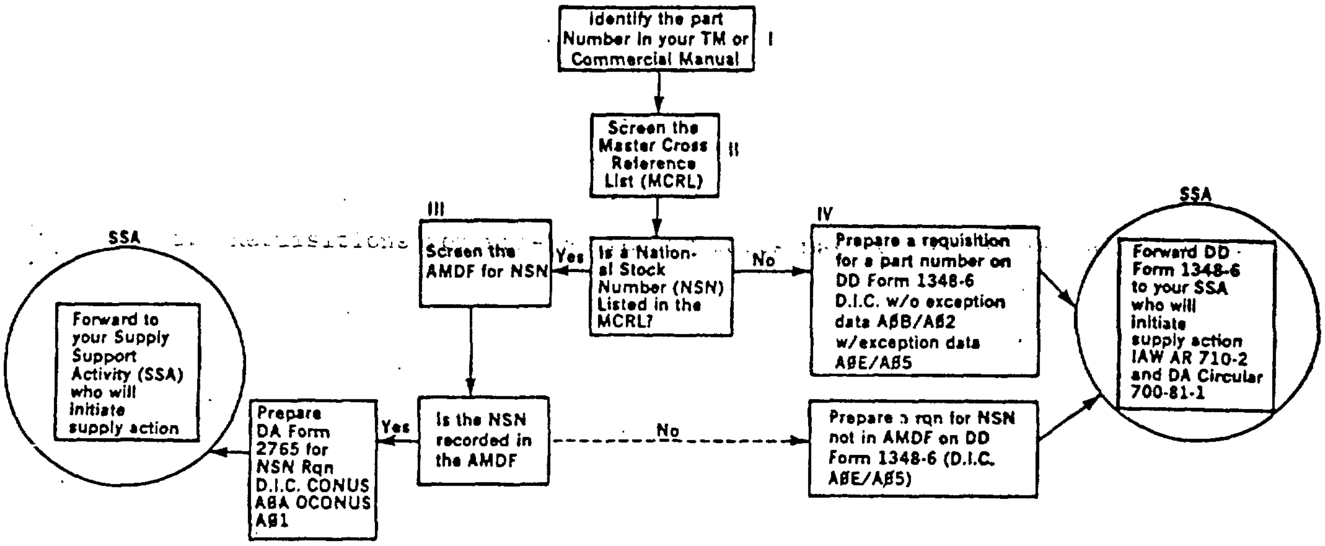
a. Project codes have been assigned to identify non-NSN repair parts requisitions placed on the wholesale supply system.

b. Hawaii, Alaska and Panama, when submitting requisitions for non-NSN repair parts for this Commercial Construction Equipment, are considered as OCONUS and will use coding applicable to OCONUS.

c. Refer to Tables 1 and 2 for applicable codes/formats.

3. Requisition Format.

Unique or Specific Coding applicable to repair parts requisitions for this equipment is furnished in Tables 1 and 2. Other entries should conform to normal AR 725-50 MILSTRIP codes and formats.



NON-NSN REQUISITION (MANUAL)

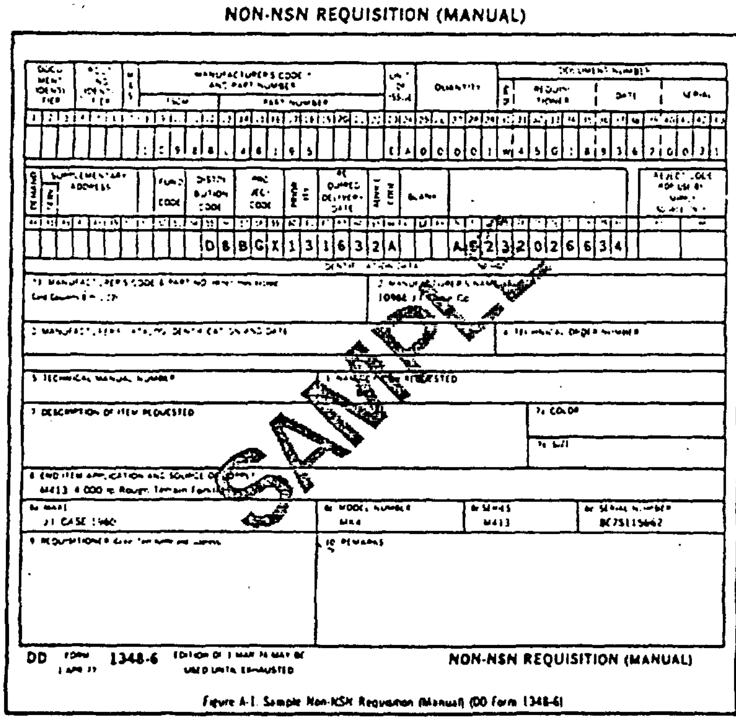


Figure A-1. Sample Non-NSN Requisition (Manual) (DD Form 1348-6)

LEGEND FOR 1348-6

CARD COLUMNS	CONUS	OCONUS
1-3 DOC Ident Code -		
PN w/o Exception Data	AØB	AØ2
PN w/Exception Data	AØE	AØ5
NSN Not in AMDF	AØE	AØ5

4-7 (LV Blank - SSA will complete)

8-22 For Non NSN: Fed Supply Code for Manufacturer (FSCM followed by Part Number (obtain from TM or Commercial Manual)

8-22 For NSN not in AMDF - enter NSN

57-59 Project Code:	MHE	CCE
CONUS	BGX	BGW
OCONUS	JZM	JZC

Reference Code for Cols 71-80:

A - Technical Order or Tech Manual.
B - End Item Application.
C - Noun Description of Item.
D - Drawing or Specification Number.

Identification of reference Data specified in Col. 70.

NOTE: All other entries will be made IAW AR 710-2/725-50. Project Codes are mandatory entries.

MANUAL BLOCKS:

BLOCK 1. Mfg Code & PN - Enter applicable FSCM and PN when they exceed Cols 8-22. (Cols 8-22 will be left blank).

BLOCKS 2-8. Enter applicable data (obtain from TM or Commercial Manual).

BLOCKS 8a-8d. Obtain data from vehicle data plate.

BLOCK 9. Self explanatory.

BLOCK 10. Enter any applicable exception data such as "NSN not in AMDF".

All NSN items for listed on the AMDF and part number req will be forward to DCSC (RIC S9C) for supply support.

TABLE H

NON-NSN REQUISITION FORMAT

CARD COLUMN	DESCRIPTION	ENTRY CONUS	ENTRY OCONUS
1-3	Document Identifier Code	AOB	A02
4-6	Routine 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	N/A	N/A
57-59	Project Code	BGW	JZC

TABLE II

NSN REQUISITION FORMAT

CARD COLUMN	DESCRIPTION	ENTRY CONUS	ENTRY OCUNUS
1-3	Document Identifier Code	AOA	AOI
8-22	National Stock Number	Enter the Applicable 13 digit NSN	
54-56	Distribution Code	Same as Table I above	
57-59	Project Code	Not Required	

PREVENTATIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

OPERATOR/ORGANIZATIONAL MAINTENANCE CIIHECKS 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 it's last use.

See TM38-750 for the required information on the forms and records.

PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PIMCS)

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.

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 broker 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 of 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 PMICS. 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 - IHEN IN DOUBT, NOTIFY YOUR SUPERVISORI

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've 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 (PMCS)

B-BEFORE D-DURING A-AFTER W-WEEKLY M-MONTHLY

ITEM NO	INTERVAL					ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/ AVAILABLE IF:
	B	D	A	W	M		
						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 Judgment 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. Do not start or operate Asphalt Pump/Engine without liquid in the pump body or damage to the pump seal will result. **GENERAL** Perform all daily and/or weekly lubrication of the Mixer, Rotary Tiller as called out in Section 2, Subsection 15, Pages 15-1 through 15-3 of your Operation and Maintenance Repair Manual, Number SP358.	

OPERATOR /CREW

PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

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:
						Tiller Body and Tiller:	
	X					a. Visually inspect for loose wiring, damaged pipes and hoses.	
	X					b. Look for evidence of fluid leakage (oil, fuel, coolant).	Class III leaks or any fuel leakage
	X					c. Visually inspect tiller for loose mounting or missing guards.	Guard missing
						Engine Diesel:	
	X					Check engine oil level. Add as needed to maintain between full and add lines on the dipstick.	
						Fan and Alternator Belts:	
	X					Inspect for loose or damaged/frayed belts. Have a loose belt tightened.	Fan belt broken/missing
						Fuel Filters (Diesel and Gasoline):	
	X					a. Inspect for leakage/damage	Any fuel leakage/broken sediment bowl
				X		b. Clean weekly by draining to remove sediment and water (gas engine only)	
						Engine Gasoline:	
	X					a. Check engine oil level. Add as needed to maintain between full and add lines on dipstick.	
				X		b. Check air intake and cylinder Vee area for dirt and chaff. Clean area, if dirty.	
	X					c. Check for damaged/missing metal shroud.	Shroud missing
						Fuel Storage Tanks and Lines (Diesel and Gasoline)	
	X					a. Inspect for leakage/damage	Any leakage/crimped lines
				X		b. Drain diesel sump to remove sediment and water	

OPERATOR /CREW

PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

B-BEFORE D-DURING A-AFTER W-WEEKLY M-MONTHLY

ITEM NO	INTERVAL					ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/ AVAILABLE IF:
	B	D	A	W	M		
						Batteries:	
				X		a. Visually inspect for damage.	Missing or will not crank engine cracked case
				X		b. Check electrolyte level. Fill as required to split ring. Do not overfill.	
						Radiator (Diesel Engine)	
	X					a. Check coolant level. (Level should be approximately 1 inch from bottom of filler neck).	Approximately 50% area damaged
				X		b. Check for damage or plugged cooling fins.	
						Gear Boxes and Differentials:	
	X					a. Visually inspect for evidence of seals leaking.	Class III leaks.
				X		b. Check fluid level.	
						Tires:	
	X					Check for cuts and general condition	One or more missing/flat, unserviceable
						Instruments:	
				X		a. Inspect for damage and loose mounting.	
	X					b. Check for proper operation of:	
						(1) Oil pressure gage (Diesel engine; MIN 18 PSI)	Inoperative oil pressure gage or coolant temperature
						(2) Oil pressure gage (Gasoline engine; MIN 4 PSI)	
						(3) Coolant temperature gage; 160-185° F (71-85° C)	
						(4) Ammeter gage; + charging	
						(5) V.P.I. Fluid handling system	Inoperative
	X					Engines (Diesel and Gasoline)	
						Listen for any unusual noise (See warning note on header page pump engine).	Engine unusually noisy

OPERATOR /CREW

PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

B-BEFORE D-DURING A-AFTER W-WEEKLY M-MONTHLY

ITEM NO	INTERVAL					ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED OR ADJUSTED AS NEEDED	EQUIPMENT IS NOT READY/ AVAILABLE IF:
	B	D	A	W	M		
	X					Fog Spray System: Check for missing or damaged components	Inoperative, missing (Asphalt Operation only).

ORGANIZATIONAL PREVENTIVE MAINTENANCE CHECKS AND SERVICES

Q-Quarterly S-Semiannually A-Annually B-Biennially H-Hours M-Miles

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
1							General Lubrication
	X						Quarterly perform all daily/weekly and monthly service (Ref.
2							Engines (Diesel and Gasoline)
	X						a. Check for leaks, loose mounts and proper operation.
							(1) Report erratic operation to DS Maintenance (Diesel).
							(2) Tune or adjust erratic operation of the gas engine (Ref.
3							Crankcase and Oil Filter (Diesel and Gasoline)
	X		or		250		a. Change oil and filter (Diesel)
	X		or		250		b. Change oil (Gas Engine)
		X	or		500		c. Change oil filter (Gas Engine)
4							Fuel Filters (Diesel Engine) and Strainer Element
	X						a. Change filter element and clean strainer (Diesel Engine)
	X						b. Service strainer (Gas Engine)
5							Fuel Tanks
		X					a. Inspect for loose mounting.
	X						b. Inspect fuel cap gaskets, if defective, replace.
6							V-Belts (Diesel Engine)
	X						Check or adjust tension (1/2 in deflection midway between pulleys)
7							Radiator (Diesel Engine)
			X				a. Check antifreeze protection (Ref.
					1000		b. Drain and flush radiator and engine.
			X				c. Inspect cap and thermostat (Ref.

ORGANIZATIONAL PREVENTIVE MAINTENANCE CHECKS AND SERVICES

Q-Quarterly S-Semiannually A-Annually B-Biennially H-Hours M-Miles

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
8							Cooling and Air Flow (Gas Engine)
		X					Clean cylinder and head fins (Ref.
9							Air Cleaner
	X						a. Check filter element and clean. (Dry type, Diesel Engine) (Ref.
					500		b. Replace filter element (Dry type) (Ref.
	X						c. Service oil bath cleaner (Gas Engine) (Ref.
10							Electrical System
	X						a. Clean and service batteries (Ref.
			X				b. Check wiring harness for corrosion or bare wires.
		X					c. Check all lights for proper operation.
11							Transmission Hydraulic Tank and Components
	X						a. Check level and inspect for leaks (Ref.
					1000		b. Drain fluid, change filters and refill (Ref.
			X				c. Inspect hydraulic cylinders for proper operation and leaks. Tighten leaking packing or report to DS Maintenance. (Ref.
	X						d. Inspect pumps and motors for leaks and proper operation. (Ref. Report defective pumps or motors to DS Maintenance.
12							Steering Pump and Components
	X						a. Check fluid level (Ref.
					500		b. Drain, flush, refill system.
	X						c. Inspect lines and hoses.
13							Final and Tiller Drives, Shafts and Bearings
		X					Inspect for proper operation and loose mounting.

ORGANIZATIONAL PREVENTIVE MAINTENANCE CHECKS AND SERVICES

Q-Quarterly S-Semiannually A-Annually B-Biennially H-Hours M-Miles

ITEM NO	INTERVAL						ITEM TO BE INSPECTED PROCEDURE: Check for and have repaired, filled, or adjusted as needed PERFORM ALL OPERATOR PMCS FIRST
	Q	S	A	B	H	MI	
14							V.P.I. and Drive Systems
	X						a. Check for loose mounting.
					1000		b. Check and adjust tach-wheel drive. (Ref.
15							Rotor Mixing Chamber and Drive
	X						a. Inspect tine for looseness or wear. (Ref.
	X						b. Inspect tailboard wearplate and skis for wear. (Ref.
		X					c. Inspect and adjust drive chains (Ref.
		X					d. Inspect and adjust drive clutch (Ref.
16							Asphalt and Emulsion Fluid System
					25		a. Inspect and clean strainer (Ref.
		X					b. Inspect, clean and adjust spray bar nozzles. (Ref.
17							Brakes
			X				Inspect and adjust brakes. (Ref.
18							Asphalt Pump
			X				Service check valve (Ref.
19							Springs and Shock absorbers
			X				Inspect for loose mountings or broken components. Repair or report to DS Maintenance.

By Order of the Secretary of the Army:

JOHN A. WICKHAM, JR.
General, United States Army
Chief of Staff

Official:

DONALD J. DELANDRO
Brigadier General, United States Army
The Adjutant General

Distribute In Accordance With DA Form 12-25B-R Nov 84 Blocks (941, 942, 943) Operator's, Organizational, Direct Support, General Support, Mixer, Rotary Tiller, Soil Stabilization, (DED), Rexworks Model HDS-E

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RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS

SOMETHING WRONG WITH PUBLICATION

FROM: (PRINT YOUR UNIT'S COMPLETE ADDRESS)

DATE SENT

PUBLICATION NUMBER	PUBLICATION DATE	PUBLICATION TITLE

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.

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.

The Metric System and Equivalents

Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 decagram = 10 grams = .35 ounce
1 hectogram = 10 decagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

Liquid Measure

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

Approximate Conversion Factors

To change	*To*	*Multiply by*	*To change*	*To*	*Multiply by*
inches	centimeters	2.540	ounce-inches	Newton-meters	.007062
feet	meters	.305	centimeters	inches	.394
yards	meters	.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	.621
square feet	square meters	.093	square centimeters	square inches	.155
square yards	square meters	.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	.405	square kilometers	square miles	.386
cubic feet	cubic meters	.028	square hectometers	acres	2.471
cubic yards	cubic meters	.765	cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	.473	milliliters	fluid ounces	.034
quarts	liters	.946	liters	pints	2.113
gallons	liters	3.785	liters	quarts	1.057
ounces	grams	28.349	liters	gallons	.264
pounds	kilograms	.454	grams	ounces	.035
short tons	metric tons	.907	kilograms	pounds	2.205
pound-feet	Newton-meters	1.356	metric tons	short tons	1.102
pound-inches	Newton-meters	.11296			

Temperature (Exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

PIN: 058206-000